# OPERATIVE THERAPEUSIS

# OPERATIVE THERAPEUSIS

EDITED BY

ALEXANDER BRYAN JOHNSON, Ph.B., M.D.

VOLUME I



NEW YORK AND LONDON
D. APPLETON AND COMPANY
1915

Printed in the United States of America

# PREFACE

Books special and general on surgical topics exist in large numbers. Unless, therefore, in offering this work to the medical profession, something more generally useful can be produced, it has no excuse for being, and in the following paragraphs I will demonstrate this assertion.

The entire field of surgical treatment is covered, both operative and non-operative. The indications, and contra-indications, for and against surgical procedures, are carefully elaborated.

After-care, postoperative complications and postoperative operations are given very fully and describe the very latest advances, and I believe that several desirable objects have been attained.

Aseptic operative technic constitutes naturally the bulk of the work and is invaluable and eminently practicable.

It often happens, more especially in the country and in the smaller towns, that the family physician is left in charge of the case after operation. These chapters give exactly the information he may need under such conditions. The methods described are those accepted as the best by the profession at large. In addition thereto many new methods are here offered to the profession for the first time. These are original with the contributors to this work.

The work was planned by selecting as contributors men who lived in Greater New York City exclusively. The majority of these men have been associated with me in hospital work; their ideas, methods and capabilities are well known to me. They are nearly all comparatively young men, who, though old enough to have had large experience, have still abundant enthusiasm. They were selected because of special fitness to write on some particular topic in which each was especially interested, experienced and skillful.

The book contains the very last word on surgical therapeusis and its aim is to tell in a practical and accessible form WHAT TO DO AND HOW TO DO IT.

It will be noted that overlapping occurs in some sections. Such overlapping is largely intentional on my part, and occurs chiefly where new and original methods of technic have been devised by the authors and where each method is good; but where a difference of opinion and a choice are entirely permissible, I think that such different viewpoints are a desirable addition to the work.

Diagnosis and pathology have, for the most part, been omitted. The two chapters on the X-ray diagnosis of the alimentary and urinary tracts are introduced because they are so important and contain so much not yet known to the greater number of the profession.

The illustrations are with few exceptions line drawings, most of them original. A large proportion were made from sketches of actual operations on the living body or upon the cadaver, showing what is actually visible during operative work, and not what may be imagined.

I desire to thank the contributors to "Operative Therapeusis" for their cordial and enthusiastic coöperation with me in the effort to have the book ready for publication at the earliest possible moment. Many of the articles are really exhaustive monographs covering every phase of the topic treated, and several might well have appeared as separate works.

Alexander Bryan Johnson.

## LIST OF CONTRIBUTORS

Fred Houdlett Albee, A.B., M.D.
Archibald H. Busby, M.D.
Schuyler A. Clark, M.D.
Howard D. Collins, M.D.
Karl Connell, M.D.
John F. Cowan, M.D.
Colman W. Cutler, M.D.
William Darrach, A.M., M.D.
John Douglas, M.D.
Francis G. Edgerton, M.D.
Charles A. Elsberg, M.D.
Charles E. Farr, M.D.
Russell S. Fowler, M.D., F.A.C.S.
Robert T. Frank, A.M., M.D.
David Geiringer, M.D.
John C. A. Gerster, M.D.
Nathan W. Green, M.D.
Anthony H. Harrigan, M.D.
Forbes Hawkes, M.D.
James M. Hitzrot, A.B., M.D.
Ranson S. Hooker, M.D.
Lucius Wales Hotchkiss, M.D.
Henry Janeway, M.D.
Alexander Bryan Johnson, Ph.B., M.D.
James H. Kenyon, M.D.
Leon Theodore Le Wald, M.D.
Henry H. M. Lyle, M.D.
Jerome Morley Lynch, M.D., F.A.C.S.
Walton Martin, M.D.
Frank S. Mathews, M.D.
Clarence A. McWilliams, M.D.
Alexis V. Moschcowitz, Ph.G., M.D.
Alfred T. Osgood, M.D.
Eugene H. Pool, M.D.
Joseph C. Roper, M.D.
Henry S. Satterlee, M.D.
T. Laurance Saunders, M.D.
Norman Sharpe, M.D.
William Sharpe, M.D.
J. Bentley Squier, Jr., M.D.
W. E. Studdiford, M.D.
Alfred S. Taylor, A.M., M.D.
Howard C. Taylor, M.D.
William S. Thomas, M.D.
Franz Torek, A.M., M.D.
Percy R. Turnure, M.D.
F. T. Van Beuren, Jr., M.D.
Arthur Seymour Vosburgh, M.D.
George G. Ward, Jr., M.D.
John Martin Wheeler, M.D.

## CONTRIBUTORS TO VOLUME I


**A. SCHUYLER CLARK, M.D.**
Assistant Physician and Chief of Clinic, New York Skin and Cancer Hospital.

**HOWARD D. COLLINS, M.D.**
Surgeon to the City and Knickerbocker Hospitals.

**KARL CONNELL, M.D.**
Assistant Surgeon, Roosevelt Hospital; Instructor in Surgery, College of Physicians and Surgeons, Medical Department, Columbia University, New York.

**JOHN F. COWAN, M.D.**
Instructor in Surgery, Leland Stanford Junior University

**CHARLES E. FARR, M.D.**
Assistant Surgeon, St. Mary's Free Hospital for Children; Deputy Surgeon, New York Hospital, O.P.D.; Surgeon, Seton Hospital.

**JAMES M. HITZROT, A.B., M.D.**
Assistant Professor of Clinical Surgery, Cornell Medical School; Associate Surgeon, New York Hospital.

**RANSON S. HOOKER, M.D.**
Instructor in Clinical Surgery, College of Physicians and Surgeons, Columbia University, New York; Assistant Surgeon, Bellevue Hospital, New York.

**ALEXANDER BRYAN JOHNSON, PH.B., M.D.**
Consulting Surgeon to the New York Hospital and to the Hudson Street Hospital (House of Relief), New York; Professor of Clinical Surgery in the College of Physicians and Surgeons of Columbia University; Fellow of the American Surgical Association; Member of the New York Surgical Society; Author of "Surgical Diagnosis."

**JAMES H. KENYON, M.D.**
Assistant Surgeon, Fordham Hospital; Babies Hospital, St. Francis Hospital, and the Neurological Institute.

**WALTON MARTIN, M.D.**
Professor of Clinical Surgery, College of Physicians and Surgeons, Columbia University, New York; Attending Surgeon, St. Luke's Hospital, New York; Consulting Surgeon, White Plains Hospital.

**JOSEPH C. ROPER, M.D.**
Associate Attending Physician, New York Hospital; Formerly Clinical Pathologist, New York Hospital.

**HENRY S. SATTERLEE, M.D.**
Assistant Attending Physician, Willard Parker and Riverside Hospitals, New York.

**ALFRED S. TAYLOR, A.M., M.D.**
Consulting Surgeon: Hospital for Ruptured and Crippled, Tarrytown Hospital, White Plains Hospital, Letchworth Village. Visiting Surgeon: Fordham Hospital. Associate Surgeon: New York Neurological Institute. Assistant Surgeon: Babies Hospital; Professor of Operative Surgery at Cornell Medical School; Special Lecturer on the Surgery of the Peripheral Nerves at Cornell Medical School.

**PERCY R. TURNURE, M.D.**
Attending Surgeon, French Hospital, New York; Associate Surgeon, New York Hospital, New York.

**F. T. VAN BEUREN, JR., M.D.**
Assistant Surgeon, Roosevelt Hospital; Instructor in Surgery, College of Physicians and Surgeons, Columbia University.

**ARTHUR SEYMOUR VOSBURGH, M.D.**
Assistant Surgeon, Bellevue Hospital; Instructor in Surgery, College of Physicians and Surgeons, Columbia University.

# CONTENTS

## CHAPTER I

## ASEPTIC SURGICAL TECHNIC

HOWARD D. COLLINS



## CHAPTER II

## GENERAL OPERATIVE TECHNIC

HOWARD D. COLLINS

## CHAPTER III

## SURGICAL ANESTHESIA

Karl Connell



## CHAPTER IV

## PREPARATION OF PATIENTS FOR OPERATION

Charles E. Farr

## CHAPTER V

## RELATIONS OF MEDICAL DISEASE TO SURGERY

Alexander Bryan Johnson and James H. Kenyon

### Part I

Alexander Bryan Johnson



### Part II

James H. Kenyon

## CHAPTER VI

## THE PROPHYLACTIC AND THERAPEUTIC ADMINISTRATION OF VACCINES AND SERA

Joseph C. Roper



## CHAPTER VII

## ASPIRATION AND ASPIRATING DEVICES IN OPERATIVE SURGERY

James H. Kenyon

## CHAPTER VIII

## THE PRINCIPLES AND TECHNIC OF OPERATIONS UPON BLOOD VESSELS

Frederick T. Van Beuren, Jr.



## CHAPTER IX

## A SPECIAL METHOD FOR THE TRANSFUSION OF BLOOD WITH THE USE OF PARAFFIN AND HIRUDIN

Ransom S. Hooker and Henry S. Satterlee

## CHAPTER X

## THE SURGICAL TREATMENT OF ANEURYSM

James M. Hitzrot



## CHAPTER XI

## LIGATIONS OF ARTERIES IN CONTINUITY

Walton Martin

## CHAPTER XII

## PLASTIC SURGERY INCLUDING HARELIP AND CLEFT PALATE, ALSO THE PLASTIC SURGERY OF THE LIPS, CHEEKS, EYELIDS AND EARS

Percy R. Turnure

## SKIN-GRAFTING

Alexander Bryan Johnson



## CHAPTER XIII

## OPERATIONS ON THE PERIPHERAL AND CRANIAL NERVES. UNILATERAL LAMINECTOMY

Alfred S. Taylor

## CHAPTER XIV

## OPERATIONS UPON THE MUSCLES, TENDONS, BURSÆ, AND FASCIÆ

Arthur Seymour Vosburgh



## CHAPTER XV

## GUNSHOT WOUNDS AND THEIR TREATMENT

Alexander Bryan Johnson



## CHAPTER XVI

## THE TREATMENT OF WOUNDS AND THEIR DISEASES

James M. Hitzrot

## CHAPTER XVII

## PREPARATION AND APPLICATION OF PLASTER-OF-PARIS DRESSINGS

J. F. Cowan

## DRESSINGS FOR FRACTURE OF THE CLAVICLE

Howard D. Collins



## CHAPTER XVIII

## RADIUM IN SURGERY

A. Schuyler Clark

# LIST OF ILLUSTRATIONS

## ASEPTIC SURGICAL TECHNIC

### Howard D. Collins



## GENERAL OPERATIVE TECHNIC

### Howard D. Collins



## SURGICAL ANESTHESIA

### Karl Connell

## THE PROPHYLACTIC AND THERAPEUTIC ADMINISTRATION OF VACCINES AND SERA

JOSEPH C. ROPER

## ASPIRATION AND ASPIRATING DEVICES IN OPERATIVE SURGERY

JAMES H. KENYON



## THE PRINCIPLES AND TECHNIC OF OPERATIONS UPON BLOOD VESSELS

FREDERICK T. VAN BEUREN, JR.

## A SPECIAL METHOD FOR THE TRANSFUSION OF BLOOD WITH THE USE OF PARAFFIN AND HIRUDIN

RANSOM S. HOOKER AND HENRY S. SATTERLEE



## THE SURGICAL TREATMENT OF ANEURYSM

JAMES M. HITZROT

## LIGATIONS OF ARTERIES IN CONTINUITY

WALTON MARTIN



## PLASTIC SURGERY INCLUDING HARELIP AND CLEFT PALATE, ALSO THE PLASTIC SURGERY OF THE LIPS, CHEEKS, EYELIDS AND EARS

PERCY R. TURNURE

## OPERATIONS ON THE PERIPHERAL AND CRANIAL NERVES. UNILATERAL LAMINECTOMY

Alfred S. Taylor

## OPERATIONS UPON THE MUSCLES, TENDONS, BURSÆ AND FASCIÆ

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J. F. Cowan

## DRESSING FOR FRACTURE OF THE CLAVICLE

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# OPERATIVE THERAPEUSIS

## VOLUME I

## CHAPTER I

### ASEPTIC SURGICAL TECHNIC

Howard D. Collins

The discovery of the causes of surgical infections and the means of combating and eliminating their activities has done more to widen the scope of surgery than any other factor. The ancients certainly appreciated that the differences between clean and unclean healing were brought about by some definite agents; but superstition played so prominent a part in their beliefs that as often as not their efforts to overcome wound infections were directed to assuaging the anger of some malign deity. Nevertheless, a few ancient and medieval surgeons learned by experience that in many cases their patients promptly healed if the surgeon abstained from too active treatment of the wounds. Others, groping in the dark, used one medicament after another, charm after charm, hoping that each would prove to be the long-sought panacea. These two groups were the forerunners of aseptic and antiseptic followers. Not until 1871, under the leadership of Lord Lister, were the causes of wound infections appreciated and methods initiated for relief. Since Lister's time our knowledge along these lines has leaped with bounds until to-day we feel that a large part of the subject has been mastered. Science, however, is infinite, and the years to come may prove us to be to-day, only at the threshold of our knowledge of repair.

The march of time will, in a few years, all too soon, eliminate from the field of active surgical endeavor those masters of their art who, trained in their subject in the preaseptic days, lived long enough to see the new era, take advantage of its knowledge and perfect themselves in the new methods. They are indeed masters of surgery, for in their early years they learned to treat wounds with respect and conserve the energy of their patients. Without the adjuncts of the laboratory and X-ray they trained their powers of logical reasoning, their sense of touch and respect for the damage they could do. With such an equipment it is not strange that they should stand out so preëminently when all the new magic was put at their disposal.

## AGENTS OF INFECTION

The varieties of streptococci and staphylococci with their protean manifestations are the commonest causes of surgical infection, but it must be borne in mind that a host of other germs may be introduced into wounds so as to interfere with aseptic results, such as tubercle bacilli, Spirochætæ pallidæ, gas-producing bacilli, pyocyaneus, anthrax, etc. The most resistant of these causes of infection are the spores of anthrax, and such agents as will destroy the anthrax spores will produce complete annihilation of all other pathogenic forms.

## SOURCES OF INFECTION

Lord Lister ascribed the main source of infection to the germ-laden air and directed his principal attention to the antiseptic action of a spray of carbolic acid so as to sterilize the air about the field of operation. At present we regard the air to be of but little moment as a source of infection, and seek to remove or destroy the germs at such points where they may already have found lodgment. The germs of infection lodge in the skin of the patient, the hands of the surgeon, in clothing, instruments, weapons, and the earth itself, so that traumatic wounds, either accidental or intentional, are prone to infection unless the inflicting objects are sterile, or means are promptly taken to render inert the germs introduced.

## METHODS OF PREVENTION AND COUNTERACTION

Schimmelbusch formulated a list of the means to prevent and counteract surgical infection, which was as follows:

1. Mechanical means
2. Germicidal agents, heat and chemicals
3. Agents that arrest bacterial growth within the body
4. Agents directed against ptomain products
5. Agents increasing bodily resistance

The last three methods imply that infection already exists and so their employment would be strictly *antiseptic.* The ideal condition we seek is *asepsis,* and this can only be obtained by complete sterilization before the wound is made, so we must direct our attention to the first two methods. The handling of infected wounds and general infection is fully covered in another chapter of this work.

### MECHANICAL MEANS OF STERILIZATION

Mechanical means are uncertain, but they should be our first step toward sterilization and are best accomplished by the vigorous use of soap, hot water, and scrubbing brush or cloth. All articles intended for surgical work which will not be injured by such a procedure should be thoroughly scrubbed with liberal applications of soap and hot water to remove palpable dirt, grease, etc. Instruments, rubber goods, glassware, surgeon's hands and patient's skin should all be so treated.

### GERMICIDAL AGENTS

**Heat.**—Heat is the most valuable of all our germicidal agents, and wherever possible should be the agent employed. Boiling in clean water is the best form of heat available, for boiling water will destroy anthrax spores in two minutes. Next to boiling water comes live steam—by live steam we mean saturated or air-free steam—which may be used at normal pressure, or better yet if superheated, i. e., under increased pressure (7½ kilos or 15 pounds, twice the normal atmospheric pressure, raises steam to 121° C. or 250° F.). Steam under such a pressure will enter all crevices and interstices of gauze, cotton clothing, etc., unless they be compressed very tightly. Live steam destroys anthrax spores in 15 minutes or less.

HOT AIR.—Hot air at 140° C. or higher is a fairly valuable sterilizer, but requires about 3 hours to kill anthrax spores.

CAUTERY.—The actual cautery is positive as a germicide, but of course destructive to tissue. An unclean surface, as an ulcer for example, may be rendered completely sterile by its use, although, of course, at the expense of all the superficial tissue.

Careful study of the results of sterilization by boiling or steam (our most efficient means) has shown that the ordinary pathogenic bacteria, as well as anthrax spores, are destroyed in a short time, but cultures made of the sterilized objects at the end of 24 hours have often shown the development of isolated and attenuated growths of spores whose effect on the body has not been determined. That these spores are probably harmless is proved by the nearly uniform asepsis of wounds where reliance has been placed on the ordinary processes of sterilization of surgical materials by boiling and steam. Nevertheless, as long as any development does take place, the material cannot be considered perfectly sterile in a strict scientific sense. To render materials absolutely germ-free it is necessary to submit them to **fractional sterilization.** This consists in subjecting the materials, catgut, gauze, etc., to three, four or even five separate boilings or impregnations with steam at intervals of 24 hours. This method renders surgical supplies absolutely germ-free, but is a refinement hardly called for in order to destroy the recognized infectious bacteria.

**Chemicals.**—Chemicals are in many instances active germicidal agents and form a valuable armamentarium in our aim for asepsis. No chemicals can compare with boiling or live steam for efficiency, but much of our material will not submit to boiling or steam, and so perforce we must resort to chemicals. The lists suggested as being active germicides are appalling, and gradually the surgical world is confining itself more and more to a few of the highly recognized germicidal chemicals.

BICHLORID OF MERCURY.—At the top of the list should be placed bichlorid of mercury. This chemical, in strengths of 1:300,000, checks but does not destroy growths of anthrax spores. Used in strengths of 1:1,000 it is a most valuable agent for sterilizing glassware, rubber goods, etc., if the articles are free from grease and allowed to remain immersed in the solution for a sufficiently long time—one hour. Even under these conditions anthrax spores are not destroyed. Bichlorid of mercury solution has but little power to penetrate unbroken skin unless applied for a long time, and so is of no use in destroying bacteria underlying the more superficial skin layers. Bichlorid of mercury on raw surfaces forms an albuminate of mercury coating which is a serious barrier to further activity of the drug, and the destruction of healthy surface cells is of more harm than the value of its application. But little reliability should be placed on its use for sterilization of the patient's skin or surgeon's hands. Bichlorid of mercury should not be employed in sterilizing metal instruments, as it is destructive to the metal itself.

CARBOLIC ACID.—Carbolic acid was the mainstay of the early days of antisepsis, and in strengths of 1:20 to 1:40 is germicidal for most pathogenic organisms, but not for spores. In greater strengths it is highly injurious to the tissues of the body. It presents one advantage over bichlorid of mercury in that it is not destructive to metal instruments. As an application to the skin it is decidedly superior to bichlorid of mercury, owing to its increased permeability of unbroken skin, but the weak solutions necessary for safety are so mildly antiseptic as to render it but of slight value. Lysol, creolin and other coal-tar products act in a similar manner to carbolic acid, but are less dangerous.

IODIN.—Iodin (in tincture) has a powerful germicidal action, and has in the last few years attained great and deserved popularity as an agent for sterilizing the skin, catgut, etc.

POTASSIUM PERMANGANATE.—Potassium permanganate (1:20) is a good sterilizer of skin, but its stain is deep and fairly lasting, requiring decolorization by a saturated solution of oxalic acid.

IODOFORM.—Iodoform, it is claimed, has a specific action in arresting tubercle bacilli growths and stimulating the tissues. Its objectionable odor and poisonous properties counteract its value to some extent.

ALCOHOL.—Alcohol (95 per cent.) is a valuable destroyer of the ordinary bacteria of infection, but of little value against spores. It has great efficacy, however, as a stimulating and soothing dressing, preferably when used in strengths of 50 to 60 per cent.

FORMALDEHYD GAS.—Formaldehyd gas is a powerful disinfectant and is extensively used for disinfecting clothing, rooms, etc. This gas is the best agent known for sterilizing zinc oxid adhesive plaster and gutta-percha tissue. An aqueous solution (40 vols. of gas) is a valuable disinfectant but irritating to the living tissues.

In addition to the chemicals already mentioned, the list could be greatly extended by mentioning ether, hydrogen peroxid, boric acid, acetate of aluminum, salt solution, etc.—all chemicals possessing more or less active germicidal properties.

The selection of one or more of the individual drugs mentioned in the foregoing list is highly proper for the treatment of infected wounds. Practically, but little reliance is placed on most of them to-day for the purpose of rendering aseptic the field and appliances for a modern surgical operation.

Their indications and uses in the treatment of infected wounds will be taken up in its proper place, and such of the chemicals used in the preparatory stages of operative procedure will be discussed in detail when called for.

## SUTURE MATERIAL

The surgeon should bear in mind that sutures only serve to hold in apposition the tissues of the body until such time as agglutination of the tissues themselves is sufficiently strong to hold the parts together without danger of disruption by muscular retraction or pressure from within or without until complete continuity or healing has occurred.

It is impossible for any suture to hold the parts, be they skin, fascia, muscle or bone, together for any length of time in the presence of retraction unless agglutination takes place; for without adhesion of the opposed surfaces and in the presence of traction, the suture is bound to cut through in time and thus vitiate its purpose.

Now the length of time required for agglutination and healing to be accomplished, and in its absence or delay the time required for a suture to cut its way through the tissues, is a variable and difficultly determinable factor; and in our selection of material, size and method of application of the suture material we must be guided by the healing force of the patient, the character of the tissues and the strain to which they will be subjected during repair.

If the foregoing proposition be accepted as a fact, the corollary to it will have to be conceded; namely, our suture should be of such a size and strength and so placed as to serve only until agglutination and repair be well established and by its fineness and smoothness be as little irritating as possible and, furthermore, when its purpose be accomplished, that it disappear either by absorption or removal.

It is a common practice, which the writer deprecates, to use very long-lasting or non-absorbable suture material with the claim that "the patient's tissues may drag on those sutures for a lifetime without danger of the sutures breaking." If repair of the parts does not occur the sutures are *bound* to cut through, and that is equivalent to their rupture. It is absurd to repair a hernia or a fractured patella with silver wire, basing our hope of a cure on the wire not breaking and that the resistance to muscular traction will be transmitted for all time through the wire. The use of heavy non-absorbable material, if it serve the purpose until repair is complete and then when properly buried cause no irritation, is right enough; but how much more ideal the condition, if after the suture has served its purpose, it be removed.

**Catgut.**—Of all suture material at our disposal, catgut to-day presents the nearest to the ideal. It may be had in any size from but little coarser than hair-line thickness to a heavy strand. Its strength is very great, its period of absorption hastened or delayed by methods of preparation, and what is most important, it can be completely sterilized.

PREPARATION OF CATGUT.—Catgut is obtained from the submucosa of the small intestine of the sheep which has been macerated and treated so as to destroy the serous and mucous layers. The gut is then "spun" into strands of various sizes and lengths. As it comes from the manufacturer the gut is strong, soft and pliable, but highly infected with countless bacteria. The first stage in its surgical preparation is to wash and soak the gut in ether for 24 hours to remove the grease, etc. After this a number of different procedures have been devised of which the oldest, and theoretically the most ideal, method was to boil the gut for half an hour. Water, as the solution in which to boil the gut, was of course out of the question, for water turned the material into a gelatinous pulp. Alcohol does not destroy the character of the gut, but the boiling point of alcohol is too low to be of use in destroying many forms of bacteria. The plan then used was to boil the gut in alcohol under pressure sufficiently great to raise supposedly the boiling point of the alcohol to that of water. This method required a complicated apparatus, and was expensive and dangerous, owing to the highly inflammable quality of alcohol. In practice it is found that even the best appliances fail to raise the boiling point of alcohol to that of water (100° C.). Furthermore, the absolute alcohol of commerce contains ¼ per cent. of water, and unless infinite pains be taken in the manipulation, the alcohol readily picks up ½ to 1 per cent. This amount interferes with the reliability of the gut as to strength, consistency, etc.

CUMOL METHOD.—The cumol method consists in heating the gut in a bath of cumol. Cumol is a highly inflammable but non-explosive hydrocarbon with a boiling point of 170° C. The cumol is heated in a vessel standing in a sand bath to a point just short of boiling and the catgut, previously thoroughly dried, is put into the cumol. The gut is kept for one hour in the cumol at 165° C., when it is ready for use and may be stored in jars of sterile alcohol. There is no question but that catgut can be rendered absolutely sterile by this method; but the preservation of the gut in a sterile condition requires considerable care and is subject to easily committed errors in technic. It is customary to store the gut in jars of sterile absolute alcohol. It has already been pointed out that under these conditions the alcohol easily absorbs water and thus interferes with the value of the catgut. The removal of a spool of gut from time to time from a general reservoir is hazardous from the standpoint of asepsis.

The large commercial purveyors of surgical supplies have adopted the custom of furnishing catgut sterilized by the cumol method in hermetically sealed glass tubes filled with sterile absolute alcohol. Each tube contains only a few feet of gut, and thus the amount wasted at an operation is but small. The glass tubes may be and should be boiled in water at the time of the operation, so as to render the outside of the glass tube sterile, permitting of its being handled for the purpose of opening by sterile hands. Catgut so prepared by reliable commercial houses can be absolutely depended upon to be as nearly uniformly sterile and of proper strength as could be desired.

The mechanical appliances for preparing and preserving the catgut by the above described methods are too complicated to render them practical for use on a small scale. To overcome these difficulties the preparation of gut by the iodin method was devised.

Iodin Method.—Several methods of procedure have been suggested. One of the earliest and simplest was that of Claudius, which consists in immersing the catgut for eight days in an aqueous solution of iodin and potassium iodid (1 per cent. of each). Various modifications of this method have been adopted, several of which are a combination of sterilizing the catgut in a bland oil (albolene or cumol) with a high boiling point, and then storing the gut in an iodin tincture. (This is practically the cumol method plus iodin storage.)

Moschcowitz has originated the method of sterilizing the catgut (previously warmed to drive off all moisture) in a 5 per cent. alcoholic solution of iodin. The gut is left in the tincture for five days, then dried in a sterile towel and stored dry in a sterile jar. Moschcowitz has shown by a series of ingenious experiments that catgut so prepared is not only sterile in itself, but checks all growths in its vicinity when placed on artificially contaminated culture media. For over six years catgut so prepared has been used extensively at the Mount Sinai Hospital, New York City, with most excellent results. The simplicity, cheapness and proved results call for the heartiest commendation of Moschcowitz's method.

In addition to the foregoing methods, catgut has been prepared by sterilization in formalin, bichlorid of mercury, silver salts, etc. These methods present no advantages over the cumol or iodin processes.

Chromicized Catgut.—Many surgeons feel that the life of a strand of catgut buried in living tissue is too short to fulfill the purpose for which the suture or ligature is intended, and so the gut should be treated in such a way as to lengthen its period of absorption. This is best done by soaking the gut for 24 hours in a 4 per cent. aqueous solution of chromic acid, which raises the time of absorption of the gut by 10 to 20 days or even longer. The gut so treated is sterilized in the usual way (moist heat in cumol, albolene, etc.). The iodin method in itself renders the catgut less absorbable than plain gut, and so it is not usual to chromicize gut that is sterilized by the iodin process.

**Kangaroo Tendon.**—Kangaroo tendon is another suture material derived from animal tissue and behaves in the same way as catgut, but is less readily absorbable and has greater tensile strength. It is prepared in the same way as catgut.

**Silkworm-Gut.**—This is prepared from the contents of the silk sacs of the silkworm. It is a fine, pearly white strand, very springy like fine steel wire, non-irritating but non-absorbable. It is very popular as a firm tension suture to pass through and roughly approximate several layers of tissue, but should never be buried. Silkworm-gut is sterilized by simply boiling in water. It must be used in a wet state.

**Silk.**—The product of the activities of the silkworm is the oldest of all suture material. Commercially it is obtained in long strands of various thicknesses, either twisted or braided, bleached or dyed black. Silk is soft and pliable and its knots seldom slip. It is non-absorbable and should never be buried except occasionally under cover of the peritoneum. Silk is sterilized by boiling.

**Pagenstecher's Thread.**—This consists of a plain linen thread treated with celluloid. It presents similar characteristics to silk, but size for size is stronger, and owing to its celluloid coating is smoother. It is sterilized by boiling and, like silk, it should not be buried except in the peritoneum.

**Silver Wire.**—Made from ordinary "sterling" silver or pure silver, this is a very reliable non-absorbable suture and is extensively employed for retention purposes in bone work. The surgeon should always plan to remove the wire after it has served its purpose of holding the parts together until living union has occurred. Silver wire should always be annealed before using, by passing through a Bunsen or alcohol flame until a dull red. The annealing renders the wire more pliable, less brittle, and at the same time thoroughly sterilizes it. If the wire has been previously annealed it may be sterilized by boiling.

**Aluminum Alloys.**—Aluminum is known to be absorbed in time by the tissues, and aluminum or various alloys of aluminum are used as substitutes for silver wire. The uncertainty of the time of absorption is so great as to interfere with their usefulness. Aluminum and its alloy wires are sterilized by boiling.

## DRESSINGS

Material for surgical dressings should be capable of freely absorbing exudates and discharges from wounds, and be easily and perfectly sterilized. Gauze or "cheese cloth" fulfills these conditions admirably. Cheese cloth, as furnished from the cotton mills, comes in lengths of about fifty yards by one yard wide. Its fineness or coarseness varies in accordance with the number of threads to the inch—the intermediate numbers being best suited to ordinary surgical work. Cheese cloth in its preparation at the mill is usually submitted to a process of "sizing" or coating with a solution of starch, which interferes seriously with the absorbent powers of the material. To free the goods from the sizing it is necessary to boil the cloth in a 1 per cent. solution of sodium carbonate. The manufacturers of surgical supplies furnish gauze free from sizing in various sized packages hermetically sealed and already sterilized. Gauze so furnished can be depended upon with reasonable confidence, but **it is much safer to resterilize gauze before use.**

**Gauze.**—Gauze is best sterilized by superheated steam for thirty minutes in an autoclave, and should be subjected to fractional sterilization (2 or 3 steri-

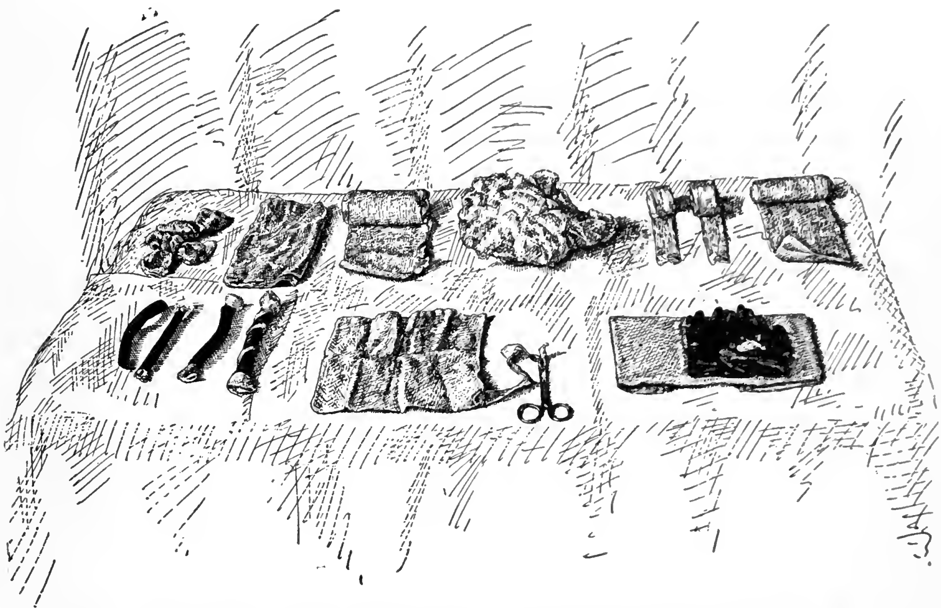

FIG. 1.—GAUZE PADS; HANDKERCHIEFS; ROLLS; RUBBER GLOVES; DRAINAGE TUBES.

lizations at intervals of 24 hours). The technic is as follows: The gauze is cut and folded into squares of suitable size and placed in metal cylinders or boxes which are so designed as to have perforations in the top and bottom to permit the free passage of the steam through the material; furthermore, the receptacles are equipped with sliding covers, which when slipped into place tightly cover over the perforations and prevent contamination of the gauze during storage. Caution should be exercised in packing the gauze in the boxes before sterilization not to compress the gauze tightly, as this interferes with the ready flow of the steam.

I have gauze cut and folded in the following shapes for various uses: Gauze handkerchiefs, about 1 yard square and fluffed up; squares about 4 by 6 inches of 4 thicknesses of folded gauze; abdominal sponge pads 1 foot square of 4 to 6 thicknesses with the edges stitched together and a piece of tape 6 inches long sewed to one corner; "leg rolls" 6 inches wide, 2 yards long, of 6 layers of gauze; narrow drainage strips from $\frac{1}{4}$ to 1 inch wide of various lengths and 2 to 4 thicknesses; sponge pads 2 by 2 to 4 by 4 inches of 4 thicknesses. In folding the gauze to make these various sized pads **great care must be taken to so enfold the "raw" edges of gauze that these edges are placed in the center of the pad so as to prevent shreds entering the wound.**

The assortment of pads is packed in metal boxes or cylinders, as already described, or put into large towels so folded over and pinned as to practically seal the package from the air at normal pressure. The whole is sterilized in an autoclave. [The packages may be further covered with paraffin paper.—Editor.]

**Cotton.**—Cotton is an indispensable member of our list of surgical dressings. It is furnished either as non-absorbent cotton, which is the raw cotton cleansed and beaten and then rolled into flat sheets about 1 inch thick and 18 inches wide, or as absorbent cotton, which is the same as the other, only bleached and freed from oil. Non-absorbent cotton is more springy and, being non-absorbent, does not become matted when wet, and is of great value under splints.

Absorbent cotton, as its name implies, is capable of retaining a great amount of moisture, and is of inestimable value in absorbing pus, blood, and other discharges.

Cotton is sterilized by steam in the same manner as gauze. In using absorbent cotton as a surgical dressing it is not a good plan to put the cotton next to the wound, but several thicknesses of gauze should intervene. Flat sheets of cotton about one foot square put into a "pillow case" of gauze is a practical way to use it for a dressing.

Lamb's wool, moss, oakum, felt, etc., have their advocates as outside dressings. Some of these substances are absorbent and can be used in extensively discharging wounds. Others are springy and serve as excellent padding. All can be sterilized by dry steam heat. They have no advantage over cotton.

**Sponges.**—No material is as efficacious for absorbing blood and discharges from a wound during an operation as the natural sea sponge, but the well-nigh impossible task of rendering a sea sponge sterile has led to the universal abandonment of this material. About the only "sponges" in use to-day for surgical work are squares of gauze folded as already described. Little balls of absorbent cotton 2 inches in diameter and covered with a piece of gauze gathered at the top and tied with a bit of cotton thread are used by some.

**Impregnated Gauze.**—The practice of antiseptic surgery called for the use of gauze impregnated with various chemicals, to be placed on or into wounds with the idea that the chemicals so exhibited would serve to destroy the pathogenic bacteria. In discussing on the previous pages the various chemical germicides the writer has tried to make clear that the substances at our disposal are either so irritating to the tissues of the body as to do more harm than good, or else are so feeble in their bactericidal action as to be of little or no avail. The use of impregnated gauze or dusting powders on supposedly clean wounds is a frank avowal of lack of faith in one's asepsis.

The argument might be raised that, given a wound already septic, is it not a wise plan to use impregnated gauze to destroy the bacteria now manifestly present? Our answer is yes, if there be a drug capable of destroying the bacteria which does not at the same time do harm to the body cells. My belief is that the function paramount of gauze packed into wounds is to absorb and imprison the discharges and to hold the wound open and prevent pocketing. As soon as the gauze has reached the limit of its power of absorption it should be removed and fresh packing introduced. The saturated gauze has removed in its meshes many noxious germs and detritus, all well rid of, but the real struggle takes place beneath the surface of the walls of the wound and no germicide in the form of antiseptic packing can penetrate to the scene of conflict without having harmed the superficial cells, the very guardians on whom we place part of our reliance. If we use such mild substances as not to injure the body cells, the bactericidal action is wanting and no harm results except that the absorbent power of the gauze is much diminished, as many of its meshes are filled to occlusion by the drug.

Most surgeons have seen very satisfactory results from the injection of Beck's paste or iodoform wax into tuberculous or simple suppurative sinuses. In such cases the satisfactory results depend not so much on any germicidal action as on the distention of the walls of the sinus, thus obliterating folds and pockets, and at the same time the waxy paste furnishes a smooth surface along which the discharges readily run to the outer dressings.

The usual way to prepare medicated gauze is to dip or roll strips of gauze of the desired size in solutions of selected strength of the drug, as, for example, bichlorid of mercury, 1:1,000, boric acid saturated solution, balsam of Peru, etc.

Iodoform gauze is prepared as follows: Strips of gauze are dipped into and allowed to become thoroughly impregnated with a mixture consisting of 1 part iodoform powder, 2 parts glycerin, and 2 parts alcohol, all previously sterilized. On removal the gauze is kept in air-tight sterile jars.

## BANDAGES

The usual bandages are made from unbleached muslin and from gauze in varying lengths and widths. A particularly desirable bandage, but quite expensive, is made from a material similar to an "Oxford shirting" known as "mull." This bandage is much more pliable and elastic than the muslin bandage and firmer than a gauze one. Starch bandages are made from "crinoline," a cotton gauze of firm weight highly sized (treated with starch). This bandage is wetted before application, and when dried out in place is much firmer than gauze or muslin without the objection of the weight of plaster-of-Paris. It is an excellent bandage for scalp wounds.

Plaster-of-Paris bandages are made by rolling gauze or crinoline in fine dental plaster, rubbing the plaster well into the meshes of the gauze. The work should only be done in dry weather and the bandage carefully preserved in tight boxes to keep the plaster from being air slacked.

In applying plaster-of-Paris dressings the bandages are first soaked in warm water and rolled on in the usual manner. Care must be taken that all bony prominences are well covered with canton flannel or cotton, for the amount of discomfort and danger that can be caused to a patient by the continual irritation of the hard plaster pressing on prominent points is considerable. Reënforcing plaster-of-Paris dressing is on the same principle as reënforced concrete. It is best accomplished by inserting between the turns of the bandage very thin (1/16 to 1/8 inch) strips of wood, one inch wide and long enough to extend the length of the dressing. The procedure adds very materially to the strength of the dressing with little addition to its weight. (See also Vol. II, Chap. III.)

Silicate of soda or water glass was much more extensively used in former times than now. The methods used were either to soak bandages in a watery solution of silicate of soda and apply as plaster-of-Paris bandages or to apply the bandages first and paint over with the solution. The objections to silicate of soda are its extra weight over plaster-of-Paris and the length of time required to harden it (12 to 24 hours). These objections have caused its practical disuse.

## ADHESIVE PLASTERS

The old-fashioned moleskin plaster is to-day the best plaster to apply directly to the skin, where it is intended to allow the plaster to remain a long time, as, for example, in Buck's extension, but the moleskin plaster requires to be heated so as to soften the waxy surface before it can be made to adhere. This is an objection. [Its surface may be wiped with benzin or ether.—EDITOR.]

The Z. O. plaster of to-day is rubber plaster improved by the addition of zinc oxid. It is not so irritating to the skin as plain rubber plaster, but more so than moleskin. Z. O. plaster can be had in big sheets or rolls of varying width.

Caution should be exercised in the too frequent renewal of strips of plaster over the same area. Some skins are very susceptible to irritation by Z. O. or any other plasters, and if the strips be torn off every two or three days and fresh ones applied, a most distressing excoriation may result. It is the writer's custom to cut the plasters at the point where they pass from the skin to the dressings, leaving the skin portion undisturbed, and in reapplying the fresh plaster the new piece is superimposed on the old piece still adherent to the skin. In this manner 6 or 7 layers may be formed corresponding to an equal number of dressings. After a week or 10 days the proliferation and desquamation of the epithelium loosen the plaster so that a new foundation must be laid on the skin, but this is new skin and not irritated by the frequent tearing off of the plaster, and so no irritation results. Another very good way to avoid frequent changes of plaster is to apply strips of plaster to the skin on either side of the dressing, leaving a long end to extend part way over the dressing. This long end is then folded back on itself so as to obliterate its adhesive surface. The tip is perforated and, with a tape inserted through the holes in each pair of plaster strips, the dressings may be tied in place. This method does not hold the dressing as firmly as the preceding. Benzin dissolves the rubber and is useful in cleansing the skin after using plaster.

Narrow Z. O. plaster strips placed across a wound serve to hold its edges in approximation nearly as well as sutures and are preferred to sutures by many surgeons. Plaster strips so used must be sterilized, for they come in direct contact with a fresh

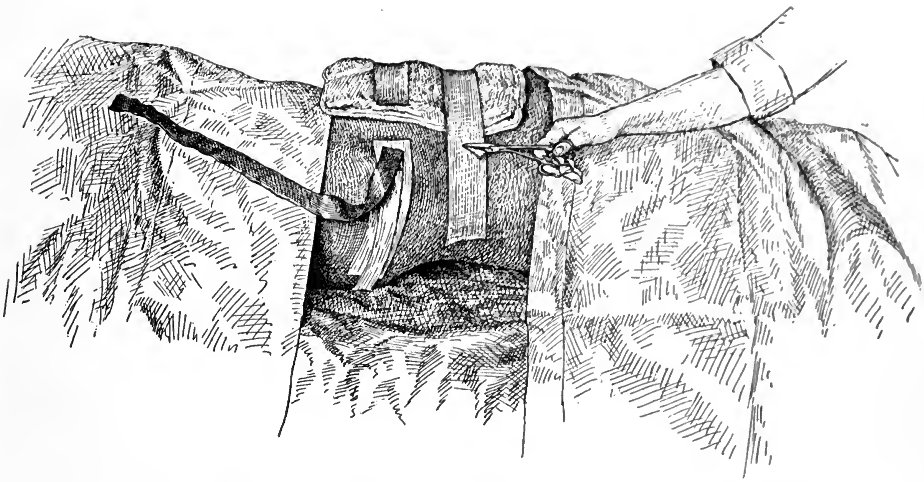

Fig. 2.—Method of Using Z. O. Plaster without Irritating the Skin.

wound. It is a most doubtful plan to attempt to sterilize Z. O. plaster after it is once manufactured, the usual way being to expose the plaster for a long time to formaldehyd gas. Reliable sterile strips, however, may be had from the manufacturers.

## DRAINAGE TUBES

At one time glass drainage tubes were extensively employed because of their rigidity in keeping sinuses open and the ease with which they could be sterilized. Their brittleness and unyielding pressure on the tissues have led to their abandonment.

Rubber tubes are much more satisfactory and may be used plain or with perforations cut into their sides, or the tube may be split lengthwise or spirally and a strip of gauze laid into the channel. Tubes so inserted should always be fastened at their outer end, for it not infrequently happens that a tube, unless so fastened, may slip into a long sinus and be temporarily lost, only to be recovered, after many weeks of mystifying absence of healing, by some rival practitioner.

**The Cigarette Drain.**—The so-called "cigarette" drain consists of a strip of gauze about which a sheet of rubber tissue has been wrapped. The gauze should project at either end beyond the tissue. The advantage a cigarette drain offers over a plain gauze packing is that the rubber tissue prevents adhesions between the gauze and the canal in which the drain lies, thus permitting the easy and less painful removal of the drain.

Rubber or gutta-percha tissue folded into strips of several thicknesses and from 1/8 to 1/4 inch wide is an excellent drainage material for slight discharges. Rubber tissue is obtained in large sheets of writing paper thickness or even thinner, is not elastic, and tears across the sheet with readiness, but not lengthwise. This should be borne in mind in making "cigarette" and other rubber tissue drains. The tissue should be folded with the "grain," for if this precaution is not taken it may so happen that a distal segment of the tissue may be left behind when the tissue is withdrawn from a wound.

Rubber tissue cannot be sterilized by boiling or steam. To prepare rubber tissue it should be thoroughly washed in soap and tepid water, rinsed off, and then immersed in bichlorid of mercury 1:1,000, or formalin, for several hours. Before using the bichlorid or formalin should be removed by washing in sterile water.

Strands of horse hair, silk, or catgut are sometimes used for drains. Rubber dam may sometimes be substituted for rubber tissue. It can be boiled.

## HYPODERMIC AND ASPIRATING SYRINGES

Syringes having leather packing about the plungers cannot be sterilized without injury by boiling, the most efficacious but still unreliable method being to soak the syringe in an antiseptic solution like strong carbolic acid (1:20) or alcohol. Bichlorid of mercury injures the metal, and formalin destroys the leather packing. All-metal or all-glass syringes with the plungers so accurately ground into the cylinders as to give a perfect fit are now readily purchased, and are so superior to the older types as to more than offset their increased cost and shorter lives. Such syringes can be boiled like any instrument.

## INSTRUMENTS

The modern armamentarium of the surgeon discards all instruments that are not exclusively made of metal so as not to be injured by boiling. Bone, hard rubber, and ivory are things of the past. In selecting instruments avoid as much as possible tools that are complicated or constructed with deep recesses and grooves which retain dirt, grease, dried blood, etc., adding to the difficulty of sterilization.

Instruments with aluminum handles had at one time quite a vogue, the advantage claimed being lightness. The very lightness is in the writer's opinion an objection. A generously made and fairly heavy instrument is far more agreeable to use than one of very light weight or of such small diameter as to strain the hand in order to maintain a firm grasp. Aluminum does not resist well the action of certain chemicals, particularly alkalies, so in time the metal becomes pitted and roughened.

Good steel, heavily nickel-plated, is the generally adopted material. Instruments should, after use, be well scrubbed with soap, brush, hot water, and then boiled; after sterilization they should be well dried and, if necessary, complicated joints touched with a very light lubricating oil (like "3 in 1"). To permit of easy cleaning, instruments that consist of two or more parts, like the blades of scissors or the two limbs of hemostatic forceps, should be equipped with the French lock or similar device for the easy separation of the component parts. [The editor prefers scissors with a screw joint. The blades hold closely together and cut longer at the points.]

Before using, instruments should be boiled for twenty minutes in water to

Fig. 3.—Instrument Boiler.

which 1 per cent. of carbonate of soda has been added. The soda plays a triple part: first, it raises the boiling point of the solution slightly above 100° C.; second, it destroys any oil or grease that may be present; third, it prevents rusting.

Any large metal tank with a cover suffices for an instrument boiler. The instruments are wrapped in a towel and placed in the boiling solution. After sterilization the bundle is removed and the instruments placed on a sterile towel spread on a suitable table, and then covered with another sterile towel, care, of course, being taken not to contaminate the instruments during their arrangement.

The accompanying cut shows a small convenient instrument boiler, the principal feature being a perforated tray with deep sides into which the instruments are placed, and after sterilization the tray containing the instruments is removed, the water draining off immediately. This obviates wrapping the instruments in a towel as described in the preceding paragraph.

The proper sterilization of keen-edged instruments like knives and razors (with metal handles) has led to much difference of opinion. Some surgeons claim that the fine knife edge is impaired by boiling, and this is doubtless true if the knives be placed in the boiler with other instruments where they are apt to be struck. These surgeons have even gone so far as to content themselves with knives soaked in carbolic alcohol or some other antiseptic solution, a practice which our theories of sterilization cannot condone. Wrapping the blades in wisps of cotton and then placing the knives in the boiler with other instruments protects to a great extent the knife edge from being knocked off, but I believe that the practice of dragging off the sheath of wet cotton markedly dulls the instrument.

Knives and razors, without other instruments, should be so placed in the instrument sterilizer that there is no danger of their striking one another, and then boiled without any cotton or gauze wrapping. A little rack of wire may be used if desired, serving to keep the knives apart and from being jolted by the boiling water. Knives should not be placed naked in a steam sterilizer, for the blades unprotected by nickel plate will be badly rusted. Grosse (2), of Munich, has conducted experiments showing that knives put into glass test-tubes with the mouth plugged with cotton and then put into a steam sterilizer at 100° C. can be sterilized in ten minutes without rusting the blades. The explanation given by Grosse is that the small amount of moisture of the air in the tube produces sufficient steam to accomplish the sterilization, and on cooling the mixture is deposited on the relatively cooler glass, and not on the steel plates.

## PREPARATION OF HANDS

By all odds the hands of the surgeon and his assistants and the skin of the patient do more to infect a surgical wound than all the other causes put together, and for that reason the greatest care must be taken in their preparation. In the great majority of instances the operative site on the patient's body is where the skin is not exposed to hardening and roughening. If it is so thickened, we have as a rule sufficient time to soften and prepare the skin so as to afford a reasonable assurance of sterility. On the other hand, the surgeon can devote but a short time each day to the sterilization of his hands, and were he to employ drastic measures he would soon put himself *hors de combat*.

Before the days of rubber gloves the care the surgeon had to take of his hands in order to prevent roughness, cracks, hang-nails, etc., and the irritating solutions and time necessary for hand cleansing were serious items, which to-day have, thanks to rubber gloves, been largely robbed of their terrors. One must not assume that proper care of the hands and cleansing before operation are no longer necessary, for a leaky or torn glove may vitiate all our dependence on gloves as a sterile hand covering, and so, to avoid infection as far as possible, we should have our hands in good condition and well cleansed.

The conscientious use of gloves in all operations and dressings, especially if the latter be suppurating, keeps the hands out of pus and the virulent pathogenic bacteria; such hands are more readily cleansed than those that have dipped into blood and pus.

None of the means of sterilizing the hands have been proved by laboratory tests to be perfect each and every time, and so we must content ourselves with such methods as give a reasonably high efficiency test and at the same time permit of frequent application.

The prime factor in the preparation of hands is the prolonged and liberal use of warm water, green soap and a scrubbing brush. The brush should be sterilized and the water running from the spigot, which latter should be controlled by pedals so as not to require the surgeon to manipulate the faucet by hand. This scrubbing should be conscientiously done for ten minutes and cover all parts of the hands and forearms and particularly the nails. The writer believes that the complete and accurate carrying out of this step accomplishes about all one can hope for in hand cleansing, but most good surgeons are not content to rest there, but finish their hand cleansing with one of the numerous chemical agents extensively advocated. The simplest and probably the best is immersion of the hands in sterile alcohol (75 per cent.) for from 5 to 10 minutes.

Bichlorid of mercury 1:1,000 is advocated by many, but to be of any avail requires from 15 to 20 minutes' immersion, and the irritation and chapping of the skin resulting from its frequent and long-continued use render subsequent sterilization more and more difficult. A momentary swish of the hands in a bowl of bichlorid is a farce.

Soaking the hands in a strong solution of permanganate of potash, followed by immersion in a warm saturated solution of oxalic acid to decolorize the staining of the permanganate, is highly approved of by many.

Scrubbing the hands with a paste made by moistening a small lump (½ oz.) of chlorid of lime in the palm and rubbing with a similar quantity of carbonate of soda is a process of great efficacy for loosening thickened epithelium and is a good disinfectant. [This is the best means of hand disinfection known.—Editor.]

A great many more processes have been advocated; those mentioned are the ones endorsed by most surgeons. Whichever methods are used, the hands are finally rinsed off in sterile water and dried with a sterile towel; the surgeon, however, must decide whether he will depend on the efficacy of his hand preparation or protect his patient and himself by the use of gloves.

**Rubber Gloves.**—About fifteen years ago the question of the use of some form of glove to be employed in operative manipulations was revived. (1. Collins.) While not a new proposition, the discussions aroused at that time were listened to with much interest by American surgeons, and particularly by those in New York City. As is always the case in the problems of the medical profession, there were numerous arguments advanced by the opposing factions, although the great majority recognized the immense superiority of the glove over the naked hand from the standpoint of asepsis. There was, though, much division of opinion as to the kind of glove to be worn, the method of use, and whether or no the surgeon's skill was handicapped.

It would not be of value to review these arguments now, but it is of interest to note that at that time there were but very few operators in this country who made any attempt whatever to wear gloves as a routine during operations. At that time the practical use of gloves was limited to occasional instances as a self-protection when operating on highly infectious cases. Now, on the other hand, the majority of surgeons look upon the use of gloves as much a matter of course as any of the rest of our aseptic technics.

The consensus of opinion is in favor of a glove made of pure, impervious India rubber, and a gum glove is the kind almost universally adopted.

The foremost argument in favor of the use of rubber gloves is the fact that it is impossible to assume beyond all question that one can by the use of antiseptics prepare the hands of all persons employed in an operation so as to be confident that each and every hand is sterile for each operation. Of course, many times some of the hands are aseptic, but one cannot be sure that all are invariably so.

Gloves of pure rubber can be unfailingly rendered aseptic by boiling or steam. Another point of greatest value is that impervious gloves preclude the possibility of exfoliations and detritus from the hands entering the surgical wound. A third point is that during an operation a smooth surface like a rubber glove can be more readily freed of coagulated blood and other materials than can the rough skin of the hand.

The actual preparation of the gloves is often very carelessly done, and unless they are simply picked from the boiler with a sterile instrument and handed hot and wet to the surgeon, there are many chances for error in their preparation by thoughtless and imperfectly instructed persons.

The best and pleasantest use of gloves is to put them on dry with sterile talcum or lycopodium as a lubricant.

Gloves may be properly prepared by either steam sterilization or boiling. The first method is as follows: The gloves are thoroughly washed and dried, the cuff of the glove is then turned back about two inches and the whole inside of the glove thoroughly dusted with talcum or lycopodium powder. One pair is then wrapped in a small towel and put into the autoclave for sterilization in the same manner as dressings, etc. Placed in the towel with the gloves is a small envelope of gauze about 2 inches square containing a dram or two of talcum powder. The gloves come out of the sterilizer perfectly dry and are kept in the original package, unopened, of course, until needed.

A more troublesome method of preparing gloves, where a steam sterilizer is not available, is by boiling and then drying them. The procedure is as follows: An ordinary box of talcum powder with a perforated top, several towels, and the little envelopes of gauze filled with talcum are sterilized in an ordinary kitchen oven with dry heat. (This is by no means a certain method, but serves fairly well in an emergency.)

The gloves are then turned wrong side out, placed in a wire cage, and submerged in clean water in the ordinary instrument boiler. Care should be taken that all of the glove is filled with water and the air driven out. Two pairs of long dressing forceps or sponge-holders should be put into the boiler with the gloves. The gloves are allowed to boil for from five to ten minutes. They are then taken from the cage and allowed to drain hastily. With the sterile forceps the gloves are placed on one of the sterile towels spread out flat and another sterile towel laid over them. If all the free water has been allowed to drain from the gloves, a little stroking and patting of the upper towel will thoroughly dry the outer surface (really the inside, for the gloves were turned wrong side out) in a few minutes. The upper towel is then turned back and the gloves, both back and palm, thoroughly dusted with the sterile powder from the box.

We are now ready to turn the gloves right side out. With one pair of forceps the edge of the wristband is lifted and the other pair of forceps introduced into the glove until the blades can grasp the web between the middle and ring fingers; by drawing on the interior pair of forceps and turning the cuff over with the other pair it takes but a moment to completely reverse the palm or hand portion of the glove. The neatest way to reverse the fingers is to grasp two diametrically opposed points of the edge of the wristband with the two pair of forceps and then twirl the glove two or three times about its transverse axis; in so doing one closes the orifice of the glove and imprisons some air in the palm. Lay the glove with the orifice still sealed on a sterile towel, and, pressing on the balloon part of the glove with another sterile towel, the compressed air causes the fingers to be everted with a rush. The gloves are next dried on their outer surface by again stroking and patting with a sterile towel until they are perfectly dry. With the forceps the cuffs are turned back, the gloves together with the envelope of talcum powder put in a sterile towel, folded over, and pinned. By this method of preparation the gloves have only come in contact with sterile towels, sterile forceps, and sterile powder. The inside is well lubricated, the outside is free from powder, and the gloves are perfectly dry.

The proper way to put on gloves is very simple; it is as follows: The hands are thoroughly cleansed by any method the surgeon elects and then thoroughly dried on a sterile towel. The package of gloves is opened by an attendant, and the surgeon carefully picks up the gauze envelope of powder; by rolling the gauze between and over his hands he thoroughly dusts his hands and fingers with the powder. He then grasps with one hand one glove by the turned-back cuff, only touching the *inside* of the glove (that part which eventually will lie in contact with his skin), and draws the glove onto the other hand. Then with the gloved hand he seizes the other glove, putting his gloved fingers into the recess of the folded cuff, thus only touching the glove on its *outside,* and draws, or, rather, pushes, the glove on the second hand. Not until both hands are gloved should the fingers be stroked into place nor the cuffs straightened out. In this manner the skin of the hands has at no time come in contact with the outside of the glove.

It seems fitting in this place to point out some gross errors in technic in the use of rubber gloves, because it is possible to witness many surgical operations where several people are employed and see gross errors of technic in the manner of using gloves; errors not so much of carelessness, but of lack of instruction and thought on the subject. This applies particularly to the internes on our hospital staffs and nurses. We assume that the surgeons-in-chief have studied the subject and errors on their part we ascribe to carelessness, but the juniors are receiving their training, and the details of instruction should not be neglected. Their thought and power of logic should be awakened so that a correct routine becomes a matter of subconscious habit.

The first argument in favor of the use of gloves is the one which the writer believes is most frequently set at naught by the careless manner in which the gloves are drawn on the hand. For example, the surgeon washes his hands in the most thorough manner, rinses them in various powerful antiseptics, according to his fancy, dries his hands on a sterile towel, and is now ready for his gloves. Are his hands sterile? Does he know it for a fact? If so, he is foolish to go to the trouble of wearing gloves. On the other hand, does he doubt the asepsis of his hands? Is he credulous? If so, note how he vitiates his technic by his manner of putting on the gloves. Over and over again, by those who should know better, one may see it done as follows: The gauntlet or wristband of the left glove is seized in a generous grasp by the right hand, and the left hand pushed into the glove as far as possible; then with the naked right hand the finger-tips of the left glove are stroked into place and the glove nicely adjusted. The right glove is now grasped by the left hand, already clothed, and the naked right hand introduced and the glove drawn into place, usually at the expense of dragging the left gloved thumb over the naked right hand and wrist. The surgeon now feels ready to begin his work, or possibly deems it wise to rinse off his gloved hands in some sterile solution.

Another favorite method of putting on gloves is to throw several pairs of freshly boiled gloves into a bowl of bichlorid of mercury solution or some similar antiseptic liquid. The surgeon, after thoroughly washing his hands as before, proceeds to draw, or, rather, to float, onto his hands the gloves lying in the bowl. During these manipulations he splashes the solution over the naked forearms and hands, the solution in turn bathes the gloves, and smears over their outer surface epithelium, etc., washed from the skin. The foregoing errors in technic are perfectly apparent when they are brought to our notice, and that they are errors in fact and not hair splittings must be conceded by all who admit the truth of the first and most important reason for wearing gloves, namely, the uncertainty of being able to sterilize all hands every time for all operations.

If one accepts the above as a fact, and nearly all up-to-date surgeons do, what possible excuse can there be for allowing the discredited and suspected hand to touch and rub up against the outside of the gloves so carefully prepared? If the surgeon adopts gloves, he places himself in the ranks of those who believe that the hand cannot infallibly be sterilized. If he then puts on his gloves as has been described, he must be a traitor to his beliefs. Successful operative results in spite of these errors do not nullify the argument. We see many perfect healings after operations where gloves were not worn, but the element of possibility of wound infection in the case of the naked hand has been proved by laboratory tests to be high, and practically nil with the sterile glove. Why, then, place on the face of the glove the very material we so eagerly strive to imprison within the glove?

Another objection to putting on gloves that are immersed in some liquid is the constant dripping from the wrist of the water imperfectly confined by the fingers in the interior of the glove. This water may have been lodged at the finger-tips for some time, and after having macerated and bathed the skin a thoughtless change of level of the hand allows this impure liquid to escape at the wrist and in all probability to fall into the wound or in its immediate vicinity. The same is true where a torn finger-tip is used. The whole glove acts as a funnel, the torn or tipless finger serving as the small end to lead with unerring aim the sweat, detritus, etc., of the whole hand into the wound.

Let us then properly prepare our gloves, properly put them on and use only such as are perfectly water-tight. The gloves are sterile only so long as we keep them so; they have no inherent virtue, no antiseptic power. One would think on seeing the carelessness with which gloves are handled that they had properties similar to radium, emitting powerful bactericidal rays, and were capable of neutralizing the grossest negligence on the part of those who abuse them.

## SKIN OF PATIENT

The remarks on the difficulty of sterilization of the skin of the surgeon's hands apply equally well, though to a lesser degree, to the skin of the patient. It has already been pointed out that the more usual sites of operation on the patient are where the skin is less exposed to contamination and roughening, and furthermore we have as a rule more time at our disposal.

A well-established rule for skin preparation is as follows: About twelve hours before operation a generous area about the operative site is thoroughly shaved and then freely lathered with soap suds and well scrubbed with a piece of gauze; a scrubbing brush is too harsh and is liable to set up a dermatitis. The suds are then rinsed off and the parts again rubbed with gauze and ether, to be followed by a third rubbing with alcohol. After the alcohol has evaporated a soft soap poultice is applied, the whole covered with sterile gauze and a bandage, which is left on until the patient is on the operating table. On the operating table the soap poultice is removed, the parts are again washed in soap and water, to be followed by ether and alcohol rubbings as already described. Skin so prepared is very nearly always sterile from a surgical point of view.

Another equally efficacious way is to carry out the procedure already giver up to the point of applying the soap poultice; this latter is omitted and plain dry sterile gauze applied instead. On the table the sterile dry dressing is removed and the operative field painted with a single coat of tincture of iodin (officinal strength) applied with a sterile brush (soft) or pledget of cotton. If this method be followed it is highly important to see to it that no water has been applied to the skin for several hours (the writer has put in his practice a minimum of eight hours) before the iodin is applied. The reason for this is that the cells of the skin absorb the water and swell up, thus preventing the penetration of the iodin.

Some surgeons apply two coats of iodin at intervals of several hours. This is hardly necessary, for if the first coat closely follows the soap-and-water scrubbing it is of no avail, and if the coats be put on at proper intervals the whole time of skin preparation is unduly prolonged.

In emergency work where no proper time for skin preparation is permitted one may have reasonable confidence in a good heavy coat of iodin applied at the last moment, provided the abstinence of water to the skin has been observed.

The use of iodin has in some cases resulted in a dermatitis of more or less severity—two fatal cases have come to my knowledge. Removal of the iodin with alcohol at the close of the operation largely diminishes the risk of subsequent skin irritation. [A liberal coat of iodin applied on the table and allowed to dry, then wiped off with alcohol, is efficacious.—Editor.]

Iodin applied to very sensitive skin areas, as the scrotum, etc., increases the risk of dermatitis, and these parts should invariably be washed with alcohol after operation and lightly smeared over with sterile oil or vaselin.

If the surgical field be the hand or foot, where the skin is more or less horny, the preparation should be started two or three days before operation. The preparation should consist of several scrubbings with soap, ether, and alcohol, and applications of soap poultices at 12-hour intervals with the final preparation as already described.

## AUTOCLAVE OR STEAM STERILIZER

Mention has been made so frequently in the foregoing pages of sterilizing dressings and surgical materials by steam under pressure that it may not be inappropriate to describe briefly the apparatus for producing this result, although so familiar an object as the steam sterilizer must be well known to all.

Different manufacturers have devised various styles of autoclave, but the main principles are the same. The following description and illustration are quoted from the catalogue of the Kny-Scheerer Company:

1. Fill the steam jacket with clear water by opening valve on metal funnel C, turning lever No. 1 to the right. The quantity of water required for sterilization depends on the length of time for which the apparatus shall be operated. It is not desirable to have the jacket filled more than half full of water. (See sectional view, Fig. 4.) The glass water gauge on side indicates exactly the height of water in jacket.

2. A permanent connection with the hydrant water supply can be made through the valve G (the clean-out valve) by connecting a Tee back of valve G and using a

gate valve on the Tee, to which you connect your hydrant water. This method of filling the water into the jackets works rapidly, and in addition offers the advantage to be able to inject water at any time even though the apparatus may be under pressure and in operation. The pressure of the water supply at point of entrance at valve G

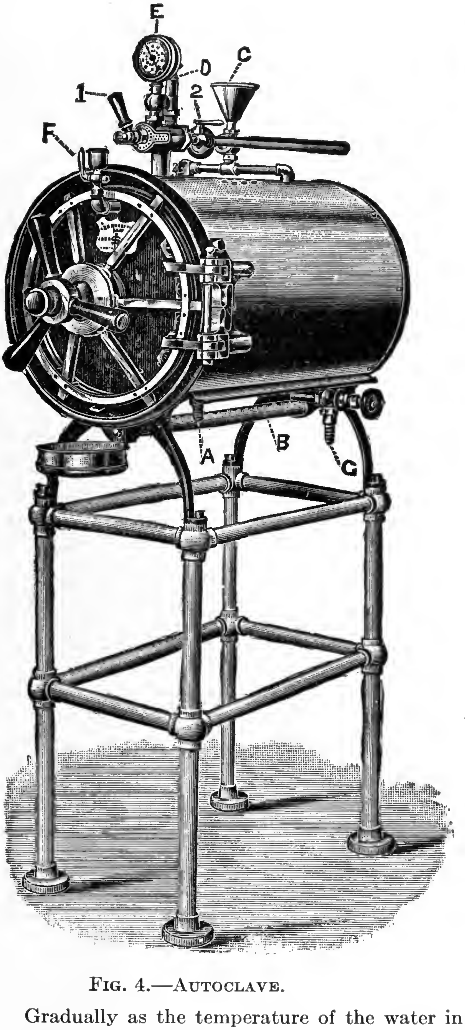


Fig. 4.—Autoclave.

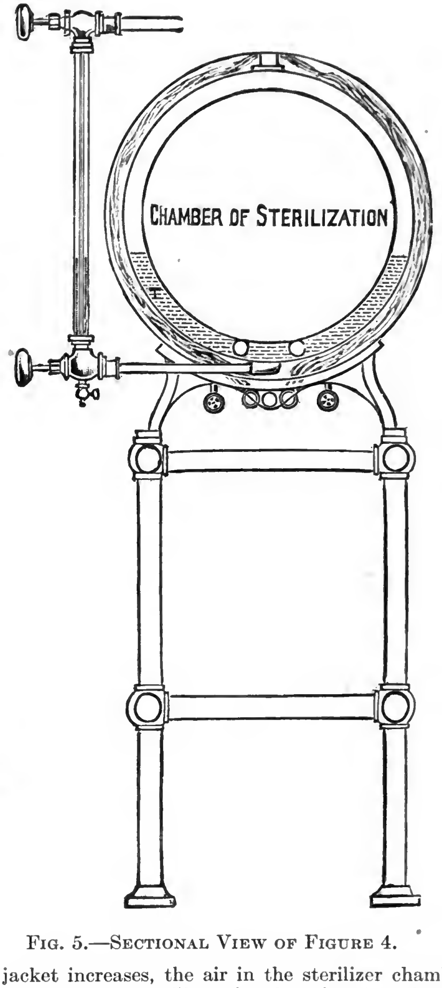


Fig. 5.—Sectional View of Figure 4.

Gradually as the temperature of the water in jacket increases, the air in the sterilizer chamber becomes rarefied and finds an escape through cup valve F. The sterilizer chamber therefore, in the first stage of the process, serves the purpose of a hot air oven, gradually warming the dressings preparatory to letting pressure steam into the chamber.

must, of course, exceed that of the steam pressure in the jacket; the latter being 15 pounds to the square inch, it follows that the water pressure should at least be 25 pounds or more.

3. The steam jacket having been filled with a sufficient quantity of water, throw lever handle No. 1 back to the left and light the burner (gas, petroleum or alcohol) leaving valve on funnel C open until steam issues, then close it tightly. The combination steam pressure and vacuum gauges E will register the conditions prevailing in

the jacket and the steam pressure safety valve D will blow off steam as soon as the latter exceeds the normal pressure of 15 pounds (= 1 atmosphere).

Whenever live steam, exceeding 35 pounds per square inch derived from a boiler plant, installed in the building, is available, we strongly recommend the use of the latter as heating medium. For this purpose we place in all of our sterilizers (with the exceptions of No. O and No. 1) a set of steam-heating coils between the two copper cylinders forming the jacket, consisting of heavy wall copper pipe, which is connected to nipples AA, one of these serving as steam inlet, the other as steam outlet.

Through these heating coils the high pressure steam circulates, and its temperature, in proportion to the respective amount of pressure, rapidly raises the temperature of the water in jacket to boiling-point and over, until it reaches the temperature of 250° F. (121° C.), which is the equivalent degree of steam or of water boiling under a pressure of 15 pounds to the square inch. The safety valve D keeps pressure in jacket under perfect control at 15 pounds.

4. The dressing material should be placed in the sterilizer chamber before the heaters are lit, or as in the case of steam-heated jackets, before the boiler steam is turned into the heating coils. Door of sterilizer is locked securely and air-filtering cup valve F, which is filled with a wad of absorbent cotton, is left open, handle being in vertical position as shown in drawing F1.

Gradually as the temperature of the water increases the air in the sterilizer chamber becomes rarefied and finds an escape through cup valve F. The sterilizer chamber therefore in the first stage of the process serves the purpose of a hot air oven, gradually warming the dressings preparatory to letting pressure steam into the chamber.

5. As soon as the steam pressure gauge indicates a pressure of 15 pounds, the safety valve will begin to operate by blowing off steam in excess of the required pressure, then close the air filtering cup valve F by thrusting handle into a horizontal position.

The moment has now arrived for exhausting the already rarefied air in the sterilizer chamber by creating a partial vacuum. This is done by throwing lever No. 1 to vacuum. The combination gauge E will soon register a vacuum in the chamber, five inches being sufficient to insure absolute result.

When this degree of vacuum has been reached, move lever 1 to chamber whereupon the pressure steam will rush into the chamber. The dressing material contained in the latter, having thus been carefully prepared by the air exhaust process for an eager absorption of live steam, will instantaneously and thoroughly be penetrated by the same. Furthermore since the inrushing steam which is of a temperature of 250° F. (121° C.) will meet with material which has for some time been subjected to dry, hot air of nearly the same degree of temperature as that of the pressure steam, the latter will not condense and therefore not wet the dressings. The process of steam sterilization shall last for from 20 to 30 minutes.

6. The dressing material can now be considered absolutely sterile and may be taken out at once, if desired. It is advisable, however, to let it remain in the sterilizer chamber for from 10 to 20 minutes longer in order to remove every trace of dampness. For this purpose move lever No. 1 to vacuum and again start the exhausting process described under No. 5, for the time above specified. After this, extinguish flame or shut off steam supply and throw lever No. 1 to the left.

7. To remove sterilized dressings from the chambers it is necessary to destroy the vacuum from the latter in order to be able to open the door. This is done by letting air enter the chamber through the air-filtering cup valve F, which is filled with absorbent cotton.

Dressings thus prepared can be absolutely depended upon as to their sterility. They may be left in the apparatus for an indefinite time before being used without becoming infected.

*Water.*—The surgeon has no need for chemically pure water, but germ-free water is constantly needed for all surgical work. Plain water boiled for a short time is perfectly reliable for all solutions, etc. The objection to boiling water

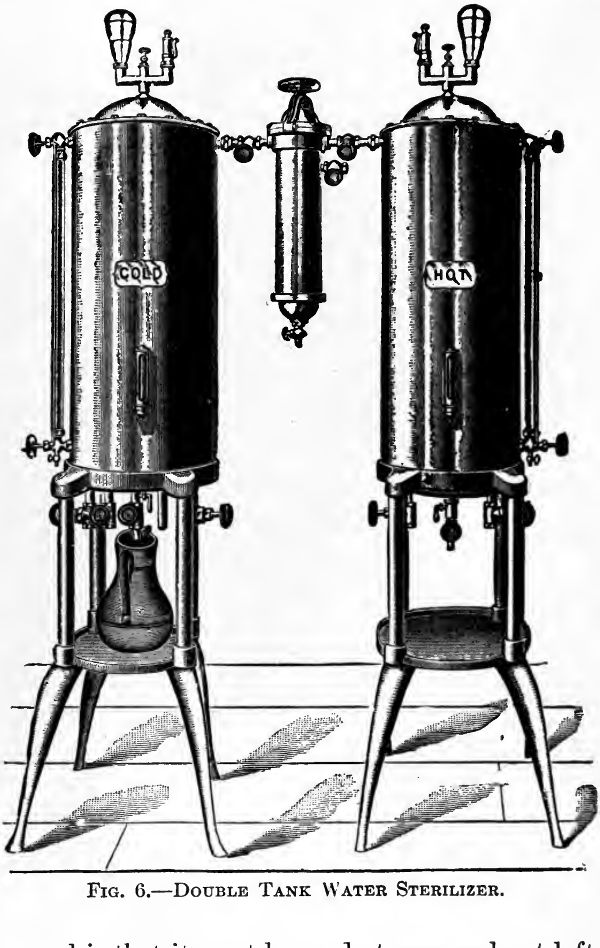


FIG. 6.—DOUBLE TANK WATER STERILIZER.

in an ordinary vessel is that it must be used at once and not left exposed to the air. For extensive hospital work water is boiled under pressure in tanks especially designed, in which the water may be stored without fear of air contamination.

The illustration shows a Kny-Scheerer double tank water sterilizer. The water from the city main flows through the filter (between the tanks) and enters both chambers. When tanks are nearly full the water is shut off and the burners lighted. A pressure gauge is at the top of each tank and set at 15 pounds. The water is heated until the pressure overcomes the gauge, which is equivalent to 121° C. This is continued for twenty minutes. The water is now thoroughly sterilized and may be drawn from the faucets at the bottom. One tank (marked "Cold") has coiled within it a number of feet of copper pipe, through which cold hydrant water may be allowed to circulate, thus cooling the sterile water in that tank (not by mixing, but by contact through the wall of the copper pipe). In this manner we have a liberal supply of hot and cold sterile water at hand.

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# CHAPTER II

## GENERAL OPERATIVE TECHNIC

Howard D. Collins

The practitioner of surgery should constantly use the details of his art so that the various steps of his technic may become a second nature to him, enabling him to perform these acts without thought on his part, leaving his mind clear for the higher faculties of judgment. In order to facilitate this training it is wise to limit our technic as much as possible to the essentials, eliminating all needless embellishments. In our discussion on antiseptics an effort has been made to show how small a part they should play in true aseptic surgery. In a properly conducted surgical operation it is assumed that all the materials furnished are in a sterile condition, and the surgeon should see to it that they are kept so, and not permit breaks in his technic, calling for the doubtful effects of antiseptics to set all straight again.

An endless list of solutions, an immense array of instruments, and countless other paraphernalia all tend to confuse and upset our aseptic plans. A skilled workman does his work best when provided with the proper tools, without being hampered by too great a variety of appliances.

The element of time is one that has advocates on both sides of the question, and, as in most other subjects, a happy medium is the wise course to pursue. An operator who is constantly trying to lower by a minute or two his operative record is very apt to be led away from the real purpose of the operation, namely, complete and speedy recovery of the patient. He will slur over little details—not essentials, it is true, but of great importance to the postoperative comfort of his patient—because he has one eye on the clock. On the other hand, dilatory action is not to be recommended. The longer an operation, by so much longer is a patient under an anesthetic, the more opportunity is given to handle the parts, and the longer is the pressure of retraction kept up. All of these factors are exhausting and tend to diminish the chances of smooth recovery.

One of the greatest masters of the art of operating, Charles McBurney, gave the impression of being a slow operator because all of his movements were comparatively deliberate; but when put to the test of the clock he was found to equal, and in most instances to exceed, the speed of well-recognized rapid operators. The secret of this lay in the fact that all of McBurney's operative surroundings were of the simplest, and in doing the work itself he never had to take a backward step or go over the field a second time. One should cultivate the habit of passing through the steps of an operation in a logical manner, taking up each feature in turn and completing it as far as may be possible before passing on to the next. Clean-cut incisions, complete hemostasis, and the accurate replacing of the parts, together with as little trauma as possible, are the fundamental underlying principles leading to the best results.

## INCISIONS

The incisions vary, of course, for different operations, and the special forms of incisions will be dealt with in discussing special operations. Where a choice is left to the operator he should choose as far as possible to make his skin incision correspond to the natural folds or creases of the skin; this is evidently of more importance where a cosmetic result is desired, but even where a well-concealed scar is not sought for it is wise if possible to choose the "run of the grain," for if this be followed subsequent suture of the skin is more accurate, and more prompt healing results. A long skin cut, if subsequently closed, will heal as promptly as a short cut; hence it is good surgery to make our skin incision as long as necessary to give a satisfactory view of the deeper parts, except, of course, where cosmetic effect plays a prominent part. No instrument is so good for making the skin incision as a scalpel. Some operators pinch up a fold of skin and cut through with a pair of scissors; this is rapid but at the expense of bruising the tissues. The scalpel should be "full-bellied," that is, the cutting edge should have a generous convex curve and the middle or most prominent part of the blade should be employed for the cutting. Do not scratch through the skin with the point of the knife. The handle of the scalpel should be large enough to give a firm hold, and should be grasped by the whole hand, and not by the fingers alone. The skin cut is best if made with one stroke of the knife, and should, of course, be at right angles to the surface. Both ends of the incision should be plumb and not gutter-shaped.

Wherever practical, the underlying tissues should be divided in the line of their cleavage. For very large wounds this is of course impracticable, but it is surprising how satisfactory an exposition of the deepest parts is permitted by following the natural lines of separation. Following this method, even at the expense of a little more time and some limiting of the field of exposure, one is well repaid by the diminution of trauma and the prompter and firmer healing of muscle tissue.

## HEMOSTASIS

Too great stress cannot be laid on the value of stopping all bleeding before wound closure, save in those operations where a blood clot is purposely left with the hope of its becoming organized. The more fully the point of a bleeding vessel can be isolated from the surrounding tissue, then grasped with a hemostat, and tied with as fine a ligature as the diameter and elasticity of the vessel will warrant, the nearer we approach the ideal. It would be folly to waste time in freeing the end of a small bleeding artery from its surrounding fat or muscle by a process of dissection before we attempt to clamp the vessel, but it is good practice to train ourselves to catch the bleeding point with as little other tissue as possible. A somewhat blunt-pointed hemostat, such as is shown in the accompanying illustration (Fig. 2), is the best for all around purposes. The comparatively big, blunt point prevents the instrument from puncturing into the tissues and seizing too large a grasp. The large blades, with their curved surfaces, aid the ligature while being tied to slip down and off the instrument at its very tip, and not pass on to the tissues for a greater distance than necessary. With a capable assistant, who understands the art of sponging, it is nearly always possible to see the bleeding point, when it may be caught as nearly isolated as possible by the hemostat without having to resort to the reprehensible practice of making a bold grasp in the direction of the bleeding, and by catching as much tissue as the forceps will hold, trust to having clamped the vessel. Finer pointed hemostats have their place and are very valuable for more delicate work, but should be used with increased care and circumspection. Where a vessel has retracted into the tissues and cannot be clamped, it is good practice to surround the vessel with a fine suture and then tie.

Bone bleeding can usually be stopped by very hot, wet compresses and pressure, or by breaking down the bony wall of the channel in which the vessel courses, or plugging the canal with a strand of catgut.

**Pedicles.**—Large pedicles, containing a number of vessels, should never be tied *en masse,* but should be separated into as many divisions as can be done conveniently and each part tied off individually.

For the nicest results in extensive dissections, say of the axilla, for carcinomatous lymph-nodes, it is far better practice to tie off each small vein as soon as exposed, by means of an aneurysm needle and double ligatures, rather than depend on clamping and subsequent ligation, thus avoiding the drag of many clamps.

Many surgeons after clamping bleeding points twist them instead of tying off. For small vessels this is a matter of choice, but it should never be done on large vessels.

One should never depend on chemicals to check bleeding other than surface hemorrhage. It is proper enough to apply adrenalin or similar substances to bleeding skin or mucous membrane, but not to the deep parts of a wound which is to be closed, for the action of the hemostatic cannot be depended upon to last long enough to permit firm clotting in the divided vessels, and so hidden hemorrhage may occur after the wound is closed.

**There is no step in operative technic that pays a higher reward than is received from a complete stoppage of all hemorrhage.** With a dry wound, with vessels carefully tied so that large masses of strangulated tissue are avoided, the healing should be prompt and satisfactory. Where subsequent bleeding occurs the tissues are forced apart and a most suitable nidus is formed for the development of pathogenic bacteria.

Excessive loss of blood is a most serious factor in producing shock and post-operative fatalities. The surgeon has already been cautioned to carefully clamp and tie the bleeding vessels as soon as possible, and thus avoid hemorrhage of magnitude. If hemorrhage of serious degree has already occurred the loss of blood may be compensated for to a fairly successful extent by the exhibition of normal salt solution. This may be administered in one of three ways: (1) the saline, at a temperature slightly higher than body heat, say 40° to 42° C., may be injected directly into a superficial vein; or, (2) introduced into the subcutaneous tissues; or, (3) injected into the rectum. Saline so administered is rapidly picked up by the blood, and being of the same density as blood serum, is perfectly incorporated into the blood current. The added watery bulk gives the heart something to work on, and also furnishes a vehicle for the rapidly forming red cells thrown out by bone marrow. A direct blood transfusion is a more ideal procedure, but does not permit of emergency application.

Better than repairing the damage done by hemorrhage is to conserve the blood as much as possible beforehand. In cases where hemorrhage is anticipated, or where the patient is much enfeebled, the principle of sequestration anemia, as advocated by Dawbarn, is to be highly recommended. Its application is as follows: At the time of, and just prior to, operating, such of the four limbs as may not be the site of the operation are elevated and stroked toward the trunk so as to empty them as much as may be of blood. An elastic bandage, preferably the pure gum bandage of Esmarch, is then wound on the limb, beginning at the extremity and passing up to the trunk and there fastened. This has forced most of the blood out of the limb and prevents any more blood entering the limb as long as the bandage is in place. The quantity of blood that would have entered the sequestrated limbs is now stored up in the trunk and brain, where it will do the most good. The bandages may be removed at the close of the operation or subsequently, but care must be taken not to leave them on too long, or the limbs may suffer.

In amputations or other operations on the extremities, where a bloodless field is desired, the limb to be operated upon may be rendered bloodless by the use of the Esmarch bandage, but the operator should invariably remove the bandage before closing the wound and be sure to clamp and tie all bleeding vessels. It is often possible to see an Esmarch bandage wrongly applied, and then it is worse than no bandage at all. To make proper application of this method the writer prefers two Esmarch bandages. They are used as follows: The limb is raised and stroked toward the trunk. The bandage is wound on spirally, quite tightly, beginning at the extremity and extending up to Scarpa's triangle, or the insertion of the deltoid, as the case may be. A pad of gauze, or simple roll of gauze bandage, is placed over the femoral or brachial artery.

This roll of bandage should have its long axis form an acute angle with the long axis of the vessel, so as to overlie, and be nearly but not quite parallel to, the vessel. The second Esmarch bandage is now passed circularly about the limb, covering the gauze plug or bandage, compressing the artery between the gauze and the bone. Three or four turns of the second Esmarch bandage is sufficient; it is then clamped or tied in place. The first Esmarch bandage is now removed, and the limb will be found completely anemic. Care must be taken that the pressure on the artery is not excessive, so as to bruise it and its accompanying nerves.

An Esmarch bandage applied about a limb which is filled with blood, or where the bandage only serves to retard the venous flow without checking the arterial supply, is a nuisance; the limb continues to ooze venous blood from every little vessel and no satisfactory view can be obtained.

For high amputation of the thigh, where an Esmarch bandage is of no avail, McBurney hit upon the clever plan of making a small intermuscular incision through the abdominal wall in the iliac region. Through this an assistant can compress the common iliac artery against the brim of the pelvis, completely controlling all hemorrhage. A similar procedure can be done for the subclavian, but requires a more discriminating touch on the part of the assistant doing the compression, owing to the proximity of the brachial plexus. (The writer recalls a case of paralysis of the arm lasting six months from too wide a field subjected to pressure.)

## TRAUMA TO TISSUES

It is surprising what a lot of abuse the tissues will stand in the absence of sepsis, but it is far wiser to show the body structures proper respect and not subject them to needless injury. Parts should never be torn where they can be cut; needless pinching with clamps, forceps, etc., is harmful, and prolonged severe retraction bruises and temporarily paralyzes muscles and nerves. Prolonged **handling of intestines, and especially dragging on their mesentery, is a very potent factor in producing postoperative shock.** Much subsequent pain may be avoided by seeing to it that cut nerves are not included in the ligation of vessels. If cut nerves can be identified the operator should invariably pull the nerves as far out of the surrounding parts as possible, and cut away the loose end in order that the cut nerve may not be involved in the subsequent scar.

## BONE OPERATIONS

The secret of success in bone operations is the preservation of the periosteum. A bone largely deprived of periosteum will usually necrose, but where the periosteum is peeled off during the operative work and then allowed to fall back on the bone it will promptly adhere to the bone, and the vitality of the latter will be preserved. Small areas of bone may be deprived of periosteum without subsequent necrosis; for the periosteum will bridge across from the edges of periosteum left intact, and if this bridging over occurs before the vitality of the bone is exhausted all goes well. If large areas completely or in great part encircling the bone be denuded, the subsequent necrosis will probably entirely vitiate the operative procedure. The beginner in operative practice should bear in mind that the periosteum is more easily stripped from the bone than the surrounding tissues can be freed from the periosteum, with the result that when the bone is thoroughly exposed it is denuded of periosteum, but on closing the wound the periosteum falls back into place and necrosis is avoided. All cuts into bone should be as clean and smooth as possible, and all splintered and bruised fragments removed. In cases where the bone is divided with the intention of replacing the ends in apposition the ends should be so shaped as to make as good a fit as possible.

## CLOSURE OF WOUNDS

Too much stress cannot be laid on the importance of accurate apposition of the parts in the closure of wounds. The small amount of additional time spent in accomplishing this is well repaid by the increased rapidity of healing and the greater strength of the scar. It is not good, or at least refined, surgery to close an abdominal wound with a generous retention suture passed through the whole thickness of the abdominal wall, trusting that the cut edges of the divided parts will be brought into accurate contact when the suture is tied. Such a plan is all well enough when great haste is called for, because the resultant scar serves in most instances sufficiently well, but there can be no assurance that one wall of the wound does not lie on a slightly different plane from the other, and while the skin may fit accurately, the chances are that the underlying tissues do not.

In the previous chapter we have discussed the advisability of using absorbable sutures and also the value of bringing the parts together without undue tension. It is my practice to use as fine a suture of plain catgut as will assuredly last until tissue agglutination has occurred. In the case of endothelial tissue, such as peritoneum, serous membrane, pia mater, etc., this occurs in 24 to 48 hours or less, and the finer numbers of catgut suffice. For split muscle fibers where the replacement is almost spontaneous fine catgut lasts long enough. Where a muscle has been divided across its fibers, or where muscle is transposed as in a hernia, treated by the Bassini method, the union is much slower, and here it is necessary to employ a suture that lasts at least two weeks, for which purpose a so-called 20-day chromic gut is best. The time for absorption of different strands of catgut of the same size, or similar degree to which they have been chromicized, depends on the greater or lesser amount of blood bathing the parts where the gut is buried. Thus a 20-day chromic gut employed to suture muscles, as in a Bassini operation, may not last more than the required 2 weeks, whereas, if employed to suture fascia, it might last the full 20 days. Fat is slow to heal and at the same time shows considerable objection to the presence of coarse suture material, which peculiarity of the fat may be met by using a fine non-absorbable suture such as silk or celluloid linen thread (Pagenstecher), which serves to close both the skin and subcutaneous fat. To do this a fairly long curved needle is used. The needle pierces the skin at a point away from the line of incision, equal in distance to the depth of the subcutaneous fat; the needle now penetrates the skin and the full thickness of the fat, crosses to the opposite side, and passes through the opposite fat and skin in the reverse direction, appearing at the skin at a corresponding point to its spot of entrance; the suture is of course drawn through with the needle. Several such sutures are passed at intervals, but are not tied until all have been placed. When tied, these sutures bring the cut wall of fat and skin in close contact, and it is surprising how few are needed to close a wound of considerable length, four or five sufficing for a six-inch wound. It is a more rapid method than closing the fat by buried catgut suture and then sewing the skin separately. In six or eight days at most the sutures have served their purpose, are then removed, and firm healing without dead spaces is the result.

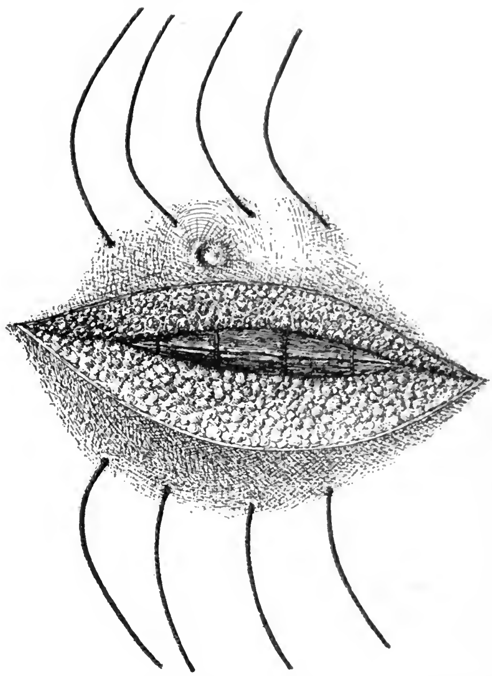

Fig. 1.—Showing Suture of Skin and Subcutaneous Tissues Down to the Deep Fascia in One Layer.

In curved incisions the sutures should be passed so that they correspond to the radii of the circle or curve on which the incision was made.

At one time Michel's clips and subcutaneous skin closure enjoyed considerable popularity, but one sees them much less practiced now than formerly. Michel's clamps are small strips of metal with sharp prongs at the ends; by means of a special holder and applicator these clips are placed across the skin wound with its edges approximated, then pressed into place and held by being slightly bent on themselves. The advantage in their use is speed, but they only serve to hold the skin and provide no support for the underlying fat. The resultant scar is not as perfect as may be obtained by careful interrupted suturing.

**Subcuticular Suture.**—The subcuticular suture is placed by introducing the needle with its suture into the edges of the wound just below the surface, and passing the needle back and forth from one side of the wound to the other. Thus we form a continuous suture without the objection of the numerous needle punctures on the surface. The removal of the suture may be somewhat troublesome and the apposition is not very perfect.

## DRAINAGE

When to drain and when not to drain is a problem that taxes the experience or guessing powers of the surgeon to an annoying degree. In the presence of infection there is no question; there is but one rule—and that is to drain. But for the borderline cases, or where there has been uncontrolled slight oozing, it may be worth while to close the wound, trusting to complete operative asepsis to avoid trouble. Rather than take the chance in doubtful cases, I prefer to drain, using, however, only a very small drain of gauze or folded gutta-percha tissue led down to the suspected point; in two or three days this may be removed, inspected, and replaced if conditions warrant. Its presence for a few days retards ultimate healing very little, and may save much distress.

Where frank drainage has to be employed one should respect the laws of gravity and physics. Wherever possible the point of exit of a drained wound should be at its lowest point, so that the discharges may escape by gravity; where this is impracticable we must depend on the capillarity of the drainage material. If gauze be the material employed, as soon as the gauze is saturated it should be replaced, be it 8 or 48 hours, for the gauze will only hold so much, and when soaked it fails of its purpose.

The only other point to be mentioned here in the drainage of wounds is to see that the orifice of the drained tract is larger than any of the underlying parts, and that the channel is as straight as possible. It is folly to attempt to drain and heal up a large buried area through a small skin orifice. Laying the superficial tissues wide open will save much time, distress, and risk to the patient.

## DRESSINGS

The application of gauze to a wound, open or closed, serves a threefold purpose: (1) to absorb moisture and discharges of the wound; (2) to prevent objectionable material from coming in contact with the wound; (3) to serve as a splint for keeping the parts at rest. Plain, dry sterile gauze is the most efficient agent to accomplish the first purpose. The same material serves admirably for the second, and if helped out with cotton is very satisfactory for the third, unless absolute absence of motion is desired, as in cases of fracture where some rigid material must be employed on the outside, as plaster-of-Paris.

Too little stress is laid on the value of rest of the parts after operation, and one may frequently see the dressing of a post-operative wound left to one of the junior house staff, who has never received proper instruction on the subject. Take for example a simple closed appendectomy wound. The usual procedure is something as follows: The surgeon and his principal assistants have closed the wound and turn away, a junior places a square of gauze on the wound and over that presses a couple of strips of adhesive plaster; a binder may be then put over all. Now, if the patient have a fairly full-rounded belly, the adhesive, if properly put on (and it seldom is), or the binder, may serve well enough for a splint and keep the abdominal wall at rest. If, on the other hand, the patient be thin, or with a contracted belly, or prominent anterior iliac spines, no proper support has been given. Those who apply the dressings and who value the comfort of their patients should study each case and mark its needs. Personally, I make it a practice to use shaken out fluffs or handkerchiefs of gauze, and with these build up a dressing which will smooth out the inequalities of the region about the wound, so that when the bandage, adhesive, or binder is applied, a uniformly firm but light pressure is evenly distributed over the parts, serving to keep the muscles at rest.

This is well illustrated in operations for hemorrhoids, where the anus has been stretched. One of the great discomforts following these operations is from the sagging of the entire perineal floor due to the relaxed levator ani muscle. This may be very largely relieved by building up a pyramid of gauze, the apex of which impinges on the anus and the plane of the base is on a level with the tuber ischii. The T-binder holds this wedge in place and the perineum is given proper support, which it does not receive from flat sheets of gauze, no matter how many in number.

## USE OF INSTRUMENTS

The illustration shows a few of the ordinary instruments, and an explanation of them may aid the beginner in laying the foundation of his armamentarium. A great variety of instruments is needed for special work, and such instruments will be discussed under the description of the special operations.

The knife shown is of the "full-bellied" type already referred to, and the operator should again be cautioned to do the cutting with the prominent part of the blade, and not depend on the point to "scratch" through the tissues.

Two artery clamps are shown. The one with the blunt, thick tips is to be recommended for general work, as the conical blades aid the ligature to slip off on to the tip of the vessel during the act of tying, and this blunt instrument is less liable to puncture into surrounding tissues while clamping the bleeding point. The finer nosed forceps should be used with increased care.

It will be noted that the scissors shown are quite heavy, blunt-tipped, and the blades quite short, with relatively long handles. It is very seldom that the surgeon is called on to make a cut over an inch or two in length with his scissors, and consequently it is needless to have the blades longer than two inches. The longer the handles are in proportion to the blades (within reason, of course) the more easily the cuts are made, and with less fatigue to the hand. Sharp-pointed scissors are very liable to puncture surrounding structures unless great care be used, and present no value for delicacy of work over blunt-pointed ones, and consequently are not to be recommended save to the most experienced operator. Scissors with blades curved on the flat are of great assistance because, while using them, the vision is less obstructed by the instrument itself, thus assuring one that he is cutting only the structures desired and nothing more.

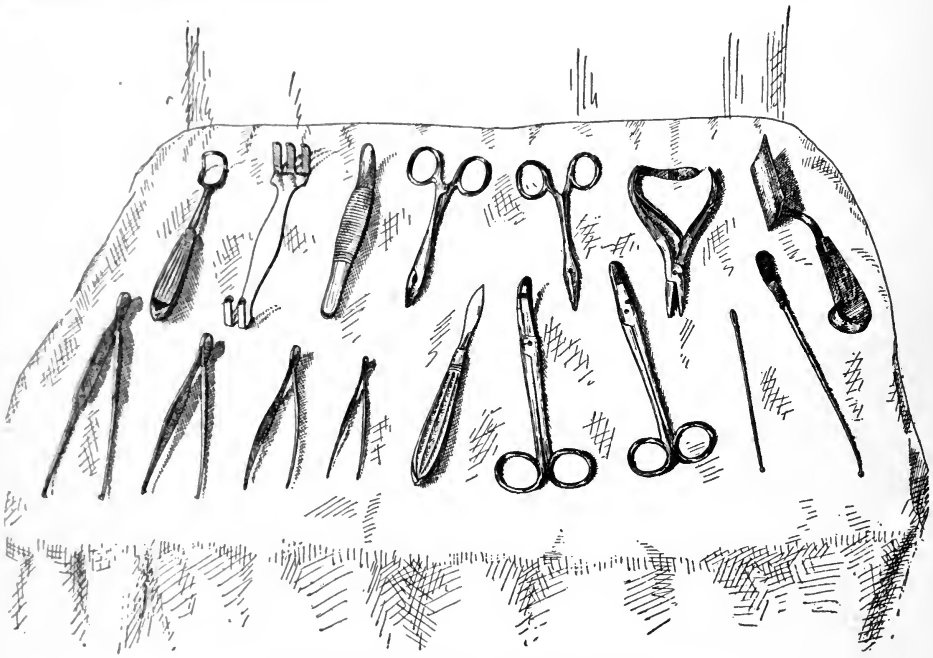

Fig. 2.—Assortment of Instruments.

Thumb forceps are of two varieties: those with flat, corrugated blade tips and those whose tips terminate in sharp interlocking teeth. The flat-bladed ones, or dissecting forceps, as they are called, depend on the pressure exerted in pressing the blades together to maintain their hold on the structures grasped. If the tissue be resistant or under tension, considerable force must be used to prevent the forceps from slipping. The result is that the tissues are badly bruised between the blades, and the operator is fatigued if the tension has to be long maintained.

The other variety, the mouse-toothed, depends on the sharp teeth puncturing the tissues for maintaining the grasp. They are much superior to the dissecting forceps except in situations where the puncture of the sharp teeth may cause damage, as, for example, grasping a blood-vessel or thin-walled loop of intestine. In ordinary work where the tissues are not injured by the puncture of the teeth, as for example the skin, muscle, fascia, etc., the mouse-toothed forceps maintain a firmer and less fatiguing grip and do less damage. The very long pair of mouse-toothed forceps shown in the picture has slender blades of uniform diameter for a large portion of their length. They are particularly valuable in doing deep dissections, as they do not interfere with the field of vision. The very delicate small pair of forceps is constructed just like those described except for the size. They are particularly useful in inverting small hollow stumps like the stump of an amputated appendix or the divided cystic duct after cholecystectomy.

The tension or spring of a pair of forceps depends on individual choice, but I find that the forceps that require the least pressure to close them and yet have sufficient resiliency to relax their hold on the tissues are pleasantest to use. There is quite a little muscular effort expended to keep a firm grasp on the tissues, and if the spring is strong and the operation lengthy the fatigue to the fingers is very marked.

Two probes are shown. The one is the usual fine silver probe, and the other much larger in diameter and longer. Both have bulbous tips. It is almost impossible to guide the small probe along a crooked sinus, the diameter of the orifice of which is the size of, or but little larger than, that of the probe, without having the probe puncture into the surrounding tissues and make a new tract for itself, thus obscuring the information sought. Nearly all sinuses that the surgeon seeks to explore with a probe are of sufficient size to admit the larger instrument, provided the orifice be enlarged by a slight cut or stretching. The larger probe with its heavier end is less prone to force its way out of the sinus, and with a little manipulation and bending of the probe a fairly crooked sinus can be safely explored for some distance.

Retractors, except the very coarsest, are with difficulty held in place unless the retractor has its toe turned backward for a short distance, or else terminates in sharp prongs. Sharp-pronged retractors are to be used circumspectly, for they easily may cause damage by puncture. The smaller retractors shown in the picture are very practical varieties for general use, and others of various sizes, built on the same plan, are suitable for larger and deeper work. The large pair shown is the so-called "trowel retractor" of Child. They are designed and especially adapted for pelvic work through the abdomen. They aid in keeping the surrounding structures from slipping into the pelvis, and serve as excellent light reflectors.

## OPERATING THEATER

It would be a very difficult matter to prescribe the arrangement of an operating theater and its accessory rooms which would meet the approval of a majority of surgeons. Every operator has his own individual preferences based on custom and experience, and if called on to build an operating-room would incorporate his personal views. Likewise architects should not build a surgical equipment without consulting those who will have to use it.

There are certain general principles agreed on by all that it may be proper to mention. Foremost of these are suitable light and ventilation, accessibility of the various parts of the plant, and a construction that permits of a high degree of cleanliness.

**Light.**—The best of all lights is bright daylight (but should not include direct sun-rays), and to accomplish this an overhead skylight either flat or slightly sloping toward the north (in the northern hemisphere) furnishes the most satisfactory natural light. The skylight should not be placed so high above the floor that a large amount of light is lost, and the skylight should be sufficiently large to amply cover the space occupied by the operating-table and its surroundings. Ordinary wall windows are well enough for lighting if the operative field can be brought close to the window, but such light entering the room horizontally, or at an acute angle, is of little use for illuminating a deep wound. For perineal work a side window light is of the greatest convenience and satisfaction.

Electric lighting is the best of all artificial light, as it is safe and clean. For ordinary purposes an electric fixture with half a dozen bulbs placed so as to throw their light directly downward onto the table is a very satisfactory arrangement. This may be further supplemented by one or two portable electric lamps equipped with reflectors, to be held by an assistant or fixed to an adjustable stand so as to throw the light at any angle desired.

For thoroughly equipped operating theaters the plan of using reflected electric light has recently been adopted. The principle is as follows: A powerful arc light is placed in a room adjacent to the operating-room and through a hole in the wall the light from the lamp, gathered by a lens into a beam of parallel rays, is projected into the operating-room and cast upon a mirror fastened on the opposite wall. The lamp, hole in the wall, and mirror are all several feet higher than the heads of the operators. The mirror is swiveled and can be adjusted to cast the reflected light directly, or by other mirrors, on the operative field. The advantages of this method are a stronger concentrated light cast directly on the desired field, and a very large diminution of heat, as the arc lamp is placed some distance away and in another room.

A much more expensive equipment consists of a group of mirrors on which the beam is first received. The surfaces of these mirrors are not in the same plane, but are placed at slightly different angles one to another. From this battery there will be reflected as many rays of light as there are mirrors in the battery, and each ray will diverge from the others. These various secondary beams are each caught on other mirrors, which in turn reflect the light so as to concentrate all the rays onto the desired field. The advantage of this plan is the absence of shadows. Where the light comes from but one reflected beam it is very probable that some object, say the surgeon's hand, will get into the path of light and thus cast a shadow; whereas, with a "battery" of seven mirrors or so, we have seven rays from different angles concentrated on the field. This would require seven objects, each placed in a separate path of light, before we would get more than the faintest shadow. An equipment of this sort has been in use at the Presbyterian Hospital of New York and has given great satisfaction.

No matter how well equipped with electric light an operating theater is, there should be some accessory system which may be put in commission on the shortest notice. The best for this is gas, burning in inverted mantles. The light is powerful, steady, and clean, but of course throws out much heat and presents the danger of a naked flame for ignition of ether vapor, etc.

**Ventilation.**—A very high temperature is not essential in an operating-room, but the patient should be protected from all drafts and the air of the

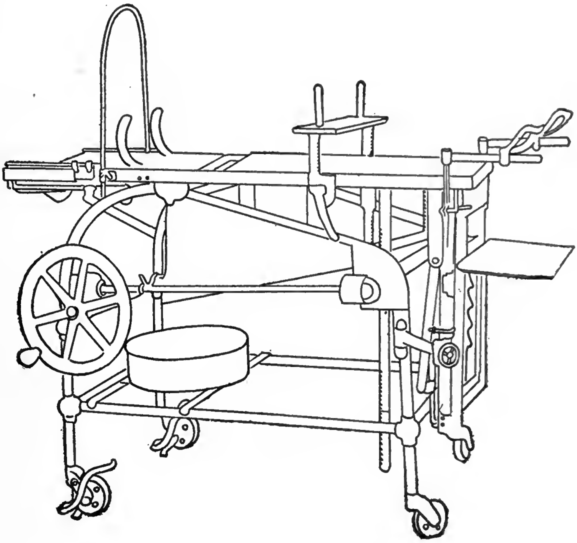

FIG. 3.—MARKOE OPERATING TABLE.

room should be as fresh as possible. I believe a temperature of 70° F. (21° C.) is quite warm enough, provided there are no drafts, and the drafts can be avoided by keeping doors and windows shut if some form of artificial ventilating system has been installed. Engineers and architects who may be engaged in equipping a ventilating system for operating-rooms should be instructed to make the entrances and egresses for air larger for operating theaters than for ordinary rooms, to insure rapid removal of the anesthetic vapors, and to guarantee very perfect ventilation without resorting to opening the windows. The air entering the room should pass through some sort of screen or sieve to remove palpable particles and dust.

**Accessible Secondary Rooms.**—In addition to the operating-room proper there should be in close communication with it a room in which the staff may dress and wash, a sterilizing room for preparing surgical materials, and suitable storage rooms, together with a room devoted exclusively to anesthetizing

Fig. 4.—Patient in Celiotomy Position.

Fig. 5.—Trendelenburg Position.

Fig. 6.—Rose Position.

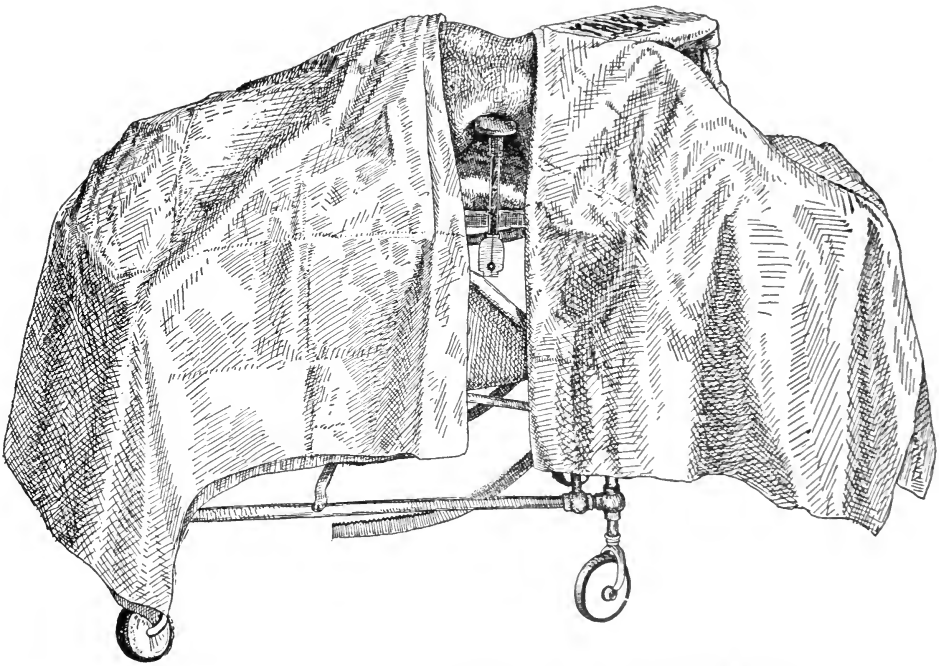

Fig. 7.—Nephrotomy Position, Showing Use of Cunningham Bridge.

the patients. The perfect sealing of waste traps, with which modern plumbing is provided, offers but very little risk of contamination from that source; and so basins and sinks may be placed directly in the operating-room, but they add to the labor of keeping the operating-room as dustless and clean as possible, and hence it is far better that all plumbing and fixtures be placed in one of the adjoining chambers.

**Cleanliness.**—The material and construction of the operating-room and its accessory chambers should permit all parts to be flushed out with a hose, playing a generous stream of hot water, without in any way injuring the surfaces. Marble or tiles set in Portland cement have been the favorite materials for this purpose and are ideal on account of their durability, smooth surfaces, and beauty. Such an equipment is expensive, and for all practical purposes Portland cement well troweled furnishes an equally good surface, but lacks the attractive appearance. Corners, wherever possible, are rounded, and all wood-

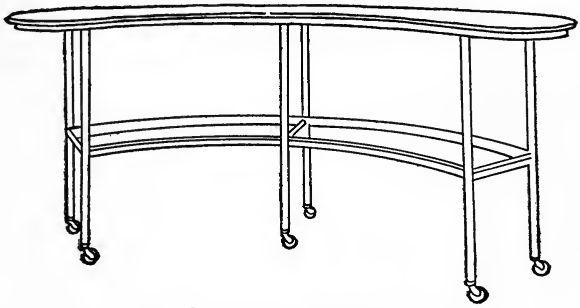

Fig. 8.—Kelly Instrument Table.

work should be free from grooves and mouldings and painted with hard enamel paint. A number of patent floorings have been used, but none are so good and lasting as the marble mosaics set in Portland cement, or the plain cement itself.

**Furniture.**—The prime requisite of an operating-table is that its height is such as to permit the surgeon to do his work without unduly stooping over. In addition, the table should be adjustable, allowing the patient to be placed and firmly held in various postures adapted to the work at hand. I know of no better table than the one that bears the name Francis Markoe, or the Hartley-Murray table. This table is of tubular metal frame, metal edges and braces, and may be equipped with a glass or sheet iron or copper, nickel-plated top. It permits of being adjusted for the Trendelenburg, lithotomy, Hartley, Rose, and other positions. The Cunningham bridge is also furnished, elevating the waist of the patient while lying on the side, a most valuable feature in kidney operations. The drainage is provided for in a very satisfactory manner, and a hoop of iron to be draped with a curtain shuts off the anesthetist from the field of operation.

In connection with operating-tables it is proper to mention the Bentley-

Squier's portable table. While not designed as a feature of permanent operating-room equipment, the table is a most useful adjunct to the surgeon's kit. The table can be folded into a small space and is of light weight so that it may be easily transported from house to house for work in private. When in position the table is very rigid and capable of several adjustments.

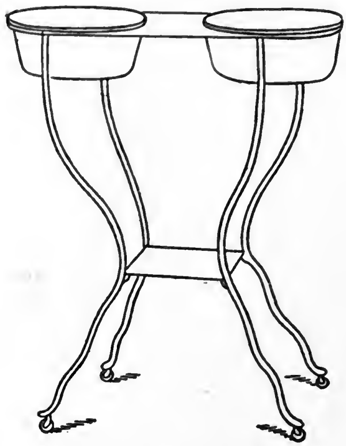
Fig. 9.—Hand Bowls.

Beside the operating-table, the operating-room should be equipped with several tables and stands for instruments, dressings, and gloves. A very serviceable type for instruments is that of Kelly. This is usually furnished with a glass top, but one of sheet iron is just as useful, lasts longer, and is cheaper. Hand bowls and irrigating stands shown in the cuts explain themselves.

When in use the tables should be draped with sterile sheets, and on these the sterile instruments, dressings, etc., are placed and covered over with sterile towels.

## POSITION AND ARRANGEMENT OF PATIENT

Before being anesthetized the patient should be clothed in a canton flannel gown, with the opening in the back, permitting its removal and replacement while in the recumbent position. There should also be provided a pair of loose stocking-like garments of canton flannel, reaching up to the knee. The hair is covered with a rubber bathing-cap. Thus clad, and covered with a light but warm blanket, the patient is well protected while taking the anesthetic, lying either on a stretcher or in bed.

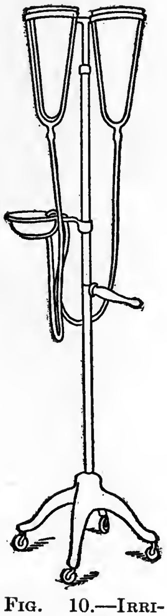
Fig. 10.—Irrigating Stand.

On the operating-table the patient should lie on a soft pad to serve as a protection against the glass or metal top of the table. Care is taken to see that the patient's arms or legs do not hang over the edge of the table, producing a pressure that may result in a very annoying paralysis.

The site of operation is now exposed, the final sterilization given, and the whole body covered with a sterile sheet reënforced by sterile towels, leaving the operative area free. If the field be a small one a hole of suitable size in the sheet makes a very practical arrangement. If a whole limb is to be in view, the rest of the body is covered as described and the limb in question rests on sterile towels or a second smaller sheet.

If the operation be about the face or neck, the rubber cap is covered by sterile towels, and towels are so placed as to leave the desired parts exposed.

For operations on the back the patient lies on the abdomen; but care must be taken that one shoulder is supported on a sandbag so that the breathing is not restricted, and that the arm of the unsupported shoulder be alongside of, and not doubled under, the body. For perineal work the foot of the table is lowered and the thighs strongly flexed on the body and abducted with bent knees; the buttocks are raised slightly on a sand-bag. To maintain this position the rods and stirrups with which most tables are equipped serve fairly well, but personally I prefer the Clover crutch. This appliance consists of a telescoping rod of metal capable of being adjusted and clamped at varying lengths, each end of the rod terminating in a leather strap to be buckled below the patient's knee. A long strap is passed behind the patient's neck; one side passing in front of the shoulder, the other passing through the opposite axilla; the ends of this strap are buckled to either end of the extension rod. With this device the thighs can be flexed and the knees abducted as much as may be desired.

The accompanying cuts show the patient in position for several types of operation. In the Trendelenburg position the hinge between the body of the table and the footpiece should correspond with the knee-joint, and the braces against which the shoulders rest should be so adjusted that a good part of the patient's weight is supported by the shoulders rather than let the patient hang by the knees.

In the "Rose" position the head hangs over the edge of the table. This is a most useful position for operation in the mouth, as, for example, resection of the superior maxilla, the blood necessarily accumulating in the back of the pharynx being less prone to enter the trachea. It is also the correct position for introducing the tube when intratracheal insufflation is to be employed for anesthesia. In operations on the kidney through the lateral route the patient lies on the side with the waist line resting on the "Cunningham bridge." The bridge is then elevated, which widens the costo-iliac space and crowds the kidney nearer the surface—a great comfort to the surgeon.

## SURGEON'S DRESS

Operating dress is subject to the dictates of fashion and individual taste, as are other articles of clothing, and one can but mention one's personal choice. The writer prefers a simple cotton pyjama suit with short sleeves. This suit is put on when preparing for the operation, and while furnished sterile, as a matter of routine, no attempt is made to keep the garments aseptic. After preparing the hands the rubber gloves are put on and then a sterile linen gown is donned. This gown reaches from the neck to well below the knees, is buttoned at the back, and has long sleeves. The sleeves are gathered at the wrist with elastic bands placed in the puckering hem, or tapes may be used. As the gown is put on after the gloves, the sleeves at the wrist lie superficial to the gauntlet of the glove. This I believe to be a better and neater arrangement than drawing the gauntlet of the glove over the lower end of the sleeve. The sleeve of the gown should be made sufficiently long so that no movement of the arm drags on the cuff, allowing a gap to exist between the sleeve and glove, exposing an area of naked wrist.

A cap and a mask, if desired, are then adjusted by the attendant nurse. The surgeon, enjoying good health, who observes the niceties of the toilet as

Fig. 11.—Face Mask and Gown.

Fig. 12.—Another Type of Face Mask.

regards the hygiene of the mouth and scalp need fear but little from them as sources of wound infection. If, however, the surgeon suffers from a coryza he should invariably wear some form of mouth and nose covering; likewise the victim of dandruff should wear a cap. A variety of these coverings has been adopted. The commonest form of cap used is a simple cap of cotton cloth, which covers about as much of the surgeon's scalp as the ordinary hat, and is well enough as far as it goes; but the temples are left exposed and no assurance given that perspiration from the forehead may not drop into the wound. The masks are simple squares of folded gauze with a tape sewn at each corner. The upper pair of tapes pass around the head above the ears and are tied behind; the lower pair pass around the neck and are there tied. Such a mask covers the nose and mouth. The combined mask and head covering in the illustration is the one that appeals to me. It resembles the "casque" of a medieval armor. It covers the entire head and face, leaving only a generous space for the eyes. Being in one piece, and having no strings to tie, simplify its application.

# CHAPTER III

## SURGICAL ANESTHESIA

KARL CONNELL

### INTRODUCTION

The abolition of the sensation of pain, together with surgical asepsis, has made possible modern surgery.

Pain is abolished by any physical or chemical agent which suspends for the moment function of the sensory nerve terminals, the conducting paths, or the receiving neurons of pain perception.

**Local Anesthesia.**—(See Résumé, p. 71.—EDITOR.) The nerve terminals and conducting paths are acted upon physically by cold and pressure, and by other physical agents. They are acted upon chemically by a group of alkaloid-like bodies, which are so administered as to act locally as transitory poisons on a group of nerve terminals or on a selected nerve trunk. The administration and dosage of the poison are so adjusted as to cause the minimal systemic effect.

**General Anesthesia.**—The receiving neurons, on the other hand, are anesthetized only by agents whose diffusion is general. For the most part these agents are volatile and gaseous drugs, administered usually by the pulmonary route. They abolish first the function of the cerebral cortex, followed by that of the basal and spinal nuclei, until finally in overdosage the great vital centers cease to act.

For completeness there may be mentioned certain forms of anesthesia incidental to toxic overdosage of alkaloidal and other narcotics. Anesthesia is also present in trauma to the central nervous system, in the state of hypnosis, in that of catalepsy and hysteria, in profound shock, and in the intense intoxication of various diseases. Anesthesia so induced or accidentally present is occasionally used wholly or in part for painless surgical procedure.

### LOCAL ANESTHESIA

Local anesthesia is secured by temporary inhibition of the conductivity of the nerve ends or the nerve trunks distributed to a given area, through *physical* or *chemical* agents.

## LOCAL ANESTHESIA BY PHYSICAL AGENTS

Certain forms of electricity, of light, and radio-activity are anesthetic, yet the only really useful physical agents available for surgical purposes are pressure and refrigeration.

**Pressure.**—Inhibiting the function of a nerve trunk by local pressure or by a tightly constricting band is of historical interest only, since it causes pain, is uncertain, and may result in long-continued or permanent motor palsy. The only common example of useful pressure anesthesia is that of pinching up a spot of skin for the painless insertion of the hypodermic needle.

**Refrigeration.**—INDICATIONS AND LIMITATIONS.—Numbing by cold is useful for superficial anesthesia and for the psychic effect, in anticipation of puncturing through the skin by needle or trocar or of a superficial incision. The anesthesia is superficial, incomplete, and transitory, and the discomfort of chilling often exceeds that of the surgical procedure in hand. For deep incisions chilling is at best an emergency makeshift.

TECHNIC.—The traditional method is to pack against the area pulverized ice and salt, equal parts, inclosed in a rubber bag for from 3 to 5 minutes, or until the surface is numb. The operation in hand is speedily carried to termination. In olden days this chilling was repeated as successive planes of tissue were met. Sodium sulphate as the refrigerant salt is more effective than sodium chlorid.

A more rapidly effective method is the vaporization of the volatile liquids upon the surface. For example, a fine spray of ether may be directed against the part, vaporization being hastened by blowing. This results in superficial chilling of the tissue. As soon as the tissue begins to blanch and stiffen the spray is discontinued, since superficial anesthesia is now present. Hard freezing is not desirable, for the tissue cuts with more difficulty, the after-pain is considerable, and necrosis may follow.

The standard method of to-day is to direct at the part from a distance of 5 to 10 in. a spray of ethyl chlorid held as a liquid in a commercial container (Fig. 1). The tissue is superficially frozen by the rapidly volatilizing liquid within half a minute, resulting in transitory anesthesia.

## LOCAL ANESTHESIA BY CHEMICAL AGENTS

**Introduction.**—Chemical agents are more generally useful than physical agents. They are for the most part alkaloid-like, loosely combining nerve poisons of the cocain type, and act on the nerve terminals or the nerve trunks.

**Anesthesia by Action on Nerve Terminals.**—Sensory nerve terminals may be reached: first, by osmosis through mucous membrane and other absorbent surface; second, by hypodermic injection into and diffusion through the lymph spaces—infiltration anesthesia; third, by local injection into the sequestrated venous system of a given area—intravenous anesthesia; and, fourth, by injecting the anesthetic into the arterial system supplying the desired area—end-arterial anesthesia. A method which may be dismissed with a word consists in driving the anesthetic chemical into the tissue by electric current—cataphoresis.

**Anesthesia by Action on Nerve Trunks.**—Entire regions may be anesthetized by blocking the nerve trunks, either by injecting directly into the trunk—intraneural anesthesia, or by infiltration in the neighborhood—perineural anesthesia.

By injecting the agent into the spinal fluid extensive segments of the body

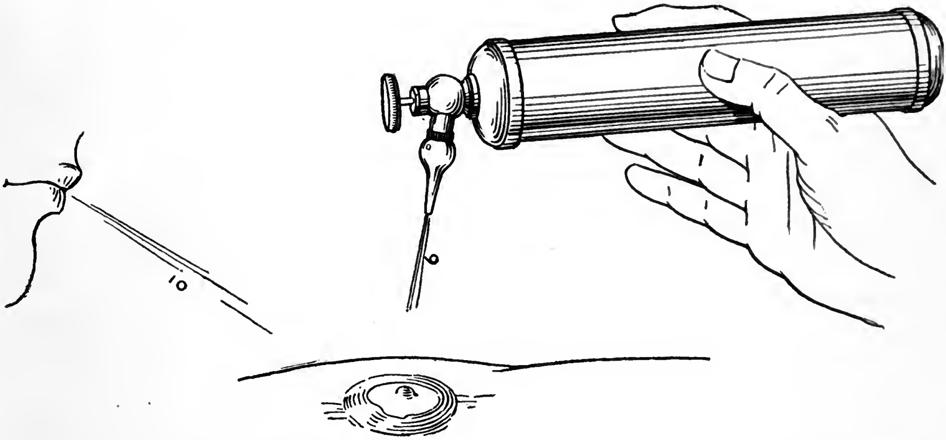

Fig. 1.—Refrigeration by Ethyl Chlorid. The ethyl-chlorid container is adjusted to spray a fine stream from a distance of about 6 inches. Evaporation is hastened by blowing on the spot from a distance of about 10 inches. When the area for operation has become frosted and stiffened, superficial anesthesia is present.

may be anesthetized by there blocking the nerve roots in the spinal canal—spinal or intramedullary anesthesia.

**Agents.**—COCAIN.—Cocain is the most rapid and effective of local anesthetics. It has a marked local vasoconstriction action, tending to render dry the operative field and to prolong the local anesthesia. The vasoconstriction inhibits the re-absorption by the blood plasma of the drug from the nerve tissue with which it has loosely combined. By the addition of adrenalin the vasoconstriction is rendered more efficient, the union of the anesthetic in the local area is more complete, anesthesia is increased in depth and in duration, absorption is delayed, and the liability to systemic intoxication much diminished.

Cocain has three drawbacks: first, it is unstable when in solution, hence for full anesthetic value it must be freshly dissolved; second, it is largely destroyed by boiling, hence difficult to sterilize; third, it is an excitant to the central nervous system of high toxicity. It should not be used in quantities exceeding 0.05 gram actually to be absorbed. Even less quantities than this frequently cause excitation of speech and motion and cardiac palpitation. Sudden deaths from cardiac failure have been ascribed to minute doses of the drug.

**Preparation of the Solution of Cocain.**—The solutions of cocain are as a rule from ¼ up to 2 per cent. One-half per cent. is the routine strength for minor operations. This solution may be safely used up to 10 c. c. for anesthetizing the skin and deeper structures in minor operations, or for cutaneous anesthesia in major procedure. Two per cent. is the preferred strength where intense effect with little distention of tissue is desired, as in acutely inflamed areas.

Where the sterility of the solution must be unquestioned only the sterile crystals in sealed ampules from the manufacturer should be used. These should be dissolved at the time of use, preferably in sterile normal saline solution.

For routine work it suffices to drop the commercial crystals or tablets into water, or preferably into freshly boiled normal saline solution just as boiling ceases. The crystalline drug is permitted to sink quietly to the bottom. Thus contaminating pyogenic or other surface organisms, if present, are washed off and killed in the hot upper stratum of water while the cocain dissolves in the cool bottom stratum.

A method more surely effective but rarely used on account of deterioration of the cocain is fractional sterilization, i. e., exposure of the solution on 3 successive days to a temperature of 67° C. for ½ hour. A method for large quantities is filtration through a Berkefeld filter.

Plain water is frequently used as the solvent, but it is in itself a cell irritant, produces pain, waterlogs the tissue and may injure the cells. These are negligible factors with small injections, but for use of considerable quantities the solution should be made isotonic by salt. The weight of the required cocain salt may be disregarded in calculating tonicity, since cocain must be present in large quantities (5.8 per cent.) to in itself render the solution isotonic. When epinephrin (adrenalin) is added such quantity is used as to make a strength of 1 : 20,000 solution.

NOVOCAIN.—Of the many substitutes for cocain, this synthetic alkaloid is the best. It has the advantage over cocain of being 7 times less toxic. The solution keeps many weeks without change, and it may be sterilized by heat, since the drug does not perceptibly decompose on boiling. Only after prolonged or repeated boiling is evidence of deterioration noticeable. It lacks the vaso-constriction action of cocain and is not so rapidly nor so persistently anesthetic. Under favorable conditions anesthesia appears in about 2 minutes and persists about 15 minutes. For more lasting anesthetic effect it must be combined, as must weak cocain solution, with epinephrin (adrenalin) 1:10,000 to 1:40,000. It is non-irritating to tissue.

Novocain is used in solution of the same percentage as cocain, and because of less toxicity in quantity 7 to 10 times as great, i. e., up to gm. 0.5 (grains 7.5).

It is the routine agent for use after the skin has been anesthetized by cocain and is the anesthetic of choice in all extensive infiltration and endovascular injection procedures.

STOVAIN.—The usage of this drug is largely confined to the induction of spinal nerve root anesthesia. Although only about half as toxic as cocain, it is mildly irritating, lowers the vitality of tissue, is a mild vasodilator, and causes after-pain. It inhibits the motor as well as the sensory nerves.

The solution may be sterilized by gentle boiling for 3 minutes. It is more powerful, more toxic, and less stable than novocain. It is precipitated by alkalies and for spinal injection the solution must be acidified with lactic acid, and sterilized by Pasteurization at 67° C.

QUININ AND UREA HYDROCHLORATE.—This drug is used where prolonged local anesthesia is desired. Anesthesia appears slowly, i. e., in from 15 minutes to ½ hour. It persists for 1 or 2 days or longer. Solutions are sterilized without deterioration by boiling. It is used in the same strength as cocain, i. e., ¼ to 2 per cent.

Locally quinin and urea hydrochlorate is a cell irritant. It causes edema and lowers the vitality of the tissue. Wounds heal less promptly and the establishment and spread of infection is promoted. Even dilute solutions may cause sloughing of the tissue and strong solutions must be used with caution. It should not be used in infected areas, or those liable to become infected, nor in tissue of low vitality. It has very little general toxicity.

OTHER DRUGS WHICH ARE LOCALLY ANESTHETIC.—The foregoing agents are generally recognized as the best available, although even they are not completely satisfactory. Many other drugs have been tried and found wanting, among these *tropococain,* which, although only half as toxic as cocain, is much less anesthetic and is a vasodilator; *alypin,* which in toxicity almost equals cocain, causes pain and vasodilatation, also marked after-pain and irritation. To these may be added *eucain, beta-eucain, holocain,* and many other drugs.

**Adjuvants to Local Anesthetic Agents.**—EPINEPHRIN.—This agent is a powerful vasoconstrictor, thereby it delays the absorption of an anesthetic, diminishes the systemic intoxication, and prolongs the regional effect. The vasoconstriction effect may be so marked and prolonged as to devitalize the tissues. Epinephrin should not be applied to mucous membrane stronger than 1:2,000, or injected subcutaneously stronger than 1:10,000. Epinephrin has a general toxic effect in overdosage. It should not be used in intravascular methods of anesthesia. Although subcutaneously the systemic effect is only 1/40 as powerful as by intravenous dosage, yet even for infiltration anesthesia solutions should contain in total not more than 5 c. c. (75 minims) of the 1:1,000 stock solution.

The *alkaloidal narcotics,* hydrocarbon and other *general anesthetics* as adjuvants to local agent are considered later.

### 1. Local Anesthesia by Osmosis

Mucous and other moist membranes may be rendered superficially anesthetic by local application of the selected agent. Through normal skin anesthetics are not absorbed in sufficient quantity for surgical anesthesia.

The only efficient agent on absorptive surfaces is cocain hydrochlorate, in strength of from 1 to 10 per cent. solution in sterile water. Two per cent. blunts sensation within 2 minutes. Ten per cent. accomplishes complete analgesia within 5 minutes. Occasionally on very restricted areas the pure cocain crystals are applied. To anesthetize periosteum beneath mucous membrane 10 per cent. of cocain must be held in contact for 15 to 20 minutes.

For nose and throat operations the usual procedure is to spray sparingly with weak solutions, securing thereby sufficient anesthesia so that stronger solution may be applied directly to the desired area by a cotton swab without irritation, or for deep and prolonged anesthetic action held in contact by packing the part.

On structures with poor circulation, such as the cornea, the action of cocain as a protoplasmic poison contra-indicates the use of solutions stronger than 2 per cent.

The general toxic effect of cocain must be ever borne in mind by the surgeon and a total of cocain which could be absorbed in excess of 0.05 gm. (¾ grain) should never be used. Fatal results have followed the local application of much smaller amounts than the above, notably in the urethra. Larger amounts, even up to 10 grains, are used locally in the expectation that a toxic dose will not be absorbed. It should be used with great caution. None should be swallowed.

As an osmotic agent novocain is a feeble anesthetic and lacks altogether the highly desirable quality of cocain in blanching the field of mucous operations.

## 2. Local Anesthesia by Infiltration

**General Considerations.**—The agent is injected into or beneath the skin. By diffusion throughout the neighboring intercellular spaces it inhibits the nerve terminals of pain perception. By the usual agents, i. e., cocain and novocain, touch perception is not so fully inhibited as is pain sense. Voluntary motion is inhibited very little.

Diffusion of the anesthetic may be interfered with by dense planes of tissue, or by the brawny edema of acutely inflamed area; or, again, the anesthetic may be rapidly absorbed by blood or lymph flow before it can combine with nerve tissue. These adverse factors are met by grading the strength of the anesthetic; by proper distribution of the solution in the various planes of tissue, and by there delaying absorption of the drug into the circulation, either by mechanically stopping the circulation or by adding to the solution a vasoconstrictor.

**Apparatus for Infiltration Anesthesia.**—The best syringe for infiltrating dense structures, such as skin and acutely inflamed area, is one of small capacity, 1 to 2 c. c., with slender piston so that the solution may be injected economically, accurately, and with little pressure on the piston. For infiltrating loose tissue with very dilute solution larger syringes, 5 to 10 c. c., are more convenient.

Steel needles are the best, holding a sharper edge, are more rigid, and much cheaper than those of iridioplatinum. These latter, however, should be used for deep puncture, where motion of the patient may snap the needle. The best needle points are those ground on a short bevel with a rounded cutting edge.

The apparatus should be sterilized by boiling in plain water. Syringes of metal and glass are fragile to heat; those of the Luer all-glass type and those of the all-metal type are most practicable.

**General Technic of Infiltration Anesthesia.**—The needle is inserted into the skin obliquely at an angle of 30°. As soon as the lumen of the needle is buried, from about 2 to 4 minims is gradually injected until a whitened wheal is raised and spreads in the substance of the skin. Into this the needle may be thrust further and the wheal rapidly elongated. When further thrust ceases to raise a wheal effectively the needle is withdrawn and inserted at the edge of the elongated wheal and a second injection made, so progressing until the line of incision is infiltrated. A very effective means to prolong the cutaneous anesthesia is to widely block off by circumferential infiltration the entire area of operation, after the manner of Braun. Effective anesthesia is induced, not by massive edematous infiltration, but by complete diffusion of proper strength of anesthetic.

If immediate anesthesia is not desired the skin may be liberally infiltrated through deep layers by weak solution. An extensive skin area may thus be more rapidly infiltrated than by the wheal method, yet anesthesia is not so rapidly established nor so persistent. The anesthetization of the zone of incision being completed, the needle is plunged into the deeper structures and injection made into those layers of the field of operation which carry pain sense. Many tissues such as fat, muscle, areolar tissue, and fascia give no sense of pain to sharp dissection, and require no infiltration.

Those tissues to which special care must be given are skin and mucous surface, nerve trunks, vascular trunks, periosteum, parietal pleura, parietal peritoneum, and joint structures. All these tissues must be independently infiltrated when reached.

Traction and excessive pressure on tissue should not be used. These give rise to sensation, against the blockage of which local anesthesia is not effective. Some of these sensations, while not those of conscious pain, impair the function of great vital systems such as the circulatory, respiratory, and sympathetic. An especially gentle, clean, sharp-cutting technic must be developed for success with local anesthesia.

**Preferred Technic for Special Groups of Operations.**—MINOR OPERATIONS ON NON-INFLAMED AREAS.—The skin is anesthetized by ½ per cent. cocain or novocain with epinephrin 1:20,000, by line of wheals. Incision is made and the deeper parts injected as need arises.

MINOR OPERATIONS ON INFLAMED AREAS.—When in a condition of acute inflammation all tissues become more or less sensitized. If the area of operation be small, as, for example, in a furuncle, the area is blocked by slowly surrounding it with wheals of injected anesthetic, preferably ½ per cent. solution of freshly dissolved cocain. The deeper subcutaneous tissue must be more liberally infiltrated than when dealing with non-inflamed tissue. For more rapid and certain anesthesia and to decrease the pain caused by distention of tissue already tense the percentage of cocain may be advantageously increased to 1 or 2 per cent. solution. The toxic limit, i. e., ¾ grain, must not be exceeded in the total amount of cocain used.

MAJOR OPERATIONS ON NON-INFLAMED AREAS.—For extensive and prolonged operation under local anesthesia it is desirable to induce by morphin or

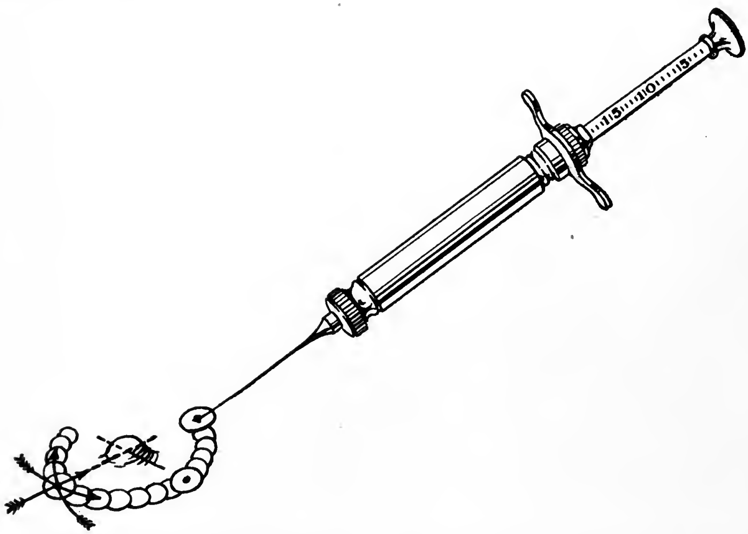

FIG. 2.—INFILTRATION ANESTHESIA: FURUNCLE. A line of wheals encircles the septic area. The needle is reinserted only so often as further infiltration ceases to raise a wheal. It is reinserted in an area already anesthetized. The desensitized area within the circle of wheals is infiltrated by four or more separate punctures, infiltrating the skin and the underlying tissue. Line of crucial incision diagrammed.

other alkaloid light preliminary narcosis. Thus the harmful psychic dread of operation and the acute cognizance of the unaccustomed surroundings and procedures in the operating room are blunted, the dosage of local anesthetic may be lessened and the duration of effect increased. At any stage of the operation this narcotic state may be deepened and the effect of the local anesthetic markedly increased by administering by inhalation about 1 drop of ether per second for a few minutes.

The usual narcotic is morphin, grain ¼, with atropin, grain 1/150, given hypodermically ½ hour before the operation; a more active combination is morphin, grain ⅙, and scopolamin, grain 1/100.

The line of incision is anesthetized by widely surrounding it by wheals, preferably of ½ per cent. novocain in normal saline with epinephrin freshly added 1: 20,000.

Through this blocked-off area deeper tissue is infiltrated, preferably with ¼ novocain-adrenalin solution; the skin is then incised. Next each successive layer is infiltrated with novocain in the degree which its sensitiveness requires, infiltrating with special care parietal peritoneum, pleura, and periosteum. Solution of 1/4 per cent. novocain, combined with epinephrin 1:40,000, is the most generally useful for extensive infiltration.

Where the need of a considerable quantity of anesthetic is anticipated it is well to measure out prior to the operation the maximum total dose which may be safely used. One measures out for a stock solution 50 c. c. of novocain, 1 per cent. solution in normal saline, to which is added epinephrin sufficient to make 1:10,000. This contains 0.5 gram or 7 1/2 grains of novocain, the limit of safety. From this stock is withdrawn for the first cutaneous injection, full strength solution; for subsequent infiltration the stock solution is diluted with 3 parts of saline solution (0.8 per cent.) to yield a 1/4 per cent. novocain solution with strength of epinephrin 1:40,000. Weaker solutions are ineffective.

When sensory nerve trunks are encountered, as, for example, in herniotomy, these are separately infiltrated. Thus a wide area becomes anesthetic and requires no further infiltration.

The novice in local anesthesia must beware of pressure by blunt instruments, of the spreading of the muscle fibers, and of traction on the viscera. Such manipulations, while not painful to the patient, give rise to undesirable stimuli, which may result in vomiting, syncope, shock, postoperative neurasthenia, and other nervous derangement.

EXTENSIVE OPERATION ON ACUTELY INFLAMED AREAS.—Infiltration anesthesia is inadvisable for extensive incision of inflamed areas, or for deep-seated tendon and joint lesions. The pain of injection, the unsatisfactory anesthesia, and the toxic dosage necessary to secure any reasonable degree of anesthesia render general anesthesia much preferable.

**Types of Operation Performed Under Infiltration Anesthesia.**—OPERATIONS ABOUT THE HEAD AND FACE.—*For the dissection of small superficial tumors and plastic operations on the head and elsewhere* the line of incision may be infiltrated, or the entire tumor may be blocked by a circle of wheals as described under Minor Operations on Uninflamed Areas. Dissection proceeds with the usual gentle manipulation necessitated by local anesthesia. The deeper planes of tissue are anesthetized only as need arises. On the face and other highly vascular parts the proportion of epinephrin must be as high as 1:10,000 to secure the vasoconstriction needful for the maintenance of anesthesia.

*Wounds of the scalp* and elsewhere are best treated without local anesthesia, since the pain of infiltration equals that of cleansing and suture.

In *fractures of the skull* small fragments of bone may be elevated or removed by a trephine under infiltration anesthesia, particular care being used to forcibly inject the anesthetic circumferentially under the pericranium. The meninges and brain are insensitive. Large operations are preferably done under general anesthesia.

Any section of the face may be readily anesthetized by infiltration for the excision of *small tumors* and *basal cell epitheliomata.* However, absorption is rapid and anesthesia transitory, even when the usual strength of epinephrin is doubled. For larger procedures infiltration is of little service.

Operations, such as prolonged *plastic work on the eyelids, nose and mouth, the excision of epitheliomata involving glandular dissection, operation on the maxilla and mandible,* are feasible only by blocking the various sensory branches of the trigeminus at strategic points. The elaborate and precise technic is best described in the monographs of Braun and of Hirshel. For the smaller procedures see Intraneural Infiltration.

The *ear drum* may be anesthetized for puncture by infiltrating deeply into the superior wall of the external auditory canal.

Individual *teeth* may be anesthetized by forcibly injecting the anesthetic with a small, strong syringe into the gum at the margin and beneath the periosteum of the alveolar border, both on the buccal and lingual aspect.

For operations on the *mandible* see Intraneural Infiltration.

For operation within the *nose* see Local Anesthesia by Osmosis.

MINOR OPERATIONS ON THE NECK AND THROAT.—The *tonsil region* may be anesthetized by swabbing the pillar with 10 per cent. cocain and then infiltrating the peritonsillar tissue with 1/4 per cent. cocain or novocain solution.

*Superficial lesions and encapsulated tumors* may be removed and *abscesses* opened under infiltration anesthesia. For extension dissection of glands and lymph nodes local anesthesia is inadequate.

For *furuncles, carbuncles, etc.,* the area is surrounded by a circle of cocain infiltration in a line of wheals as described under Minor Operations on Inflamed Areas. The line of incision within this circle is infiltrated, care being taken that the needle once fouled in the septic area is not inserted in the surrounding healthy tissue. Finally several deeper punctures in the septic area are made and the underlying base infiltrated.

TRACHEOTOMY.—For tracheotomy local anesthesia by infiltration is particularly satisfactory.

THYROIDECTOMY.—An oval area embracing the line of collar incision is injected with anesthetic, first infiltrating the skin circumferentially by line of wheals, then the subcutaneous tissue and platysma with weak anesthetic solution (see page 54). Incision is then made, exposing the deep cervical fascia, through which the deep muscle plane is infiltrated in a wide band. After a moment this plane may be divided gently by sharp incision. The lobes and the isthmus of the thyroid are now exposed. With great caution to avoid intravascular injection of the anesthetic, the areolar tissue outside the thyroid is scantily infiltrated as need arises, particular care being given to the superior pole and to the space between the trachea and thyroid. Each lateral lobe may now be carefully dislocated and resected or otherwise dealt with. Thyroid tissue proper is not sensitive.

THORACOTOMY.—The area of incision is widely blocked as in the foregoing procedure. The periosteum of the rib is infiltrated and then the needle is directed up beneath the overhanging lower edge of the rib and the region of the intercostal nerve is infiltrated. The rib is now resected and the parietal pleura separately infiltrated before being incised.

CELIOTOMY.—The area of incision is widely blocked by infiltrating the skin

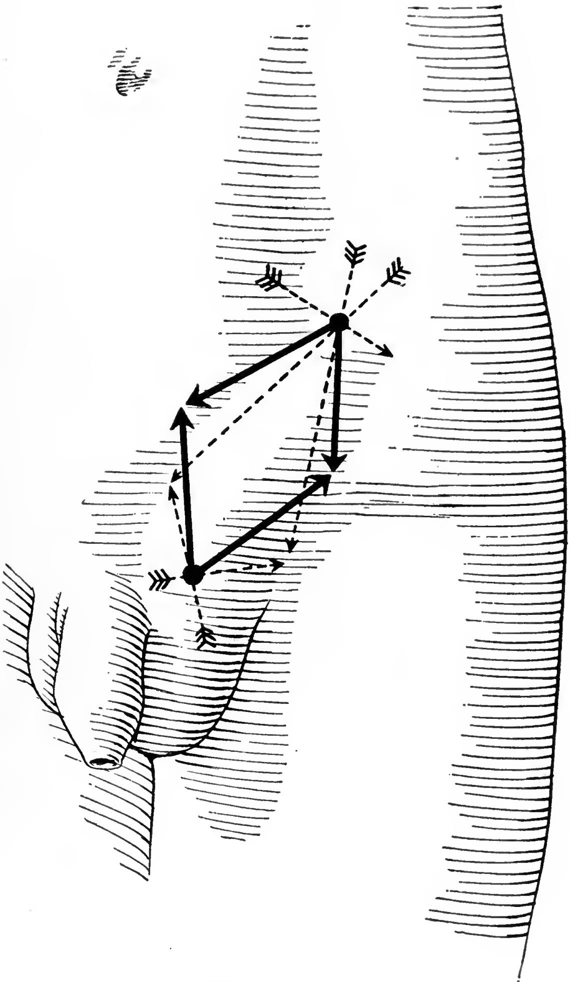

FIG. 3.—INFILTRATION ANESTHESIA FOR REPAIR OF SMALL INGUINAL HERNIA. Indication of area blocked by line of superficial wheals and by deeper infiltration.

and subcutaneous tissue down to the muscles, as in major operations (see page 54). Incision is made and the muscle planes are scantily infiltrated as one proceeds. These are now divided by clean dissection with little traction, exposing the fascia transversalis. Through this layer the subperitoneal areolar tissue is infiltrated as widely as is feasible. The peritoneal sac is now opened.

The manipulation of the abdominal viscera induces no immediate sensation of pain, and they may be operated on without anesthetization so long as pressure and traction are avoided. For closure and suture of the abdominal wall after prolonged operations the parietal peritoneum and skin may have to be reanesthetized. If reënforcement of the local analgesic be needed the best agent is a few drops of ether (see the Zone of Confusion in Ether Anesthesia,

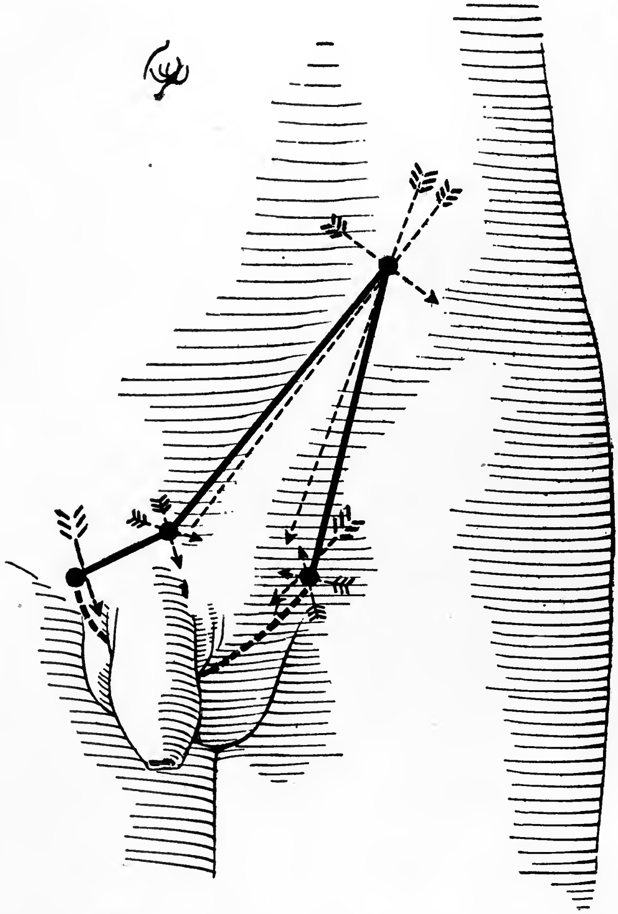

**Fig. 4.—Infiltration Anesthesia for Repair of Scrotal Hernia.** Groin and entire scrotum blocked by line of wheals. Deeper tissues infiltrated and nerve trunks blocked.

page 82). One has recourse to the prolonged anesthetic action of quinin and urea as a supplementary procedure, but the drug interferes with wound healing and has been largely abandoned.

OPERATION FOR SMALL INGUINAL AND FEMORAL HERNIA, HYDROCELE OF THE CORD, AND GLAND OF THE GROIN.—The area is blocked as in Figure 3. If the operation be for scrotal hernia the field is infiltrated by more extensively surrounding the scrotum as in Figure 4. In about 3 minutes the skin and the external oblique muscle may be incised and the internal ring ex-

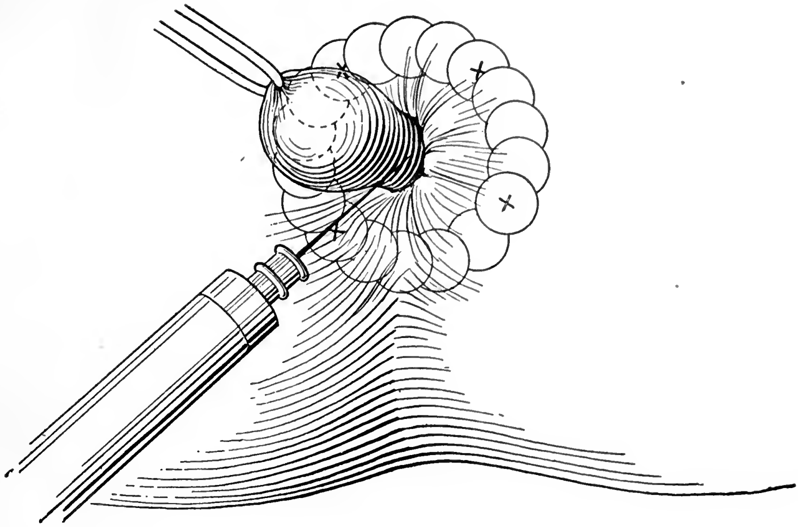

Fig. 5.—Infiltration Anesthesia for Hemorrhoids. Anus surrounded by line of wheals; sphincter relaxed by deep infiltration; polyp delivered and mucous membrane anesthetized by infiltration across line of excision.

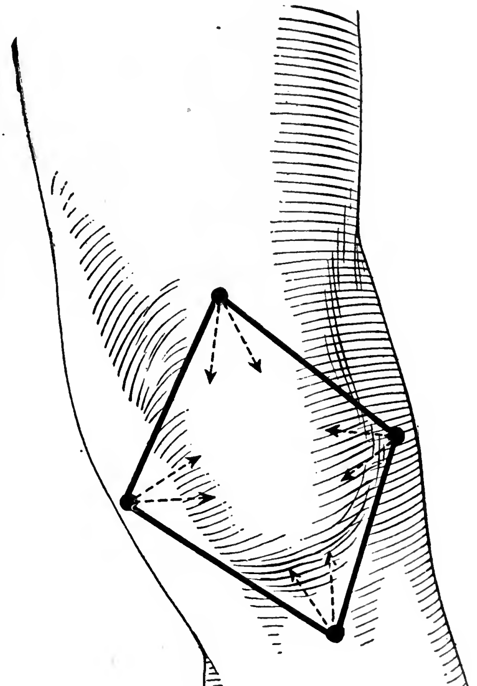

Fig. 6.—Infiltration Anesthesia: Region of Knee. For excision of prepatellar bursa, or repair of fractured patella, showing area blocked by line of wheals and direction of deeper infiltration.

posed. The ileohypogastric nerve is now identified lying upon the internal oblique muscle above the upper margin of the internal ring. The ileo-inguinal nerve is identified with more difficulty, running with the cord through the inguinal canal and lying on the under surface of the cord facing Poupart's ligament. Each nerve is blocked as it is exposed by intraneural injection (see page 61). Further surgical manipulation thereupon becomes painless, save the tying off of the sac. This must be blocked separately by local infiltration of the subperitoneal tissue. The skin may have regained sensation before the close of the operation and then must again be scantily infiltrated to be sutured.

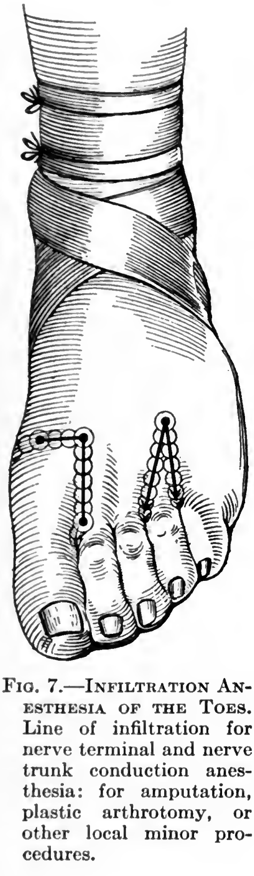

FIG. 7.—INFILTRATION ANESTHESIA OF THE TOES. Line of infiltration for nerve terminal and nerve trunk conduction anesthesia: for amputation, plastic arthrotomy, or other local minor procedures.

OPERATIONS FOR HYDROCELE, OPERATIONS ON THE TESTICLE, ETC.—The area of incision is blocked by infiltration. The sac is exposed and each line of dissection infiltrated before incision.

CIRCUMCISION.—The penis is constricted by a ligature of rubber tubing. The sheath of the penis is infiltrated through the superficial layer proximal to the line of circular incision, and the reflected portion separately infiltrated near the corona, infiltrating with special care the frenum. A collar section of the prepuce may then be excised, preferably by sharp dissection.

HEMORRHOIDS.—See Figure 5.

OPERATIONS ON THE UPPER AND LOWER EXTREMITIES.—For *excision of patellar bursa* or *adjustment of patellar fracture* the area is blocked as in Figure 6. The periosteal layer beneath the bursa must be separately infiltrated by deep puncture.

For *amputation of the smaller toes and the fingers* the proper line of infiltration is shown in Figure 7.

For *amputation of the great toe* or *arthroplasty,* as for hallux valgus, the procedure is indicated by the same diagram.

For *operations on the distal phalanges of the toes and fingers* the nerve trunks may be blocked by perineural infiltration at the first phalanx (see page 27), or the site of operation may be locally infiltrated as by the general technic of infiltration on uninflamed areas.

*Fractures of the long bones* such as Colles' fracture may be reduced under infiltration anesthesia.

## REGIONAL ANESTHESIA

**Introduction.**—When it is desirable to anesthetize entire regions with minimal manipulation and small dosage of local anesthetic one has recourse to the following method: The most effectual method, where it can be applied, is infiltration into a nerve trunk—*intraneural infiltration.* A nerve trunk may also be blocked by infiltrating into the surrounding tissue—*perineural infiltration.* Or the nerve trunk may be bathed in the proper anesthetic solution, as by injecting the agent into the spinal canal—*spinal or medullary anesthesia.*

An entire segment of an extremity may be anesthetized by injecting the agent into the vascular channels of that part—*intravenous and intra-arterial local anesthesia.*

### Regional Anesthesia by Intraneural Infiltration

For the infiltration of an exposed nerve trunk the nerve is held steady by gauze or grasped in special forceps which do not pinch or bruise. Into the nerve is injected through a fine hypodermic needle sufficient solution to make a bulbous swelling on the nerve. The best agents are a solution of ½ per cent. cocain or of 1 per cent. novocain.

The puncture and injection cause momentary tingling and other paresthesiæ over the distribution of the nerve. Within 2 minutes anesthesia appears and gradually deepens for the next 10 minutes. This anesthesia is absolute only at the center of the nerve distribution, indeed there may be hyperesthesia at the periphery of the area of distribution where the nerve is overlapped by neighboring supply. Anesthesia lasts 30 to 90 minutes, occasionally longer.

For intraneural injection of unexposed nerve trunks only those trunks which have a definite course and landmarks are available. The entrance of the injecting needle into these trunks is signaled by a sensation like an electric shock along the nerve. Thus the proper trunk from a plexus may be identified and injected. *For this blind method the solution should be twice as strong as when the nerve is exposed.*

The following are the areas commonly anesthetized by these methods: (1) the frontal region, by injection of the supra-orbital nerve at its foramen; (2) the side of the nose and cheek and the upper lip, by injection of the infra-orbital nerve in the canal; (3) the lower jaw and the region of the chin, by injection of the inferior maxillary nerve at the inferior maxillary foramen; (4) the upper extremity, by injection of the brachial plexus in the supraclavicular triangle, or in the axilla; (5) the little finger, by injection of the ulnar nerve behind the internal condyle of the humerus; (6) the groin and scrotum, by injection of the ileo-inguinal and ileohypogastric nerves during herniotomy; (7) the leg below the knee, by injection of the great sciatic at the sacrosciatic notch; (8) the outer side of the leg and dorsum of the foot, by injection of the external popliteal nerve in the popliteal space lying parallel to the tendon of the biceps.

The less common procedures of cranial, spinal nerve, and plexus injection are beyond the scope of this article. (See Braun's monograph.) Illustrative of these procedures is Figure 8 and the following description of brachial plexus anesthesia.

**Brachial Plexus Anesthesia.**—The subclavian artery is palpated above the clavicle. External to and above the artery a hypodermic needle is inserted into

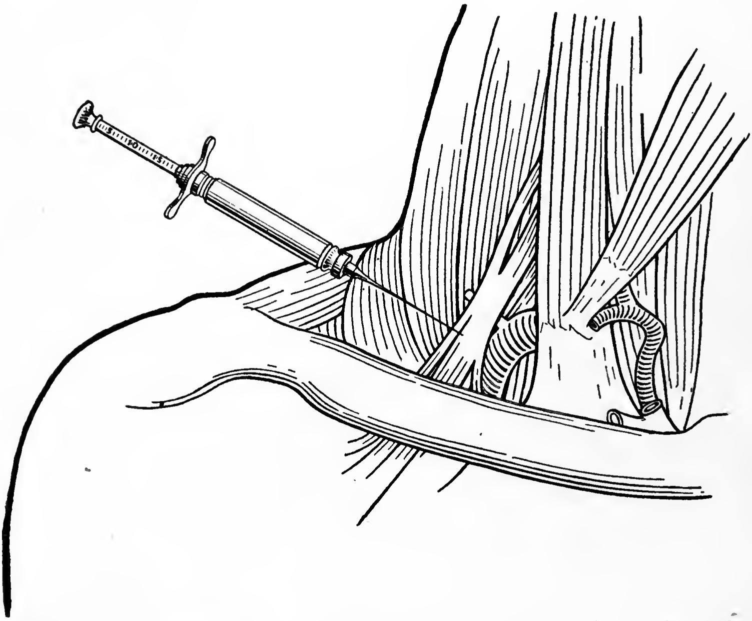

FIG. 8.—BRACHIAL PLEXUS ANESTHESIA. The illustration shows the position of the cords of the brachial plexus as they emerge from between the scaleni muscles where they are punctured in the posterior cervical triangle and rendered anesthetic and non-conductive by intraneural infiltration.

the brachial plexus as the nerve trunk emerges from between the scaleni muscles. Puncture and injection of each nerve trunk give immediate paresthesia over the area supplied by that trunk. Anesthesia develops in about 2 minutes and gradually deepens. If the nerve trunks be definitely entered a solution of $\frac{1}{2}$ per cent. cocain or 1 per cent. novocain suffices as an anesthetic agent. If the injection be perineural the strength should be doubled.

As accidents of this method the pleura may be punctured with subsequent pleurisy, or the dose may be injected intravascularly with general intoxication, or a long-continued neuritis may be caused. A similar procedure is used in anesthetizing various branches of the brachial plexus in the axilla as they surround the axillary artery.

Nearly all nerve trunks have such ill-defined surface landmarks that direct injection of the non-isolated trunk is not feasible. In such case one has recourse to perineural infiltration, next to be considered.

## Regional Anesthesia by Perineural Infiltration

A nerve trunk traversing an infiltrated area absorbs anesthetic from the surrounding lymph and becomes blocked. When the blood flow is active the anesthetic may be washed away before affecting the nerve trunk, hence blockage by perineural infiltration is limited preferably to the nerves of the digits and larger extremities which can be isolated by hemostatic tourniquet. The procedure elsewhere is uncertain, requiring a dosage of anesthetic double that of the preceding method in strength.

When possible the part is exsanguinated by gravity and by bandage, and sequestrated by elastic ligature as for intravenous anesthesia (see page 70). An area of tissue about ½ in. wide is infiltrated across the path of the nerve at proper depth to bathe the nerve trunk. If the anesthetic be successfully distributed anesthesia appears over the area of nerve distribution in about 10 or 15 minutes and persists while the circulation of the blood is cut off and for 15 minutes or more after circulation is reëstablished.

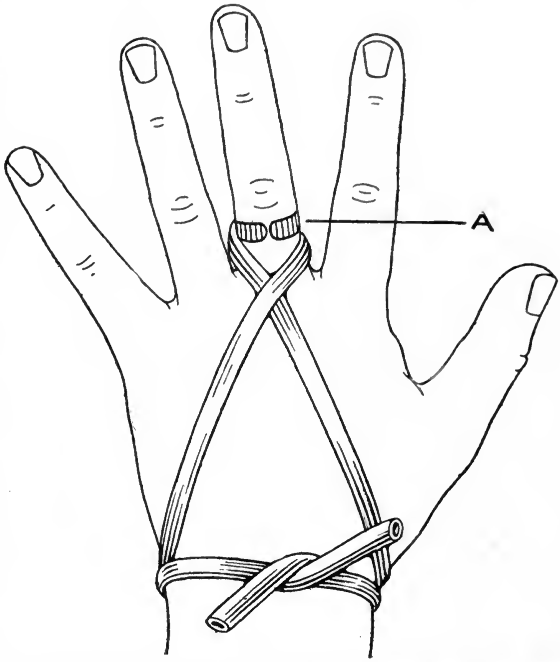


Fig. 9.—Perineural Conductive Anesthesia of the Finger. Showing method of hemostasis and location (A) of ring of infiltration. (See also Figs. 10 and 11.)

**Special Technic.**—The *finger* is the area most commonly anesthetized by perineural infiltration. The special and anatomical features and technic are considered in diagram and legend (Figs. 9, 10, 11). The operator should proceed only with a clear conception of the course and anastomosis of the 2

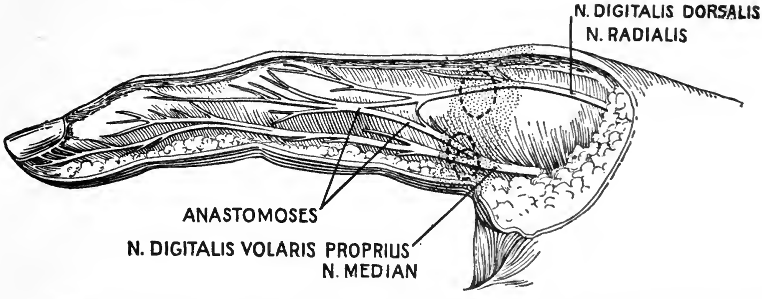


Fig. 10.—Nerves of the Right Index Finger. Showing the course of nerves and the placement of the solution to obtain, by perineural infiltration, conductive anesthesia of the distal portion of the finger.

dorsal and palmar nerve trunks (see Fig. 10). Then by following the general technic given above, infiltrating in the manner illustrated in Figure 11, a satisfactory anesthesia of the distal phalanx may usually be obtained in about 10 minutes.

The entire *hand* may be similarly anesthetized. The hand is exsanguinated by elevation, and rendered ischemic by elastic ligature in the middle of the forearm. The nerves are blocked by infiltrating round about at the wrist, except for a space over the dorsum, where no trunks exist. The bracelet or band of infiltration is about ½ in. wide and is placed 1 in. above the wrist. First the skin and subcutaneous tissue are anesthetized, then the deeper tissues, special care being taken to infiltrate: first, the region traversed by the median nerve where it lies at the inner side of the tendon of the palmaris longus; second, that of the ulnar nerve external to the flexor carpi ulnaris, lying between this muscle and the ulnar artery; and, third, that of the radial nerve as it winds external to the shaft of the radius about 1½ in. above the styloid process.

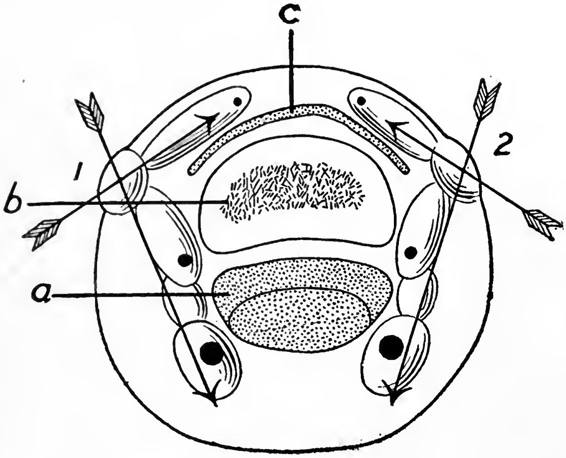


Fig. 11.—Cross-section of Finger through First Phalanx. Showing in black a cross-section of the nerves, illustrated in Fig. 10, and showing the relative position of infiltrated tissue, indicated by elliptical wheals. a, The volar tendon; b, the bone; c, the dorsal tendon.

The *arm* is anesthetized preferably by other methods, such as brachial plexus infiltration, or better yet by intravenous anesthesia.

The *foot* may be anesthetized in a manner similar to the hand by a band of superficial and deep infiltration above the malleoli.

Perineural anesthesia of the less common areas of operation on the upper and lower extremity requires a special knowledge of cutaneous nerve distribution and surgical approach of the various sensory nerve trunks too voluminous for this work.

## Regional Anesthesia by Injection into the Medullary Canal: Spinal or Medullary Anesthesia

**Introduction.**—Spinal nerve roots when bathed in proper anesthetic solution cease to functionate. Pain impressions from the lower segments of the body may thus be blocked by intrameningeal injection of a proper dose of an anesthetic agent. This fact was first demonstrated by Corning with cocain, and its practical application made by Bier. With the recent discovery of agents less toxic than cocain the margin of safety in the method has increased until it now has become a routine method in certain clinics for operations below the diaphragm.

**Physiology.**—Following intramedullary injections into the spinal cavity the anesthetic agent diffuses itself through the cerebrospinal fluid and rapidly combines with all exposed nerve tissue, which it deprives of conductivity. The spinal nerve roots are most affected, the cord proper less so. Within a few seconds sensations of paresthesia appear. In about 2 minutes pain sense is abolished and touch sense is much impaired over the distribution of the nerve roots affected. Motor and sympathic paralysis follow, reaching their height in about 15 minutes. The sense of position of any limb affected is lost. The cord proper, being protected by the pia mater, is only superficially influenced by the anesthetic and continues to carry nerve impulse to and from distal segments.

Control by the operator as to the area to be anesthetized and the degree and duration of anesthesia is secured by proper selection of drug and dosage, by the site of injection, and by the predetermined course of distribution of the agent injected. The distribution is controlled by having the agent in solution of a specific gravity either distinctly lighter, so as to rise, or distinctly heavier, so as to fall in the cerebrospinal fluid surrounding the cord. The specific gravity of cerebrospinal fluid being uniformly between 1.0055 and 1.0065, the solution is made heavier than this by lactose, or lighter by alcohol. The sacral, lumbar, and lower dorsal segments are those usually blocked, securing anesthesia below the level of the nipple. Following such blocking the following physical signs are to be noted in addition to the anesthesia:

The abdominal walls become completely relaxed and abdominal breathing is largely abolished. The anal sphincter relaxes and the contents of the large intestine escape aided by active peristalsis of the entire intestinal tube, which is now released from the inhibitory control of sympathic nerves.

CIRCULATION.—The vasomotor control of the area affected is lost. The pulse is slow, and the blood pressure falls, proportionately to the upward extension and intensity of the anesthetic action. With involvement of the upper dorsal segments the pulse may drop to 40 or 30 per minute and be indistinguishable at the wrist.

The fall in blood pressure is due to the combined action of vasomotor paralysis in the lower segments of the cord, to the limitation of respiratory movement, and to unopposed inhibitory vagus action on the heart. This fall begins soon after the motor paralysis, reaches its height in about 15 minutes, and slowly passes off.

Untoward depression of circulation is combated by adrenalin, administered intravenously in normal saline. From 2 to 10 minims of the adrenalin solution is added to each 6 ounces of saline infusion. As little as 2 minims may be effective or as much as 70 may be required.

RESPIRATION.—Respiratory movement is similarly inhibited. Abdominal respiration is first lost, then thoracic, and finally, with involvement of the phrenic nerve at the fourth cervical segment, the diaphragm itself becomes paralyzed. The respiratory motor palsy reaches its height in from 15 to 20 minutes, and may last for several hours.

If the phrenic nerve be involved by untoward upward extension of the anesthetic, life may be sustained by artificial respiration until the nerve recovers its conductivity. But without adequate artificial respiration or with additional involvement of the floor of the fourth ventricle, death ensues.

UTERUS.—The uterine muscle retains its tone and contractile power but lacks the aid of voluntary expulsive forces of the abdomen.

SKIN.—The surface of the body tends toward paleness and is dry. Heat is lost less rapidly in this method of anesthesia by radiation and evaporation than in the suffusion of general anesthesia.

**Limitations.**—The method should not be used in conditions of shock. It is applicable with safety only to operations below the level of the nipple, preferably below the diaphragm. To extend the field of anesthesia to the upper thoracic, brachial, and cervical regions may be best characterized as fool-hardy.

The method should be adopted only after a thorough training in the technic of injection and full knowledge of the physics and physiology involved.

As a casual method by the inexperienced, or without facility for artificial respiration, the method is much more dangerous than the inexpert administration of general anesthetics. The method does not promise to replace general anesthesia.

**Utility.**—The method seems to some observers to be indicated in operations below the level of the nipple where general anesthesia is contra-indicated; also when peculiar skill in this method is developed, and in prison, military, and hospital surgery, where for local reasons facility or trained skill is lacking in methods of general anesthesia.

**Apparatus.**—The best syringe is of the Luer, glass type, capacity of 2 c. c. with accurate graduation.

The needle should be a special lumbar needle of iridium platinum 7.5 cm. long and .1 cm. thick. It should be provided with a stylet which effectively closes the lumen, so that it may not become clogged in its introduction. The needle point should be ground on a short bevel of not over .2 cm. and should be keenly edged. The syringe and needle should be boiled only in pure water for 15 minutes before using, as any trace of alkali may decompose the anesthetic. The syringe should be taken from the water still hot, so as to warm the anesthetic solution.

**Preparation of the Anesthetic Agent.**—The agents employed in order of efficiency are stovain, tropacocain, and novocain.

These are dissolved in water and sterilized. The solution is rendered either distinctly lighter, or much heavier than the cerebrospinal fluid, so that the route of diffusion, which occurs slowly, may be plotted in advance and the position of the patient adjusted accordingly.

The solution is made of lighter specific gravity by alcohol and heavier by sugar of milk. The stovain solution must be acidified to avoid precipitation by the alkaline cerebrospinal fluid.

The lighter solutions are the more useful. Even for cervical analgesia these may be employed, injected in the lumbar region, and allowed to diffuse upward.

Solutions Employed in Spinal Anesthesia (Babcock)

| | | | |
|---|---|---|---|
| Light Solutions: | | | |
| A. | Stovain | 0.08 | gm. |
| | Lactic acid | 0.04 | c. c. |
| | Absolute alcohol | 0.2 | c. c. |
| | Distilled water | 1.8 | c. c. |
| B. | Tropacocain | 0.1 | gm. |
| | Absolute alcohol | 0.2 | c. c. |
| | Distilled water | 1.8 | c. c. |
| C. | Novocain | 0.16 | gm. |
| | Absolute alcohol | 0.2 | c. c. |
| | Distilled water | 1.8 | c. c. |
| Heavy Solutions: | | | |
| D. | Stovain | 0.08 | gm. |
| | Lactic acid | 0.04 | c. c. |
| | Milk-sugar | 0.10 | gm. |
| | Distilled water, to make | 2. | c. c. |

These solutions are conveniently kept in ampules, each containing 2 c. c. of solution. They should be prepared under aseptic precautions and sterilized by the intermittent method and at temperatures not above 65° C. (149° F.).

Solutions made from tablet or powder carry some risk of infection. There is no advantage, except to alter the specific gravity, in adding to the solution adrenalin, strychnin, glucose, gelatin, or similar substances.

The dose for the adult of each solution is from 1 to 1.5 c. c., the larger dose being employed only for robust adults. Of these solutions that of stovain is the most powerful anesthetic and motor paralyzant, most toxic, most actively hemolytic, and the strongest protoplasmic poison. If not acidulated it is precipitated by the alkaline cerebrospinal fluid. It gives excellent anesthesia.

Tropacocain is somewhat less active as an anesthetic and is considered by some to have fewer untoward effects. Each anesthetic when in solution may show variations in analgesic power and in toxic action, possibly due to imperfect sterilization, to by-products not eliminated in the manufacture, or as a result of the decomposing effects of heat.

Novocain is much weaker than stovain, but is not precipitated by cerebrospinal fluid, and even in a 10 per cent. solution is not actively hemolytic. The clinical efficiency and clinical toxicity of novocain are about ½ that of stovain. The loss of the sense of touch is less under novocain.

Babcock prefers solution A, injected through one of the lower dorsal or upper lumbar interspaces. This fluid diffuses rather slowly and passes toward the head or the sacrum, according to the posture of the patient. If, for example, the injection is made through the twelfth dorsal interspace, and the patient sits up after the injection, the solution, which ascends with an approximate rapidity of about 10 cm. per minute, will usually reach the lower cervical segments in about 1 minute. The cervical segments will be involved during the second minute, and if the patient sits up over 2 minutes some involvement of the cranial nerves may occur. As the fluid becomes somewhat diluted in its ascent, a larger dose and, therefore, a more prolonged effect may be obtained, with less danger of high motor paralysis than when the higher point of injection, advocated by Jonnesco, is employed. Anesthesia involving the higher segments is not so certain or so safe as that involving the segments below the level of the diaphragm.

The heavy solution is used only where it is desired to keep the head elevated during the operation.

**Preparation of the Patient.**—Preferably, the stomach and colon should be empty as for general anesthesia.

If the patient be nervous, or partial general narcosis be desired, this is secured by morphin with atropin or hyoscin. These drugs must be administered cautiously, and are best avoided in those patients presenting respiratory obstruction or depression from grave renal disease, and in conditions of grave toxemia. The usual dosage of the narcotic for a robust individual is, beginning one hour before the operation, morphin 1/6 with scopolamin 1/100 grain given hypodermically. Atropin, grain 1/150, may be substituted for the scopolamin. Scopolamin should not be administered in the young, in fact, is undesirable up to 25 to 30 years of age. After 20 minutes if no narcotic effect is evident the dosage is repeated. Occasionally a third dose must be given to secure an obvious narcotic effect.

The field of spinal puncture is swabbed with tincture of iodin, which is allowed to dry and is then washed off with alcohol.

**Technic.**—The following technic of injection is that given by Babcock:

"The injection may be made either with the patient lying on the side or sitting on the operating table. To avoid undesirable diffusion of the solution, the injection should be made immediately before the operation and preferably on the operating table. With the patient on the side, the head should be well flexed on the chest, the thighs on the abdomen, so as to arch the back and separate the spinous processes, the patient being so arranged that the spine is not rotated. The interspace is located by a towel, the edge of which when placed on the iliac crests will cross the fourth lumbar spine or interspace; or the interspace may be located by selecting the interspace opposite the angle formed by the last rib and the erector spinæ muscle; this is the first lumbar.

"The injection should be made about opposite the upper level of the field of operation, that is, through the twelfth dorsal or first lumbar interspace for upper abdominal work, and the second lumbar interspace for operations on the lower abdomen or legs.

The needle should be entered close to the midline about the center of the interspace and at right angles to the surface of the body, and it should be introduced until the resistance of the ligamentum subflavum is felt. In the athletic this may have an almost cartilaginous consistency, and the sensation imparted usually indicates that the proper direction of the needle is being maintained. If the needle encounters only loose, non-resistant tissue it is probable that it has deviated too far to the side, and it should be withdrawn and reintroduced with more accurate orientation. The stylet is now withdrawn, and the needle is cautiously pushed forward with short, quick strokes a few millimeters at a time. The loss of resistance as the needle enters the tissue about the dura is noted, and then the slight resistance accompanied by a perceptible and sometimes audible snap as the tense dura is punctured. The needle is cautiously rotated to make sure that the point is entirely within the cavity of the arachnoid. Cerebrospinal fluid should now drop from the needle; if it does not, the lumen of the needle should be cleared by the use of the stylet, or the needle should be so adjusted that the fluid will run freely; otherwise satisfactory analgesia need not be expected. The usual errors are to incline the needle upward or laterally in the introduction. The quantity of cerebrospinal fluid permitted to escape should be about that of the solution to be injected. If the needle deviates to the side a nerve root may be touched, producing a lightning-like pain usually radiating down the leg. If this occurs the needle should be immediately withdrawn and reintroduced. Puncture of the cord produces no sensation, and, while it is to be avoided, it is relatively harmless.

"The syringe charged with the anesthetic solution is affixed to the needle and free communication with the arachnoid again proved by gently withdrawing the piston. The mixture is now cautiously injected and the needle quickly withdrawn. Apart from placing a sterile towel on the patient, the point of puncture requires no dressing. If a light anesthetic solution be used the head and shoulders of the patient must be instantly lowered and maintained below the level of the dorsolumbar region for half an hour after the injection. If a heavy solution be employed the shoulders and head must be kept elevated for a corresponding period of time. Improper movement of the patient and lack of these precautions are responsible for many of the accidents of spinal anesthesia.

"Nausea, pallor, or marked lowering of the pulse tension usually indicate that the anesthetic is reaching too high a level, and the position of the patient should be further modified to keep the anesthetic solution in the lower part of the spinal canal.

"The analgesia should develop within two or three minutes. To avoid suggestion, the patient should never be asked as to sensations of pain, but the analgesia determined by watching the face as the skin is pinched. If no analgesia is present in six minutes, the injection should be repeated, using the same dosage, and perhaps selecting another interspace. Lack of anesthesia may follow from the use of imperfect solutions, failure to introduce the needle properly, and leakage of the solution outside of the arachnoid. The analgesia gradually disappears without unpleasant sensation, from above downward in from forty-five to ninety minutes. If not contraindicated by the operation, sips of water or bits of ice may be administered while the patient is on the operating table. If the analgesia is inefficient and too transient, there is no objection to the associated administration of ether."

## Regional Anesthesia by Intravenous Injection

This method was introduced by Bier in 1909. It was designed for the purpose of anesthetizing rapidly and completely all structures, even the bones and joints, of a given segment of an extremity. Anesthesia is induced *en bloc* by filling the venous channels of that segment with a considerable bulk of saline in which the agent is dissolved. The area to be anesthetized must be one from which the blood can be emptied and shut off, hence this method is applicable only to the hand and foot, or to any given segment of a limb, such as the region of elbow or knee.

**Technic.**—The part is depleted of blood, first, by elevation, second, by applying with tension a flat rubber bandage spirally from the extremity of the limb proximally. The ingress of fresh blood is blocked by so adjusting the bandage as to check the arterial pulse. A good substitute for a flat band to cut off the pulse is a pneumatic cuff such as is used for determination of blood pressure. The extremity first being emptied of blood by elevation and bandage, the cuff is inflated by a small bicycle pump to a pressure about 50 mm. above the blood pressure, usually to 200 mm. or 4 pounds of pressure.

A vein, the location of which has been previously marked, is now exposed under infiltration anesthesia and a cannula introduced as for saline infusion.

The best *agent* in this method of anesthesia is *novocain* in dosage averaging 0.5 gram for the adult. For injection of the hand or elbow this is dissolved in 50 c. c. of saline, and for the foot and knee in 70 to 100 c. c. of saline. This amount of fluid insures thorough distribution to the entire part. If an extremity is to be amputated, then novocain up to 2 grams in 200 c. c. of saline is employed, since the overdose becomes combined in the amputated part and cannot reënter the circulation on removal of the hemostatic band. (See also Contra-indications to Surgical Operations.)

Over the sequestrated area anesthesia appears within 5 minutes, becomes complete within 15 minutes, and lasts as long as the part is kept ischemic, and usually continues about 15 minutes after the circulation is reëstablished. If the preliminary evacuation of the blood has been incomplete, this will gather at remote points, such as the finger tip, and result in non-anesthetized areas. Formerly the veins were flushed with normal saline before reëstablishing the circulation, but this has been abandoned as of no utility, since the toxic anesthetic has already entered into such union with the tissue that it will not redissolve in normal saline. The hemostatic bandage should be removed before starting suture to flush out the novocain and catch the bleeding points. It is unsafe to keep the part ischemic for more than 40 minutes, for the life of the muscle cells and other highly organized structures may otherwise be permanently destroyed.

### Regional Anesthesia by Intra-arterial Injection

In this method the anesthetic agent is distributed over the area supplied by a given artery, by injecting the agent from a syringe into the lumen of the artery.

**Technic.**—The distal part is exsanguinated by elevation and bandage as for intravenous anesthesia. The arterial pulse is cut off by proximal constriction. The artery is exposed under infiltration anesthesia and into the lumen is injected, by fine hypodermic syringe, from 5 to 10 c. c. of a 1 per cent. solution of novocain. The proximal constriction is then released, allowing a gentle trickle of blood to wash the anesthetic saline solution to that region supplied by

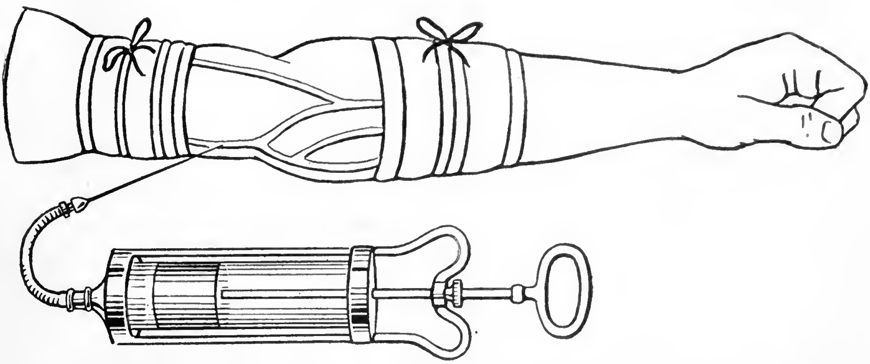

Fig. 12.—The Bier Intravenous Method of Regional Anesthesia. A segment at the elbow has been exsanguinated and sequestrated. The veins of this segment are filled with the anesthetic solution injected into any convenient vein.

the artery. The band is then tightened until anesthesia appears. The method, while using less anesthetic than the intravenous, is not so reliable in anesthetic effect.

### RÉSUMÉ

**Simple local anesthesia and local anesthesia as an adjuvant to light general narcosis have unquestionably a field of utility in major and minor surgery. Occasionally local anesthesia has decided advantage over methods of general anesthesia. Yet the enthusiasts in this method, in an endeavor to retain the consciousness of an operated case, and to avoid the dangers and sequelæ of general anesthesia—which arises largely from improper administration—have overstepped the bounds of reason, by subjecting the patient to the psychic shock of consciousness of the operative procedures, to neuroses from nerve strains, to postoperative cardiovascular strain and insufficiency far beyond that of general anesthetization, and finally in callously disregarding the protests of the physically and psychically restrained patient. By these forced methods of local anesthesia the attempt is made to accomplish practically without anesthesia, operative procedure in ways current before the days of modern anesthesia under the guise of safety and efficiency.**—Subscribed to by the Editor.

## GENERAL ANESTHESIA

General anesthesia may be secured by several drugs which suspend for a time the activity of the neurons of the central nervous system, beginning with the highest. These drugs inhibit, first, reason, judgment, and will; then consciousness; then the cortical motor and sensory activities; then the reflex activity of the basal and spinal centers. Finally, only the action of the great medullary and sympathetic centers which maintain the functions of the body necessary to life is left active. The function of these centers is impaired, as are in less degree the general cellular function and activity of all the more lowly organized body tissues.

## THEORY OF GENERAL ANESTHESIA

The general anesthetics used in surgery are hydrocarbons, all except nitrous oxid, having the common property of being active solvents of fat and fat-like bodies. These hydrocarbons belong to that group of neutral or indifferent substances which dissolve in living protoplasm without forming fixed union with the receptors of the cell as do foods and basic and acid poisons. The anesthetics enter and leave the cell freely and unchanged; the amount that the cell holds at any given moment being governed entirely by the laws of diffusion, of vapor tension, and by the solubility of the given chemical in the watery, fatty, and other elements of the cell.

Of the many hydrocarbons that are anesthetic only those are adapted to surgical anesthesia which combine the requisite physical properties of volatilization, diffusion, and capacity to dissolve fats, with a toxic action on animal protoplasm so slight as to be unimportant.

The Hans Meyers hypothesis of the anesthetic action of these drugs, as elaborated and established by Overton and Meyers, may be summarized as follows:

1. All chemically indifferent substances which are solvent of fats and lipoids are narcotic to animal protoplasm in so far as they can reach it by diffusion.
2. Anesthetization is established more rapidly and in greater degree in those cells into the structure and functional activity of which the lipoids most extensively enter, namely, the nerve cells.
3. The efficiency of these different narcotics is dependent on the relative physical affinity of the narcotic for the lipoids on the one hand, and for the other solvent media of the living body on the other hand, the bulk of which is water.
4. The efficiency is directly as the partition coefficient of the chemical between solution in oil and in water. This is obtained by dividing the amount which remains dissolved in oil by the amount which diffuses to an equal volume of water to establish a balanced vapor tension.

Of the many thousand chemicals of this group which possess anesthetic properties, only three are generally recognized as possessing proper physical qualities of volatilization, diffusion, and solubility of lipoids, combined with a low or negligible toxicity toward animal protoplasm. These are *ether, chloroform,* and *ethyl chlorid.*

## ETHER

**Introduction.**—Of the various hydrocarbon series, that radical is found in actual practice to be the least toxic toward which animal protoplasm has been longest adapted. The ethyl radical in the form of alcohol has been a normal constituent of animal food since the day the first ameba lived in stagnant swamp water. Animal protoplasm has always had to deal with the lipoid solvent action of the ethyl group.

Of this group, ethyl oxid (di-ethylic ether) exerts the most clearly defined and most readily controlled action. It is inherently the safest of all efficient anesthetics. Formerly the results of maladministration were confused with the physiological action of ether, but with the newer methods of administration and the revision of older methods, and appreciation by the surgeon of the necessity of gentle manipulation of tissues, ether has become more universally recognized as the safest and most generally useful anesthetic.

**Physical Properties of Ether.**—Ether is a clear, volatile liquid of pungent taste and odor. It is lighter than water (specific gravity, .716) and boils at below body temperature (at 35.5° C.).

The vapor tension at room temperature is about 460 mm., yielding, when saturated in air, 60 per cent. by volume of ether vapor, or 80 per cent. by weight. The vapor is 2½ times heavier than air, and until it becomes diffused it flows downward in air like water. It is highly inflammable.

On prolonged exposure to light or air ether gradually develops aldehyds and other more irritating decomposition products. The U. S. P. allows a small percentage of alcohol as a preservative.

## Physiological Action of Ether

**Local Anesthetic Action.**—When exposed to the air, as on the skin, ether is a refrigerant by rapid volatilization. The caloric loss in vaporization is only about 1/6 that of water, but the vaporization goes on rapidly at such low temperature (—20° C.) that ether is available as a refrigerant local anesthetic. Ether inhibits by direct action the sensory and motor nerve endings, being a weak local anesthetic and relaxant of voluntary muscle.

**Irritant Action of Ether on Skin, Mucous and Serous Surfaces.**—Ether produces a sense of intense smarting on thin skin, such as that of the scrotum, and on mucous membranes, but incites no lasting inflammatory reaction. On the conjunctiva liquid ether causes inflammation only when held long in contact. The so-called "ether eye" is usually of traumatic or infective origin. In the gastro-intestinal tract liquid ether produces a sense of warmth and tenesmus. Ether, 75 per cent. in oil, produces in the colon slight immediate stimulation, but exerts no lasting irritation or inflammation. On the peritoneum and other serous surfaces liquid ether induces neither acute inflammation nor adhesions. In the respiratory tract ether vapor in therapeutic dosage is a mild stimulant. At a vapor pressure of 30 mm., i. e., 4 per cent. by volume or 10 per cent. by weight of ether to air at sea level, ether vapor has so little pungency as to be scarcely noticed except for odor. Six per cent. by volume exerts slight stimulation on the larynx. (This is the mixture with which full surgical anesthesia finally becomes established and may be maintained for many hours.) On first inhaling the vapor mixture 7 per cent. causes coughing, but soon becomes unnoticed. From this percentage upward the vapor grows more stimulating. At 9 per cent. a cough is scarcely to be restrained on first inhaling the vapor, and higher percentages cause secretion of mucus, particularly in the light stages of anesthesia. Fully conscious, man cannot breathe stronger vapor without a sense of strangulation, except by gradually accustoming the mucous membrane to the vapor. With the gradual onset of general anesthesia the vapor may be increased to about 25 per cent. by volume, or a partial vapor pressure of 190 mm., without evidence of laryngeal or bronchial irritation other than slight excess of mucous secretion. This is the strongest vapor required for induction of anesthesia. Vapor above 25 per cent. by volume up to 60 per cent. (i. e., saturation) exerts an asphyxial effect and may rapidly overpower the respiratory center, yet even in this strength there is no lasting irritation in the respiratory tract.

**Effects of Ether on Body Function.**—RESPIRATION.—Ether increases the depth and frequency of respiratory movement up to the stage of deep surgical anesthesia. On overdosage gradually the respiratory center succumbs, the respiration grows more and more shallow, finally its rate decreases, and the patient may die of respiratory failure.

HEART ACTION.—The heart is stimulated in force and frequency. The rate is increased 10 to 20 beats per minute. With any respiratory insufficiency the rate rises and the force is diminished. The heart succumbs to overdosage some minutes after the respiratory center. But with artificial respiration by insufflation, the heart beat may continue for an hour or more on dosage which has caused cessation of respiratory movement.

BLOOD PRESSURE.—The blood pressure rises about 20 mm. in the initial stage of anesthesia, then slowly drops, reaching the normal in 1 or 2 hours. Embarrassment of respiration by blockage of the upper air passage, also the trauma of an operative procedure improperly correlated to the depth of anesthesia, cause a transitory rise, followed by a sharp fall of blood pressure. Chilling, loss of blood, and overdosage of anesthetic cause a progressive fall of blood pressure during ether anesthesia. From overdosage of ether the pressure almost completely regains the original level within 5 to 10 minutes after the excessive dosage ceases. The fall of pressure from trauma, hemorrhage and chilling is regained much more slowly. From these depressants, the blood pressure is sustained far better under ether than under chloroform, though not so well as under nitrous oxid.

SENSORIUM.—Ether like alcohol affects first the most highly coördinated senses. First, reason, judgment and will are suspended, and the patient becomes exhilarated and excited. Much of this excitation is due to the local stimulation of ether in the respiratory tract. The pure ether effect, as seen in intravenous injection of the dose, is induction of narcosis with very little excitement. A certain degree of general analgesia is induced even before consciousness is lost.

Next in order, consciousness is suspended and the patient passes into a subconscious or automatic state, wherein he is amenable to suggestion. The auditory, tactile and muscular senses continue for a time. Slight to violent subconscious excitement is passed through, dependent on the resistance of the individual toward the ethyl radical and the external impressions which the subconscious patient receives.

Next in order, the lower centers are inhibited so that auditory impressions, tactile and muscular sense, and all motion except the reflexes are suspended. The entire cortical function is now abolished and the deepening anesthesia continues progressively to desensitize the basal and spinal centers down to the great primitive vital centers in the medulla.

**Excretion of Ether.**—Ether is chiefly excreted by physical diffusion into the alveolar air, a small amount is oxidized in the body. Owing to the physical affinity for fat, the fats and lipoids tenaciously hold a trace of ether so that excretion continues on the breath for as long as 36 hours.

## Clinical Course of Ether Anesthesia

**First Stage or the Stage of Conscious Excitement: The Period of Cortical Disassociation.**—This stage begins with the first respiratory stimulus of the pungent rather disagreeable odor of ether. If this odor be masked by oil of orange and the administration be gradually and cautiously increased, there is little noticeable respiratory irritation. With rapid administration there is a sense of suffocation, repeated closure of the glottis, holding of the breath, cough, and repeated swallowing.

Soon the respiration becomes rhythmical and deeper and quicker than normal, and the skin is slightly flushed and the pulse accelerated. The patient becomes mentally confused and verbal response becomes progressively more incoherent. By proper suggestion on the part of the anesthetist, the patient remains quiet and reassured. Disturbances of the special senses are common. All skin reactions are present. The pupil is dilated and mobile. Loss of consciousness takes place abruptly, usually in about 2 minutes.

**Second Stage or the Stage of Involuntary Excitement: The Period of Subconscious Disassociation.**—Memory and intelligent volition are lost. The patient responds to the stimulation of external environment. If the ether be crowded the breath is held and respiration becomes thereafter irregular. Laughing, shouting, and struggling may be met with, usually in those patients who from alcoholic or other narcotic habits have acquired such association with this stage of anesthesia.

This involuntary excitement may be much diminished by proper suggestion by the anesthetist through the auditory center. If restraint be necessary, this is first exercised by full-toned verbal suggestion, for example, that the patient cannot move, later by physically misdirecting any physical effort of the subconscious patient. Rarely is direct force needed to oppose those efforts which the patient may make to escape from the subconscious hallucinations of this stage.

The pupil continues mobile, tends to be large and may be irregular. The voluntary muscles are held stiffly, occasionally in tonic spasm or in clonic tremor. The secretion of tears, mucus and saliva is stimulated. The skin grows more flushed and moistened with perspiration. Breathing tends to become irregular from such obstruction as clenching of the jaw, movements of the tongue and of the pharynx in repeated acts of swallowing, also by stiffening of the general musculature. Then comes a gradually increasing stertor, the muscles relax, the breathing becomes regular. Those paths from the subconscious mind which may stimulate or inhibit the medullary and spinal centers are broken, and the patient passes into the third stage of anesthesia.

**Third Stage or Stage of Surgical Anesthesia: The Period of Basal and Spinal Disassociation.**—With the onset of stertor and the simultaneous general muscular relaxation, the stage for surgical operation has been reached. This requires usually in the average adult not less than 8 minutes. The more smoothly and quietly anesthesia has been induced the better the subsequent status of anesthesia. Gradually the superficial reflexes have been abolished, the cornea becomes insensitive. The pupil is usually moderately dilated, is sluggish or immobile in reaction to light. The respirations are usually about 30 to 40 per minute and of increased amplitude. Soft stertor of the relaxed pharyngeal structures is constantly to be heard, unless the upper airway be kept effectively open by extending the head and carrying the jaw forward. Marked stertor should never be allowed.

When operative trauma is occasioned on some richly endowed sympathetic area the respiration grows rapid, forceful and noisy. This is always an indication that the depth of anesthesia is too light for that particular trauma, and the trauma should be immediately suspended and the anesthesia should be deepened.

The circulation is not impaired in this stage by the anesthetic. In fact, for several hours the pulse is of slightly increased or of normal force. The pulse grows more rapid and feeble, first and foremost from embarrassed respiration and partial asphyxia, usually from obstruction in the oral nasopharyngeal portion of the airway; second, after an initial stage of excitation, by those operative stimuli which cause the foregoing respiratory increase. These stimuli may be effectually blocked by proper depth of anesthesia. Therefore, the anesthetist must know the tissues and operative procedure which give rise to these trauma stimuli and gauge the required depth of the anesthesia accordingly. Another factor in the depression of the circulation is exposure of the body to refrigeration by surface evaporation. To this the patient under full anesthesia is particularly liable because of the flushed moist skin. The last factor, and the one of prime importance, is hemorrhage, the prevention of which is not in the province of the anesthetist.

Through this stage the one best guide of the depth of anesthesia is the breathing. Administration of ether should be continuous but graded according to the necessity. If on minimal dosage the breathing becomes shallow with an occasional deep breath, the patient is dropping into the subconscious zone, and in a moment will reach the level of the vomiting center.

If on full dosage the breathing is becoming shallow, especially if accompanied by slight cyanosis, the patient is being over-anesthetized. Any marked response of respiration and pulse to the momentary stimulus of operative trauma indicates too light a degree of anesthesia. Unless asphyxia enters as a factor, the margin of safety under ether is very wide in this stage.

The entire progress of administration may be governed by the quality of respiration and the color of the skin and mucous membranes. The pulse, the corneal reflex and reaction of the pupil are secondary guides. In the deep stage the cornea is insensitive. For lighter degrees of anesthesia the reflex contracture of the palpebral muscles is elicited on lightly touching the cornea with the finger tip. In the subconscious zone stroking the edge of the upper lid suffices to elicit the above tarsal reflex. In the light subconscious zone the musculature of the other eyelid also reacts and the level of vomiting center has been unblocked. These reflexes tire out easily and should not be called into repeated action by the anesthetist.

**Fourth Stage or Stage of Overdosage: The Period of Medullary Disassociation.**—In this stage the great vital centers which in the previous stage were partially or completely disassociated from reflex outside stimuli now begin to be intrinsically desensitized. The first of the 3 great centers affected is the respiratory. This loses its normal sensitiveness to carbon dioxid and the stimulating influence of asphyxia. The respiration grows shallow and with an ineffectual quick inspiratory gasp. It may even become of Cheyne-Stokes type. The skin and mucous membranes grow pale with a cyanotic tinge and the pulse becomes more rapid. Blood pressure gradually falls.

At the same time or slightly before this stage the pupil becomes dilated and fixed and the cornea entirely insensitive. The tension of the eyeball lessens. If the condition be not relieved by suspension of dosage with effective ventilation of the lungs, the patient will die of respiratory failure.

This stage may come on gradually by slight overdosage, i. e., above 90 mm. of ether vapor pressure, or may come on rather abruptly by profound overdosage, i. e., above 210 mm. This sudden overdosage may occur even in the second stage of anesthesia, by the inhalation, in the period of involuntary excitement, of excessive concentration of ether vapor. From the sudden overdosage of the medullary centers during the induction period, the respiratory center rights itself as soon as venous blood ceases to be overcharged by the pressure of ether in the alveolar air. Usually this recovery is a matter of 30 seconds to 2 minutes. However, from the overdosage wherein the body as a whole has been gradually brought to overtension over a long period of anesthesia, the respiratory center may require 5 to 10 minutes of ether excretion, through artificial ventilation of the lungs, to again resume effective automatic action.

The symptoms of overdosage may be precipitated by asphyxia, usually from high obstructive blockage in the upper air passage. With asphyxia, particularly that of gradual onset, the circulatory centers are rapidly depressed. Ether, itself, is relatively non-toxic to the circulatory mechanism.

**Fifth Stage or the Stage of Recovery: The Period of Inverse Reassociation.**—The various levels of the nervous activity are resumed inversely to the order in which they are lost. The respiratory and cardiac centers again begin to be influenced by operative trauma. Respiration becomes more shallow and quiet, the pulse becomes slightly less frequent, blood pressure is lowered, reaction by the pupil to light returns and the cornea regains its sensitiveness. Slight lacrimation is present and the lid reflex reappears. In about 10 minutes, after an hour of full even anesthesia the vomiting center is reached and any stimulation to the pharynx or operative irritation of the abdominal contents usually results in subconscious vomiting. If there be no such stimulation and if the ether has been evenly administered without repeatedly dropping from full anesthesia into the subconscious zone, vomiting is less common.

Next the patient responds to auditory and visual stimuli in a dull drunken way, but after being roused soon relapses into a narcotic sleep. The awakening of consciousness and memory is usually abrupt. The patient suddenly associates himself consciously with his surroundings and if of well-trained mind he takes command over his confused mentality.

The tendency to somnolence usually continues, but there may be marked excitement. There is partial analgesia which lasts for 2 to 3 hours. Mental and physical lassitude may last many hours. There may be headache. Conscious vomiting, as a physiological effect of ether, is the exception rather than the rule. It is present most frequently as a complication of intra-abdominal manipulation and occurs with irregular dosage of ether, and with that associated with partial asphyxia of the rebreathing methods of administration, and with asphyxia resultant from poorly maintained upper airway during anesthetization and early in the stage of recovery.

## Theoretical Consideration of the Administration of Ether

**Introduction.**—To induce ether anesthesia smoothly and carry the patient safely through, at proper depth for the operation in hand, the theory as well as the practice of ether administration must be understood. Theoretical considerations must of necessity be first expressed in scientific terms and applied later to the various empiric methods of administration. By this application, the art of crude anesthetization becomes standardized, and a definitely formulated, intelligent procedure. The data herein tabulated have been made available by an accurate mixing and measuring apparatus, the anesthetometer.

Ether is commonly introduced as a vapor with the inspired air into the respiratory tract. By diffusion throughout the lung and into the blood, thence into the neuron, a sufficient amount of ether accumulates in the central nervous tissue to establish a state of general anesthesia. Ether diffuses to the nerve cells and is held therein by a driving force known as vapor tension, scientifically expressed in millimeters of mercury pressure. Thus, to establish and maintain full surgical anesthesia, the blood flowing past the neuron must contain constantly about ¼ per cent. of ether, or, in tension, 50 mm. of ether, resulting in over 0.6 per cent. of ether accumulating at that tension in the central nervous system. The nervous system, due to its generous supply of blood, rises and falls in ether content much more rapidly than the rest of the body in response to varying ether pressure in the lungs. The general body, particularly the subcutaneous fat, being less freely bathed in ether-charged blood than is the central nervous system, comes to tension less rapidly and excretes ether more slowly. Thus the general body acts as a governor on the changes in depth of anesthesia; it is a reservoir above which the central nervous system may rise or below which it may be depleted in ether content, depending on the relative percentage of ether vapor (expressed as vapor pressure) maintained in the air of the pulmonary alveoli.

**Details of Induction.**—The objective in induction is to bring the central nervous system to full anesthetic tension as rapidly and smoothly as possible. Forty-eight to 55 mm. is the tension required by all animals to disassociate entirely the cerebral cortex, including consciousness, motor power and sensory perception and as well to disassociate completely the reflexes of the spinal cord that have to do with pain and touch stimuli, and abolish the reflex tonicity of voluntary muscle.

The ideal curve of ether vapor pressure to be maintained in the tidal air is shown in Figure 13. To induce full anesthesia this curve must be followed approximately no matter how crudely and unintelligently the anesthetic may be given. The more evenly and intelligently the curve can be followed, the better the anesthesia and less undesirable the immediate and after-effects of ether anesthesia and of operative trauma. The curve differs in various physical types of man only in the time required to induce anesthesia and arrive at equilibrium. The depth of anesthesia established at any given level of dosage is equal for child and adult.

For induction the vapor may be started at about 4 per cent. or 30 mm. of vapor pressure. Inhalation of a few breaths at this dosage accustoms the mucous membrane to ether and carries the sensorium so far into anesthesia that successively stronger vapor may be inhaled without irritation, until within a few minutes the strongest vapor is reached. High percentages (16 to 24 per cent. by volume) are necessary for induction, since the venous blood in the early stage of anesthesia returns to the lung with little ether, having been largely depleted of ether in the capillary network of the body. Only by high percentage of vapor in the pulmonary air can the arterial blood be recharged constantly to proper anesthetic tension and the central nervous system reduced to a state of quiet anesthesia within reasonable time. If the tidal volume inhaled be relatively large, and the state of consciousness readily subdued, as in a young child, or if administration be continued for upward of 15 minutes, the vapor pressure need not rise above 120 mm. or 16 per cent. In fact, if the individual be in preliminary narcosis from nitrous-oxid-oxygen or other light anesthetic, the ether vapor need not exceed 90 mm. or 12 per cent. If, on the other hand, the tidal volume be small, due to the subconscious control which certain individuals hold over the respiratory center through the first 3 zones of etherization, or if the absorptive capacity of the lung be relatively small, as

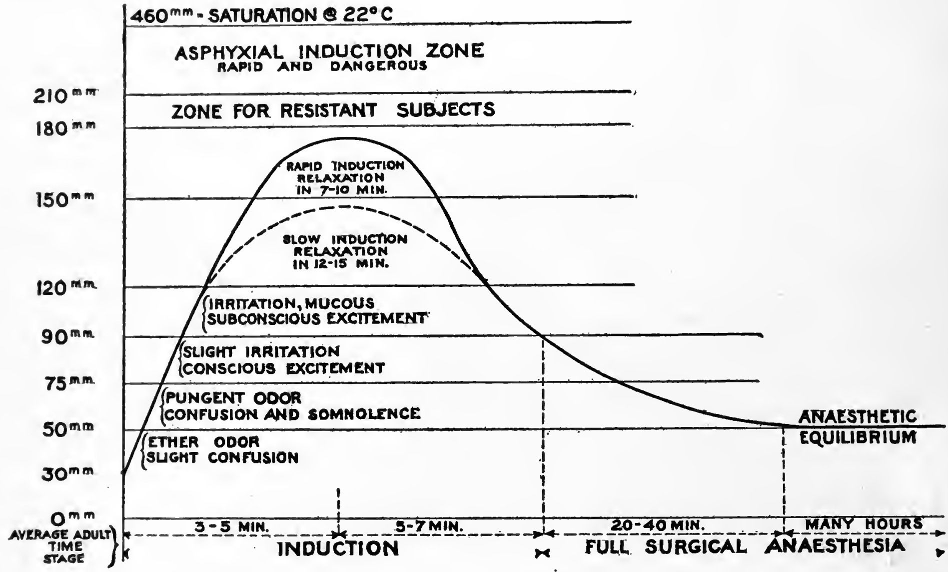


FIG. 13.—VAPOR PRESSURE OF ETHER IN TIDAL AIR FOR INDUCTION AND MAINTENANCE OF FULL ANESTHESIA. Partial pressure of vapor in millimeters of mercury.

in stout people, the vapor for the prompt establishment of surgical anesthesia must be carried momentarily to 210 mm. or 28 per cent.

This group of cases is exemplified by athletic subjects and those who have been so adapted to light habitual narcosis, by alcohol, ether, tobacco, morphin, cocain, chloral and other narcotics, as to be unusually resistant to narcotic disassociation of the subconscious centers from that of respiration. When at last these resistant low association paths are broken, then the most robust alcoholic remains in the same degree of anesthesia on the 50 mm. level as the young child.

The surgical operative procedure may be started at the peak of the induction curve (Fig. 13), but to protect fully the nervous system from reflex stimuli it is best to wait until relaxation has become complete, and the vapor pressure in the tidal air has been lowered to 90 mm. This induction period may total 3 minutes in the young child up to 15 minutes in the robust alcoholic.

**Establishment of Anesthetic Tension.**—The time and sequence of the various body tissues in reaching equilibrium are shown in the accompanying chart

(Fig. 14). After the induction period, the general body tension as averaged by the venous blood gradually rises, until at the end of the establishment period the entire body is in equilibrium. This takes about 10 minutes in the young child up to 40 or even 60 minutes in a large robust individual.

**Stage of Recovery.**—The excretion time and sequence in loss of ether by the various tissues after the administration of ether has ceased are shown in Figure 15. When the breathing is full and the excretion of ether is uninterrupted, the nervous system drops into light anesthesia in about 3 minutes, and into

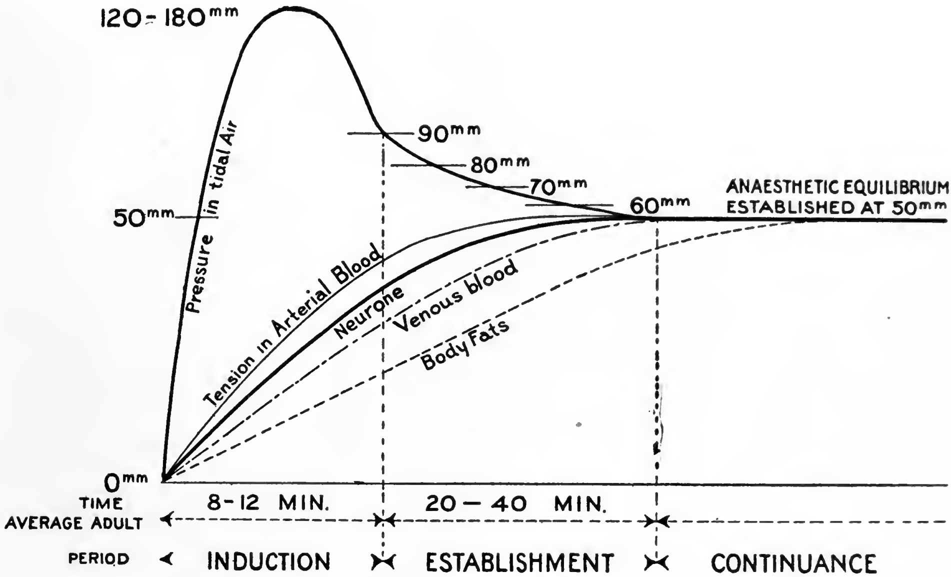


FIG. 14.—PLOT OF ETHER VAPOR PRESSURE IN PULMONARY TIDAL AIR AND ETHER TENSION IN BODY IN FIRST HOUR OF IDEAL ANESTHESIA.

the subconscious state in about 8 minutes. Usually in about 12 minutes the lower level of the subconscious zone (see page 83) is reached and the vomiting center may recover and subconscious vomiting ensue.

The light subconscious zone is entered in about 15 minutes and the zone of confusion in about 30 minutes. From the low ether tension of this zone recovery is gradual, since the fats of the body yield to the blood the last traces of ether very slowly. If at any time the tidal volume of respiration be obstructed, excretion of ether ceases from the venous blood and the patient relapses into deeper anesthesia.

If the administration of ether ceases before the entire body is saturated to full anesthetic tension, recovery is rapid, since the nervous system, gaining or losing ether rapidly, soon balances with and then drops below the general tension of the body. Thus, within 3 minutes after short full anesthesia, the tension of ether in the nervous system may have dropped low into the zone of confusion and the patient be fully conscious.

7

**Zones of Anesthesia.**—The depth of anesthesia is governed by the tension of ether established in the central nervous system. This tension is dependent on ether diffusing according to the vapor pressure maintained in the tidal air, either to or from the nerve tissue through various intermediate media, until a balance is finally established. The zones of ether dosage at which the various phenomena of ether intoxication become persistent are given by Figure 16. These zones have been established and the utility determined by me on about 3,000 cases at the Roosevelt Hospital, and by confirmatory findings on the dog.

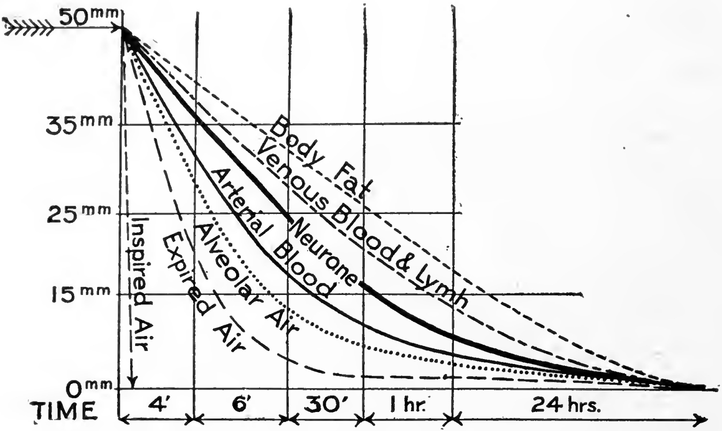


FIG. 15.—PLOT OF ETHER TENSION IN BODY. Recovery stage after full ether anesthesia.

No variation has been observed between adult and child, between strong and weak, except the time required and difficulty of bringing the subject to equilibrium in balanced vapor tension.

**Phenomena and Utility of the Zones of Ether Anesthesia.**—ZONE 1: THE ZONE OF CONFUSION (0 to 15 mm. of ether vapor tension).—Reason, judgment and will are much clouded, there is mental confusion and a tendency first to exhilaration, later to somnolence. Moderate analgesia is present. The mind is open to suggestion.

This zone is useful to produce stimulation, confusion, and analgesia on very ill cases in which some minor procedure such as thoracotomy for empyema must be performed, and where it is desirable to retain consciousness and the ability to move and cough at command of the surgeon. The analgesic action of local anesthetics is much heightened in this zone. With magnesium sulphate administered as a general anesthetic, a dangerous anesthetic action is developed.

ZONE 2: THE LIGHT SUBCONSCIOUS ZONE (15 to 25 mm.).—In this zone, as in zone 1, the reflexes are active, but the anesthetist is no longer able to control the mentality of the patient. The patient responds to stimuli by subconscious movements. Sweat, lacrimal, salivary and mucous secretions are excessive. At the top of this zone and at the bottom of zone 3 the vomiting center is stimulated. Superficial anesthesia is present.

This zone is useful to supplement those local anesthetics such as nitrous oxid which are intrinsically light. For this purpose it is the more desirable, since the vomiting center is not stimulated.

ZONE 3: THE SUBCONSCIOUS ZONE (25 to 35 mm.).—The reflexes are less active, complete anesthesia of the lighter grade is present. Severe stimuli such as trauma to nerve trunks, to peritoneal and visceral surface, cause active stimulation of respiration and circulation followed by depression.

| VOLUME EQUIVALENT IN AIR AT 760mm BAROMETER | VAPOR TENSION | ZONE | LEVEL OF NERVE CENTRE DISASSOCIATION | DEPTH OF ANAESTHESIA | UTILITY |
|---|---|---|---|---|---|
| 60.4 % | 460mm | RAPIDLY LETHAL | | ASPHYXIAL AND LETHAL | |
| 27.6 % | 210mm | SLOWLY LETHAL | CARDIAC CENTER | LETHAL | |
| 11.84 % | 90mm | PROFOUND | RESPIRATORY CENTER<br>DEPRESSION OF VASO-MOTOR<br>NUCLEUS OF THE SIXTH CRANIAL | PROFOUND | |
| 9.2 % | 70mm | DEEP | GALL BLADDER REFLEX<br>MESENTERIC REFLEX<br>DEPRESSION OF RESPIRATORY CENTER | DEEP | FOR TRACTION ON THE MESENTERY AND BILE TRACTS |
| 7.24 % | 55mm | FULL SURGICAL | PERITONEAL REFLEX<br>PUPIL REFLEX<br>ANAL REFLEX | FULL | ABDOMINAL THORACIC AND CRANIAL SURGERY |
| 6.3 % | 48mm | LIGHT SURGICAL | CORNEAL REFLEX<br>SPINAL REFLEXES<br>LARYNGEAL REFLEX<br>PHARYNGEAL REFLEXES | LIGHT | HERNIA<br>AMPUTATION OF BREAST ETC. |
| 4.6 % | 35mm | SUB CONSCIOUS | LID REFLEX<br>LACHRYMAL & MUCUS REFLEX<br>MOVEMENT OF THE EYEBALL | SUBCONSCIOUS ANAESTHESIA | PLASTIC AND OTHER SUPERFICIAL OPERATIONS<br>AVOID ON ACCOUNT OF VOMITING |
| 3.28 % | 25mm | LIGHT SUBCONSCIOUS | VOMITING CENTER<br>SUBCONSCIOUS MOVEMENT<br>VOLITIONAL MOVEMENT | SUBCONSCIOUS ANALGESIA | INCISION OF ABSCESS<br>REDUCTION OF FRACTURE<br>SUPPLEMENT OF LOCAL ANAESTHETIC AND NITROUS OXIDE |
| 1.98 % | 15mm | CONFUSION | CONSCIOUSNESS.<br>CO-ORDINATE THOUGHT<br>HIGHLY CO-ORDINATE THOUGHT | CONSCIOUS ANALGESIA | SUPPLEMENT OF LOCAL ANAESTHETIC |
| 0.0 % | 0mm | | | | |

FIG. 16.—ZONES OF ETHER ANESTHESIA.

This is the proper zone in which to establish anesthesia for merely superficial plastic work and where it is desired to maintain at the same time complete loss of consciousness, together with the presence of such reflexes as induce cough. The top of this zone gives the same degree of anesthesia with greater safety than is present in full nitrous oxid anesthesia.

ZONE 4: THE ZONE OF LIGHT SURGICAL ANESTHESIA (35 to 48 mm.).—Superficial reflexes are abolished. The pupillary reflex is sluggish, the anal reflex is present. Severe operative stimuli are still responded to by reflex muscular rigidity and other reflex action.

This zone is useful for all superficial operations where full muscular relaxation is not necessary, such as amputation of the breast, hernia, and intraperitoneal work where no visceral traction is made.

ZONE 5: THE ZONE OF FULL ANESTHESIA (48 to 55 mm.).—All superficial reflexes are lost and deep reflexes are much blunted; the pupil is moderately dilated, the muscles are completely relaxed, there is no evidence of nervous stimulation or shock by such degree of trauma as the stretching of muscle. The respiratory center begins to be depressed toward the top of this zone, but is in no danger, unless asphyxia by respiratory obstruction be superimposed on the ether anesthesia.

This is the surgically ideal and physiologically advantageous zone for all operative procedures wherein full muscular relaxation and blockage against fairly severe traumatic stimuli are required. It is the zone for cranial, thoracic, abdominal, and joint surgery.

ZONE 6: THE ZONE OF DEEP ANESTHESIA (55 to 70 mm.).—All reflexes are lost, muscular relaxation is complete, the pupil is moderately dilated and immobile to light, breathing is of lessened frequency and amplitude, blood pressure is slightly lowered, and the heart rate increased. Reaction to severe trauma such as pulling on the mesentery and the biliary tracts and section of nerve trunks is very slight.

The anesthetist carries the patient into this zone only at such stage of operation as induces profound vasomotor stimuli; stimuli which may ultimately result in splanchnic paralysis or other form of shock; such stimuli as traction on the mesentery and on the biliary tracts, operation on the heart, on nerve trunks, and on sensitized joint structures. Thus the anesthetist temporarily deepens anesthesia to the most advantageous degree in correlation with the requirements of the operative procedure. The respiratory center may become dangerously depressed if any degree of asphyxia be superimposed on the ether anesthesia.

ZONE 7: THE ZONE OF PROFOUND ANESTHESIA (70 to 90 mm.).—Respiration becomes shallow and gasping, or Cheyne-Stokes, in type, the skin cold, pale, and slightly cyanotic; the circulation fails in proportion to the degree of slow asphyxia; blood pressure falls 30 to 60 mm., and the pulse becomes rapid. At the top of this zone the respiratory center fails, but life may be continued by artificial respiration.

This zone is not useful on account of the danger of respiratory failure and circulatory depression. When the above noted symptoms present as a result of overdosage the patient is dropped to a lower zone by decreasing or stopping momentarily the administration of ether.

The following zones have been deduced from the action on human subjects of strong ether vapor in variously determining the proper dosage for inducing anesthesia. The danger symptoms have been only momentary on the human subject, but the zones have been more definitely established on the dog.

ZONE 8: THE SLOWLY LETHAL ZONE (90 to 210 mm.).—Death occurs from respiratory failure probably requiring in man on the higher percentage at least 10 minutes and usually 15 to 30 minutes. If life be continued for a while by artificial respiration and dosage be continued death is resultant from circulatory collapse. In the lower levels of this zone life may be carried on for some hours by intratracheal insufflation, with the respiratory center entirely paralyzed.

ZONE 9: THE RAPIDLY LETHAL ZONE (210 to 460 mm.).—This zone may be entered rapidly during light anesthesia by suddenly breathing highly concentrated vapors, i. e., above 28 per cent. by volume. Irregular respiration and slight cyanosis are first noticed. The pupil soon dilates and becomes immobile, the respiration and circulation diminish, cyanosis becomes more marked, and the patient may die of respiratory failure. Usually when this zone is thus rapidly entered by the respiratory center the body in general has not yet been saturated with ether and the circulation of blood and irritability of protoplasm, except in the nervous system, remain active for many minutes. After such short overwhelming dosage, on withdrawal of the anesthetic, the respiratory center rapidly balances with the general body tension and respiration is resumed. Were the tension in this zone fully established death would be inevitable.

## General Technic of the Administration of Ether

**Introduction.**—Ether for pulmonary absorption may be delivered by the *open method:* First, by a succession of drops onto gauze stretched over an open mask—*drop method;* second, by intermittently pouring small quantities into an open cone—*open cone method.* The vapor may be trapped on exhalation in a closed bag and rebreathed wholly or in part—*closed method.* Or the liquid ether may be volatilized at a distance and delivered into an open or closed face mask, blown into the nostrils or mouth, or directly into the pharynx or trachea—*vapor method—nasal, mouth, pharyngeal, and intratracheal insufflation.*

For induction, as in all anesthesia, the environment should be quiet and cheerful. The anesthetist should see that there are no loose foreign bodies in the mouth. A sympathetic psychic control of the patient should be secured by the anesthetist. The patient should be chatted with, reassured, and distracted from the procedure in hand. As induction proceeds helpful suggestions by the anesthetist may be made to the patient as to breathing and quietude.

**Open Methods.**—ADMINISTRATION BY SUCCESSIVE DROPS: DROP METHOD. —Apparatus.—A large wire mask of the modified Esmarch, Clayton, or Mayo type is covered with from 10 to 16 layers of gauze. (The object of many layers of gauze is to multiply the surface from which ether may vaporize. When gauze becomes cold and moist the proper vapor tension cannot be maintained from a small surface. Induction of anesthesia is difficult with less than 8 layers of gauze.)

Technic.—The eyes may be covered by a moist boric pad overlain by a strip of gutta-percha tissue. The mask is held loosely in front of the patient's face, and a few drops of ether are added until the patient becomes accustomed to the odor. Any pleasant odor which will at first overpower that of ether is advantageous, such as is obtained by adding a few drops of essence of orange, as suggested by Gwathmey. When the patient has become accustomed to the local stimulation of ether the rate at which the ether is dropped is increased. For the first minute about a drop a second suffices; this establishes in the tidal air of the average adult a pressure of about 20 to 30 mm. The rate is now increased to about 2 drops per second.

Gradually the mask is securely seated against the patient's face, and is enveloped by degrees in the folds of a towel, which forms a tight joint round the edge of the mask, and dams back the downward flow of the heavy, gradually increasing ether vapor. The respirations are watched and the ether dosage governed accordingly. The rate of the ether drop is gradually increased so long as the respiration keeps smooth and regular up to about 4 drops per second. At this level a vapor pressure of from 80 to 100 mm. is established in the average case. Within 3 minutes the patient passes into the stage of subconscious excitement. The enveloping towel must now be more closely adjusted so as to also cover the top of the mask. The liquid ether is now added more rapidly in 1 to 2 dram amounts at sufficient intervals to keep the gauze thoroughly impregnated. By thus gradually increasing the vapor at first and then rapidly running the pressure up to the full vaporizing capacity of the open mask anesthesia may be induced without disturbing the respiratory rhythm by other than a few halts and quickenings of the rate, and possibly by a warning cough during overstimulation.

Difficulty in inducing anesthesia arises when the early dosage is so irritant as to cause coughing, light breathing, or holding of the breath. With skilful administration the peak of the delivery should be reached in 6 minutes and then slightly decreased until stertor and relaxation appear, whereupon the dose may be gradually lowered to about 2 or 3 drops per second. On this level administration must usually be continued for the next 20 minutes.

Finally a level is reached at which a slow succession of drops carries the patient to full surgical anesthesia for many hours. It is difficult to lay down a definite formula, since many factors enter, such as the tidal volume, and the amount of ether wastage on expiration, and by extraneous air currents. Technically speaking, this level is such as establishes and maintains in the tidal air a vapor pressure of 50 mm. Without wastage this would require about 11 medium-sized drops of ether per liter of air inspired, or in the average breathing somewhat in excess of a drop per second (about 2 grams of ether per minute).

The patient should be held continuously on a level that is neither light nor profound.

Drop Method in Children.—During induction of anesthesia the young child exercises no measurable control over mind and body as does the adult. To gradually induce ether anesthesia prolongs the period of excitement. Therefore one must start with such dosage as will rapidly overwhelm the consciousness. The mask is immediately saturated and seated. After a moment of holding the breath the child cries, and within 4 to 6 inspirations has established such tension in the arterial blood and neurons as to have lost consciousness. The tension may rapidly become overpowering, hence the dosage must be lessened within a minute and an occasional breath of air allowed. Full anesthesia is reached within 4 minutes. The dosage is now lessened. Gradually the entire blood stream and body is brought to full anesthetic tension of about 50 mm. This requires in the very young child about 6 minutes as against 40 to 60 minutes in the adult. Thereafter a continuous level is established, on which anesthesia may be maintained for hours. This level for the child is the same as for the adult, but owing to the dissimilar tidal volume of air the amount of ether used is proportionately less, and finally 10 drops a minute may suffice.

The liability to overdosage is greater in children than in the adult because of the greater proportional respiratory absorptive surface and smaller reservoir capacity of blood and fat.

ADMINISTRATION BY POURING OF SMALL PORTIONS: OPEN CONE METHOD.—This differs from the drop method in that the ether is added to the mask intermittently, and the face is more muffled. Vaporization is governed by the extent of vaporizing surface, the movement of air over that surface, and the vapor tension of ether as lowered by refrigeration and by water condensation. Fortunately refrigeration so lowers the vapor tension of ether that even if an excess of ether be added an approximately correct percentage of ether for induction of anesthesia is established automatically. Lower percentages of ether are obtained in a very irregular manner by increasing the interval and decreasing the amount at each pouring.

APPARATUS AND TECHNIC.—The cone may be made of folded newspaper, of a butcher's cuff, or of metal (Allis inhaler). The mask usually selected is a newspaper cone, enveloped in a folded towel. Into this is packed a half yard of gauze as an ether reservoir.

Induction is begun by pouring on the gauze, first a few drops as in the drop method, then a dram, and, finally, toward the peak of the delivery curve at the end of 3 minutes, an amount of ether 2 to 4 drams at a time, keeping the gauze continuously moistened. Gradually the amount is lessened, and the interval between the moistening of the gauze is increased until there may be an interval of 5 minutes between doses, 2 to 4 drams at each dose. This is a rough procedure, requiring the least skill of all methods, but yielding sufficient anesthesia for a short operation, such as the reduction of a fracture. The greatest objection to the method as applied to prolonged operation is the irregularity with which anesthesia is maintained. Next to the closed or rebreathing method the open cone has been the most widely used and disadvantageous method of ether administration.

**Closed Method.**—Where the exhaled tidal volume is trapped and rebreathed the method is spoken of as a closed method. Any open cone method traps the exhalation to some slight extent, but the closed method traps the exhalation in larger part. Thereby the vapor pressure of ether is kept up by small additions of fresh ether, also a small amount of heat and moisture is conserved, any desired degree of asphyxia may be induced, and carbon dioxid and other waste products are retained at will.

The method is the least desirable of any method of ether administration. To avoid a sinister degree of asphyxia, of exaggerated respiration, and the aspiration of retained mucus and saliva in refractory subjects the anesthetist must be highly skilled.

APPARATUS AND TECHNIC.—The Ormsby and Hewitt apparatus may be mentioned as early types. The Bennett apparatus is the preferable type. For induction with this apparatus nitrous oxid is usually employed as an adjuvant (see page 103). With ether alone the breathing bag is partly inflated, a few drops of ether are poured into the reservoir, and the mask lightly seated. Gradually the ether dosage is increased by the intermittent pouring of small portions. After a minute or two an air vent is opened, through which portions of the respired gases are exhausted and renewed. Thus the air may be refreshed and the percentage of ether controlled in a crude measure.

**Vapor Methods.**—INTRODUCTION.—In all vapor methods the ether is evaporated at a distance from the patient by the passage of a current of air or other respirable gas over or through the anesthetic.

For the induction of anesthesia the vapor must be delivered into a closed or open-face inhaler. After anesthesia has been secured the vapor may be blown into the nose or mouth; but preferably it is insufflated into the pharynx or trachea. The vapor may be concentrated and small in amount and be diluted in the respiratory tract by the inhaled air; or, preferably, it may be of such dilution as to furnish, in a volume of air sufficient for respiration, the minimal concentration of ether vapor necessary to induce and maintain anesthesia.

The special advantages of the vapor method are: first, that with a given apparatus, no matter how crude, ether dosage is more constant and controllable than by either the open or closed methods; second, a considerable amount of body heat may be conserved by moistening the vapor, and a small amount by warming the vapor, as is sometimes done; third (and most important), by this method the bulk of air-vapor mixture may be delivered—for example, into the pharynx—where it will satisfy air needs in the act of inspiration without undue respiratory strain, thus eliminating the partial asphyxia which so often is associated with the crude methods of administration.

This is in theory and practice the most advantageous of all methods. The only objection to it is that apparatus is needed to impel the air and vaporize the ether, and that this becomes more complex as one approaches the ideal conditions in which the entire tidal volume of vapor both in bulk and percentage is accurately measured.

THE NEGATIVE PRESSURE METHODS OF VAPOR DELIVERY.—This method depends on the negative pressure of inspiration (as, in fact, do all the preceding open methods) to draw the air over the ether for the purpose of vaporization. For example, in the Vernon Harcourt inhaler a mask is connected with an ether chamber through which an adjustable proportion of air may be drawn for the purpose of impregnation with vapor. This is then sometimes popularly called the "draw over method."

A simpler procedure advocated by Crile is as follows: After the induction of full anesthesia 2 No. 22 F. catheters are passed one through each nostril well into the pharynx—a distance of 12 to 14 cm. from the nares. These catheters are connected with a funnel, which is covered by gauze, onto which the ether is poured for vaporization. This procedure is especially applicable when the operation is on the mouth and the pharynx is packed off. The same procedure may be used for anesthesia through a tracheotomy wound.

The negative pressure method throws extra strain on the respiratory apparatus and exaggerates the negative pressure in the pharynx, thereby tending to aspirate mucus and blood into the lungs. It has now largely been abandoned for the method depending upon positive pressure.

THE POSITIVE PRESSURE METHOD OF VAPOR DELIVERY.—More effective than the preceding methods is the delivery of vapor under pressure, where it may become available for inspiration without exaggerated suction effort on the part of the patient. This may be either intermittent or continuous.

*In the intermittent method of vapor delivery* a strong vapor is blown by hand bulb, bellows, or other propulsive apparatus into the nose, mouth, or pharynx as need arises and is here diluted with inhaled air.

*The continuous method of vapor delivery* is far better. Either a small quantity of concentrated vapor may be continuously delivered to the patient to be diluted by his inhaled air or, preferably, the entire required volume of diluted vapor may be prepared and delivered by propulsive apparatus.

APPARATUS FOR POSITIVE PRESSURE METHODS.—*Apparatus to Compress Air.*—For the small quantity of air needed to vaporize and deliver a highly concentrated mixture a large hand bulb such as is used for an atomizer yields the necessary 1 to 2 liters of air per minute. A small duplex dental foot bellows yields by easy pedaling from 8 to 12 liters per minute. Oxygen bubbling from a tank may also be used as the vehicle to convey the vapor.

For the larger quantities of air needed in insufflation methods a glass-blower's foot bellows, known in commerce as size 9, is convenient (see Fig. 19). This yields about one liter of air at a stroke, requiring for face mask methods 8 strokes per minute, and for insufflation about 25 strokes per minute. Far more convenient than this is a portable rotary motor-driven air compressor. Such an air apparatus is illustrated in Figure 20.

For permanent hospital installation air should be supplied to the operating room from a central plant. The air should be compressed, washed, and stored by automatic electric-driven rotary compressor or by steam pump, and delivered from a wall cock in the operating-room at about 1 pound of pressure, thus avoiding the hum and annoyance of portable apparatus.

*Apparatus to Vaporize Ether.*—*Vaporizer for Concentrated Vapor.*—In order that small quantities of air or oxygen absorb sufficient percentage of vapor to induce and maintain anesthesia, the gases must be bubbled through liquid ether. The Gwathmey and Lumbard apparatus effectively secure this result. The well known Junker apparatus for chloroform has not the capacity for ether vaporization.

*Vaporizer for Dilute Vapor.*—The apparatus must be more capacious to vaporize the larger total quantity of ether needed to impregnate the air for insufflation methods. For in these methods, since there is no rebreathing of exhaled vapor, and the mixture is continuously delivered, about half the mixture is wasted, namely, that portion which is insufflated through the period of expiration. The total ether vaporized must, therefore, be double that used by the concentrated method to secure the same physiological effect, or about 9 ounces an hour.

The types of vaporizers are two: in the first the air passes over a surface of ether and absorbs what it will, depending on the extent of surface, the rate of the air flow, and the surface temperature of the ether; in the second and more accurate type ether is dropped in known quantity into a chamber and immediately and completely vaporized by an air current passing through this chamber.

For surface vaporization an area of at least 20 sq. in. is necessary to evaporate the ether with sufficient rapidity for the induction of anesthesia. Therefore, air is usually bubbled through a smaller container of ether at this stage of administration. After anesthesia is fully induced a surface of 4 sq. in. will suffice to impregnate the air, flowing at the usual rate of 18 liters per minute. Liquid ether is chilled by the evaporation and gradually vaporizes with less rapidity. To obtain more dilute vapor a portion of the air current is diverted around the vaporizing chamber, only a portion passing over the surface of the ether. To obtain stronger vapor the ether reservoir is kept at or about room temperature by a water bath. Such an apparatus may be readily constructed from a Wolff bottle (see Fig. 21). The Elsberg, Janeway, Boothby, and Robinson apparatus depend on this principle of evaporation.

A more controllable method, providing the rate of flow is known, is to drop ether into a chamber and there immediately vaporize it into the air, either by dropping it onto a broad bottom or, better, by providing artificial heat, as from an electric stove. The ether is usually contained in an oil cup from which it is dropped by regulating the feed cock to control the rate of drop. About 46 drops in the average equal a gram of ether. After anesthesia has been induced by face mask methods, and it is desired to start insufflation, the ether must be set dropping at the rate of 4 to 5 drops a second to maintain anesthesia, insufflating at the usual rate of 18 liters per minute. Gradually the rate of the drop is diminished until after 40 minutes full anesthesia may be continuously maintained by a rate somewhat less than two drops per second. The Flint apparatus, also my own vaporizer, a prototype of the following anesthetometer, depends on this principle of evaporation.

The most accurate, safe, and useful vaporizer, one which automatically measures the air and ether, and mixes them in any desired percentage, is the anesthetometer (see page 131).

METHOD OF ADMINISTRATION. TECHNIC OF THE VAPOR METHOD.—The administration of the ether is readily controlled by delivering the vapor mixture into the breathing bag of any closed inhaler. (For closed inhalers, see page 115, Nitrous Oxid Anesthesia.) The strength at which the vapor should be maintained through successive minutes is indicated in Figure 13. The vaporizing capacity of crude apparatus must be learned empirically and the strength governed by the reaction of the patient. The quantity of the vapor mixture for the first 2 minutes should be not less than 3 liters; thereafter at least from 5 to 8 liters should be supplied each minute. That is enough to fill the ordinary 2-gallon rubber breathing bag in about 60 seconds.

When by this face mask method the pharynx has relaxed, usually within from 8 to 12 minutes, the delivery may be changed to pharyngeal insufflation (see page 95), or, for more effective aeration and for positive pressure, an intratracheal tube may be introduced when general relaxation is obtained, usually within from 10 to 15 minutes.

## Anesthesia by Intratracheal Insufflation

**Introduction.**—A form of insufflation has long been practiced for special emergencies through a tracheotomy wound and through a tube in the larynx. Recently, however, Meltzer has devised a precise, safe, and widely applicable method of insufflation anesthesia which takes an important place among the modern surgical procedures.

In the Meltzer method the trachea is intubated by a loosely fitting endotracheal catheter. Through this tube ether vapor or other anesthetic is delivered by positive pressure well into the depths of the trachea, mixed with a proper volume of air or other respirable gas. The ether-air mixture is the safest and most efficient and will be exclusively considered here, although chloroform and nitrous oxid have also been employed in this way.

Primarily this method was designed as a differential pressure method, to keep the lungs in partial distention when the pleura is opened, and to provide perfect aeration with minimal thoracic movement during intrathoracic surgery.

A wider scope has now been developed for the method: First, when obstruction to the upper air passage is to be anticipated, during the operation either from posture, such as the lateral or prone position, or from lesions which encroach upon the trachea and larynx; second, when the aspiration of blood and mucus or vomitus is impending, as in operations on the tongue and throat, and in the vomiting of intestinal obstruction; third, in prolonged operations on feeble subjects because of the even, full anesthesia, perfect aeration, and the freedom from respiratory insufficiency and from shock which it secures.

The disadvantages of the method are: first, the need of apparatus to generate pressure and to vaporize the ether in a controllable manner; second, the depth of anesthesia by other procedures required before intubation becomes feasible; third, the occasional difficulty and time consumed in intubating; fourth, the physical and physiological risks from over-pressure.

**Physiology.**—Meltzer has shown that the tidal movement of air in the respiratory tract is not needed for aeration nor for the diffusion of an anesthetic, provided a proper air circulation be artificially maintained in the trachea. Effective insufflation secures such a circulation, from which, through diffusion, the respiratory needs are met.

The anesthetic state in insufflation anesthesia differs from the usual, in that the respiratory movement is here slower and more shallow than in the face mask methods, yet oxygenation is more efficiently maintained. No element of asphyxia enters, the color stays bright, and the pulse remains the physiological pulse of ether anesthesia when devoid of respiratory strain, namely, a full pulse of well-sustained pressure, accelerated 10 to 20 beats above normal, usually running 70 to 90 per minute. Owing to the even flow of vapor the anesthetic state may be perfectly maintained at any desired level. The patient may be placed in a zone of deep anesthesia, with complete blockage of the traumatic stimuli, yet with no danger of respiratory insufficiency.

Postoperative sequelæ are reduced to those of a perfectly delivered vapor anesthesia. "Ether" or inspiratory bronchial "pneumonia" is unknown, except as a result of preliminary and postoperative inspiratory accidents. The method in itself carries no more risk of pulmonary irritation than inhalation anesthesia. Slight pharyngeal and laryngeal mechanical trauma is occasionally caused by clumsy intubation. Owing to the ease with which inspiratory negative pressure is satisfied by the rush of intratracheal delivery, and also to the double volume that must be exhaled through the glottis, this method tends to increase the intrathoracic pressure, usually diminishing the negative and raising the positive pressure about 5 mm. If the delivery be excessive, or the return be choked, a continuous positive pressure may be maintained.

If the phase of negative pressure be totally obliterated by excessive intrathoracic pressure (i. e., in excess of 20 mm.), the patient may be rapidly thrown into a condition of shock. Therefore, when the delivery is of excessive or unknown volume, or of deliberately increased pressure, as for intrathoracic surgery, the flow should be interrupted from 2 to 4 times a minute to allow of deflation of the lungs and to remove obstruction to the return of venous blood and lymph to the right auricle from the great venous sinuses and lymphatic channels.

**Technic of Intratracheal Insufflation.**—The patient must first be anesthetized to full relaxation by the usual face mask methods.

With the patient lying supine, the head is knuckled backward down to the table, until the shoulders are slightly lifted and the plane of the face forms an angle of 60° with the table (see Fig. 17). A Jackson direct-vision laryngoscope is now inserted over the base of the tongue, and the epiglottis is identified. The upper lip is disengaged from between the instrument and the upper teeth. Care is taken not to exert leverage with the upper incisor teeth as a fulcrum. The instrument is now carried deeper and the beak engages the epiglottis, and this, with the base of the tongue and the lower jaw, is carried directly upward as if to raise the patient's head from the table (see axis of arrow, Fig. 17). The axis of the laryngoscope is now in line with that of the trachea. If the patient be well anesthetized the triangular opening of the glottis stands wide open on each inspiration. Into this opening a stiff catheter is passed by direct vision. The catheter should pass about 13 cm. into the trachea, or 26 cm. from the incisor teeth. A clamp loosely incloses the catheter at the teeth, holding it from slipping and preventing compression. The fact that the catheter is in the trachea should be established by the ebb and flow of air at the bore of the catheter by a bit of fluff cotton or by the hand. A cough, as the catheter is passed, is usually proper evidence that the tube has passed the glottis. If, on the other hand, no ebb or flow takes place on respiratory movement, it is presumable that the catheter has been passed into the esophagus.

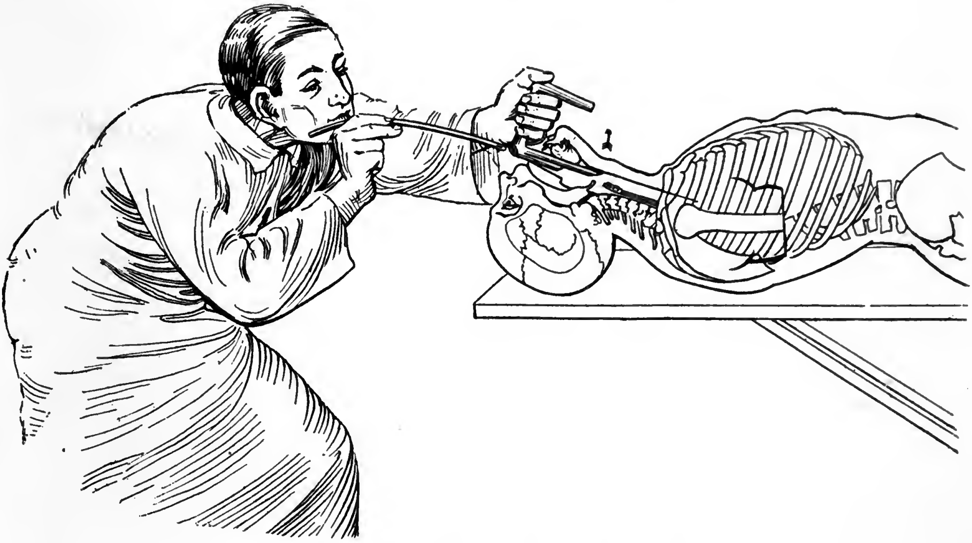

Fig. 17.—Technic of Intratracheal Intubation.

If the catheter has been so misdirected it is withdrawn and a fresh catheter properly inserted. If the mistake be not discovered until the pressure has been connected, and then discovered by the dilatation of the stomach, or by expulsion of gulps of air and gastric secretion from alongside the catheter, then the tube is disconnected, but not withdrawn until all the air has been expelled from the stomach.

Some few deft operators with long fingers can tuck in a soft rubber catheter by feel, also the catheter may occasionally be introduced blindly through a curved hollow instrument shaped like a sound, the Boothby-Cotton introducer. Such technic is not recommended. The Janeway introducer is a refinement of the Jackson instrument.

When it is evident in a breath or two that the catheter is properly placed, it is connected to the air-ether supply. The tubing should be strapped in place by adhesive plaster. A clamp may be attached to the tube at the line of the teeth to prevent compression by the bite.

The quantity insufflated should be such that on inspiration no air is inhaled from outside. Eighteen to 20 liters is the average quantity for the adult. This may be blown by 20 mm. of pressure through a 22 F. catheter. Allowing for the resistance of the connecting tube, 26 mm. is the average pressure desired at the ether vaporizer.

The quantity should suffice entirely to supply the tidal volume during inspiration. If any air can be heard sucked in alongside the catheter the quantity must be increased by raising the pressure.

When the depth of anesthesia is such that it is feasible to intubate then the patient has already passed the induction period of ether anesthesia (see Fig. 13). If anesthesia has become light from the breaths of air during intubation insufflation of strong vapor quickly deepens it again. Usually for 20 seconds the strength of the vapor should be 6 per cent. by volume, i. e., 50 mm. of vapor saturation, so as not to induce violent coughing. It is rapidly strengthened to 90 mm., i. e., 11 per cent., then gradually decreased as anesthetic tension becomes fully established until after 40 minutes in the vigorous adult, or in less time, according to the reactions of the patient, the vapor pressure may be maintained at the 50 mm. level.

On this strength of vapor anesthesia stays uniform through the succeeding hours of anesthesia. Ten to 12 minutes before the close of the operation air alone should be insufflated, which results in rapid elimination of the ether, so that the patient is in the light subconscious stage as the operation terminates.

**Maintenance of Positive Pressure.**—In those infrequent procedures of intrathoracic surgery where positive pressure is desired this pressure is maintained in one of three ways.

First, the tracheal return may be choked by a tube, disproportionately large to the bore of the trachea, i. e., 26 to 28 F. catheter. This is a blind method, since the return flow cannot be regulated.

Second, the volume delivered may be doubled by increasing the delivery pressure to 60 to 70 mm. This is the usual method, but undesirable in that the lungs may be subjected to possible over-pressure, i. e., constantly in excess of 20 mm.

Third, the best method is to choke the return by placing a hand over the nose and mouth until the cheeks remain in moderate distention. This yields the necessary 5 mm. of plus pressure. At 8 mm. air may be forced into the esophagus; if this happens a stomach tube should be inserted and left in situ.

From 2 to 4 times a minute the inflow of air must be momentarily interrupted. Positive pressure is maintained only for so long a period and to such degree as is absolutely indicated by the operative procedure. Persistent efforts to keep a lung in full distention tend toward the production of shock (see Physiology of Intratracheal Insufflation).

### Anesthesia by Pharyngeal Insufflation

**Introduction.**—Small quantities of concentrated anesthetic vapor may be blown into the pharynx, to be here diluted with air inspired by the patient. However, a highly advantageous delivery is not attained until the anesthetic is already properly diluted, and the mixture is of such bulk as will entirely fulfil the needs of inspiratory effort and of anesthesia without further dilution. This method is far more efficient than face mask delivery and ranks almost equal to endotracheal insufflation. Indeed, as a routine method, where high efficiency of insufflation method is demanded, it is preferable to endotracheal delivery, since it is mechanically much more simple in its application.

Pharyngeal insufflation shares with endotracheal delivery the following advantages: First, the common obstructive difficulties of the upper air passages are largely overcome by delivering a sufficient tidal bulk behind and below the base of the tongue. Second, the mucus, saliva, and blood from operative procedure is blown outward by positively impelled air stream. (Since no puddle forms in the pharynx to be aspirated into the bronchi, and as no negative pressure exists in the pharynx to aspirate the saliva and mucus of the mouth and the mucus of the nose, the so-called "ether pneumonia" is rarely met with under this method.) Third, the method shares the even, full anesthesia common to all vapor delivery.

**Technic.**—The same air pressure and vapor apparatus are employed as those used in endotracheal insufflation. The most convenient delivery device is a metallic Y-forked tube, bent to fit the nose and forehead, each fork carrying

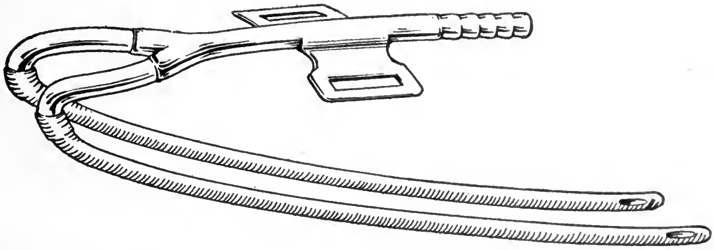

Fig. 18.—Connell Nasopharyngeal Tube. (For pharyngeal insufflation.)

an 18 F. soft rubber catheter with double eyelet. Each catheter is about 13 cm. long.

Before pharyngeal delivery can be instituted the patient must be anesthetized to the stage of surgical relaxation by the usual face mask methods. If anesthesia be too light when insufflation is instituted the patient will swallow air, halt in breathing, and may vomit. With ether as the agent, insufflation should not be started before 9 to 12 minutes as a rule.

To lubricate the catheters they may be moistened in the saliva of the patient's mouth. The nose is tilted upward and the catheters are passed directly back, one through each nostril along the inferior strait of the nasal chamber.

If the catheters be directed upward instead of backward they may become jammed and kinked. If the septum be found deflected then both catheters must be passed through the free side. If the nose be doubly obstructed the catheters must be introduced per ora. They are passed a distance measured by laying the catheters on the face of the patient from an ala of the nostril to the external auditory meatus of the same side. The eyelet of the catheter then lies at a level of the epiglottis, usually a distance of about 12 cm. from the nostril. Insufflation may also be practiced through a bent tube, introduced through the mouth into the lower pharynx. The nasal route is preferred, as the tubes are more accurately introduced and lie in place more securely.

The quantity of anesthetic delivered should be of such bulk as to satisfy totally each inspiration without extraneous dilution. To satisfy the negative pressure of inspiration at the glottis a total of 18 liters per minute must be insufflated in the average adult. When the patient is breathing rapidly this must be raised to 20 liters or may be dropped to 15 liters at quiet periods. A positive pressure of 26 mm. at the vaporizer supplies about the correct average quantity through two unobstructed, 18 F. catheters. An instantaneous gas flow gauge in circuit is highly desirable to read at all times the actual gas flow.

The percentage or vapor pressure of anesthetic to be maintained is the same as by face mask and intratracheal delivery (see Figs. 14, 15). Usually the mouth and jaw do not have to be held by the anesthetist. If the jaw tends to drop back so that the epiglottis obstructs breathing, then the head must be adjusted to one side. If the mouth tends to open widely, allowing the vapor delivered to become so dilute that anesthesia is not well maintained, then the chin should be held toward the head of the table by an adhesive strap.

The same even, quiet anesthesia, with the luxury of easy respiratory movement results as in the endotracheal delivery. The patient shows in general good condition, the absence of such respiratory strain as is often occasioned by face mask methods. The pulse and respiration tend to be but little accelerated; the depth of anesthesia may be accurately controlled and the undesirable sequelæ of crude methods of anesthesia are largely eliminated.

**Maintenance of Positive Pressure.**—Positive pressure within the lung for intrathoracic surgery may be easily maintained by obstructing the return flow with the hand over the nose and mouth until the cheeks bulge under moderate distention. While this serves for emergency, yet the following is a better method (see Fig. 25). The return flow is blocked at the nostrils by a collar of large rubber tubing slipped on over the delivery catheters, a collar of such size as to plug the nostril. The mouth is then blocked by a stiff rubber sheet or cofferdam, oval-shaped and slipped in between the lips and gums. This is perforated at its center for a pharyngeal breathing tube. To the breathing tube is attached outside the mouth a common 2-gallon rubber rebreathing bag. On insufflating a vapor mixture it is exhaled into this bag. The bag gradually distends and maintains an elastic pressure against the pharyngeal air, and in fact against the lung itself. The distention of the bag and exhalation therefrom are regulated by a cock at the distal end. The bag must be fairly firmly distended to yield 5 mm. of pressure against the lung. Occasionally the bag is deflated for a moment.

This method of maintaining positive pressure is much more controllable than face mask methods. It is not so efficient in aerating the lung as is the endotracheal method. This latter method (the endotracheal) should decidedly be chosen when both pleural cavities are to be open simultaneously.

Should the stomach become distended by this method, as it may do if a pressure of more than 10 mm. be maintained, then a small gavage tube may be passed and left in situ. Not less than 8 liters, preferably 15 to 18 liters, of fresh mixture should be insufflated in this positive pressure method.

### The Various Units of Apparatus Used in Insufflation Anesthesia

**First Unit: Air Compressor.**—As a source of air pressure, a small-sized glass-blower's foot bellows 7 by 12 in. is sufficient. This is obtainable at small cost from any hardware store. A pressure of 25 mm. and air flow of 18 liters per minute is maintained by about 25 strokes a minute. (Fig. 19.)

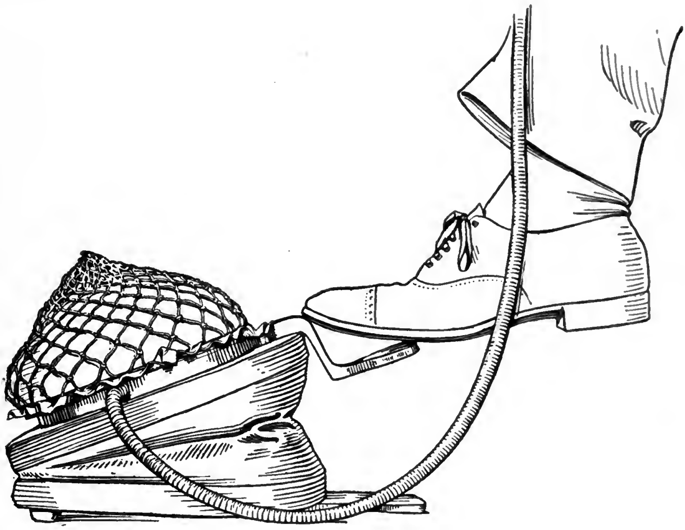

Fig. 19.—Foot Bellows of Air Compressor for Vapor Anesthesia. Size 9 yields somewhat less than one liter per full stroke, about 10 strokes a minute for face-mask methods, about 25 strokes for insufflation methods.

Motor-driven blowers are more convenient, of which the best is a rotary compressor of the "Hypress" type. Small reciprocating pumps are noisy and not capacious.

Modern hospital equipment should include a supply of compressed air to the operating room from the engine room, obviating attention to this detail on the part of the anesthetist. The Connell portable air compressor is shown in Figure 20.

**Second Unit: Filter and Humidor.**—It is customary to blow air through moist gauze for purpose of filtration and water vapor saturation. Any receptacle for the gauze, such as a bottle with 2-way opening, suffices. This is not an essential, but a desirable unit.

**Third Unit: Ether Vaporizer.**—Ether is vaporized either by blowing air over the surface or by dropping liquid ether in measured amounts into the air stream. The simplest apparatus is a 3-mouth Wolff bottle of a diameter not less than 6 in. The air enters one mouth, circulates over the ether, and leaves by a second mouth. The

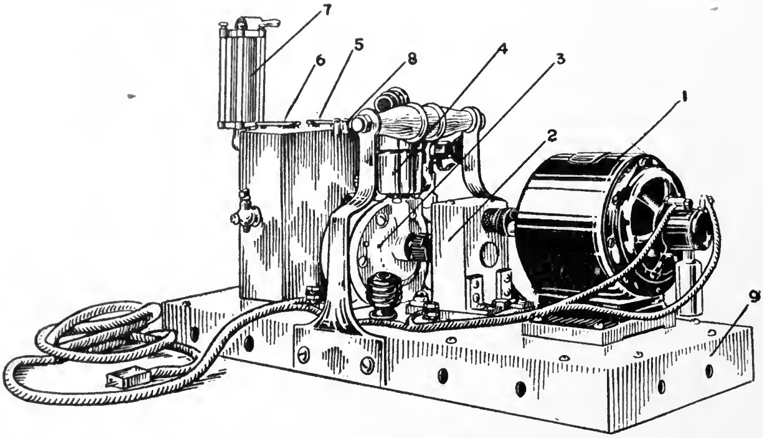


Fig. 20.—Generator for Compressed Air: Connell Portable Model. 1, Electric motor; 2, gears, oil-housed; 3, rotary compressor; 4, muffler; 5, oil tank and separator; 6, humidor and air filter; 7, instantaneous air flow gauge; 8, safety valve; 9, hollow bottom with control rheostat.

third is used for renewing the liquid ether. The tube and stop cocks are so arranged (Fig. 21) that any portion of the air may be shunted around the bottles, thereby weakening the total vapor mixture. Other types of vaporizers are discussed under vapor methods, page 89.

A convenient form of this vaporizing unit is the Robinson, where the essential tubing and stop cocks are combined in a lid which fits any common fruit jar. If sufficient ether is not taken up by the air in passage over the ether, then the vaporizer is immersed in a water bath at a heat between 75° and 80° F.

A more controllable ether feed is the dropping, from an ordinary oil cup, of liquid ether onto a warm surface. When this is done by mechanical correlation of the movement of ether to that of air, a scientifically accurate proportion may be obtained. The anesthetometer is the latest and most effective development in this method (see page 131.

**Fourth Unit: Safety Valve.**—To avoid overpressure, a safety blow-off valve must be provided near the patient; this should be set at not more than 20 mm., so that excessive pressure on the lungs is impossible. The valves are of 2 types, the submerged and the pop valve. The submerged valve consists of a glass tube buried 20 mm. into a bath of mercury held in a wide bottle, such as an Ehrlymer flask. The blow-off point may be varied by adjusting the depth of the tube. The disadvantage of this type is the weight and cost of the mercury and loss by spillage and spattering. The pop type of safety valve is more convenient. The pressures may be adjusted by increasing the weight carried on the piston by spring or by weight on a lever arm, as in the ordinary steam engine safety valves. This valve should be set at 15 to 20 mm., and should be in circuit near the patient, so that any cough is responded to by lifting the safety valve, and excessive pressure cannot accumulate.

**Fifth Unit: Intubating Catheter.**—The preferred catheter is the straight cylindrical silk-woven, shellac-covered, urethral catheter with single lateral eye, size 20 to 26 F. The patency of each catheter should be determined by blowing through it, as some catheters have an imperfect bore. Size 20 will carry sufficient air on usual pressure for the adolescent, 22 F. is chosen for the small adult, and 24 F. for the larger adult. Size 26 F. is used to block the air return alongside the tube in intrathoracic surgery.

When the catheter is to be introduced by other than the direct vision method, then a soft red rubber catheter is preferable.

**Accessories.** — Connecting tubing should be at least 5/16 in. bore. As an introducer, the Jackson direct-vision laryngoscope is preferable (see Fig. 17). The Janeway introducer is an excellent instrument. Instruments for the blind introduction of the tubing by sense of feel, such as the Cotton-Boothby hollow sound-shaped introducer, are to be decried.

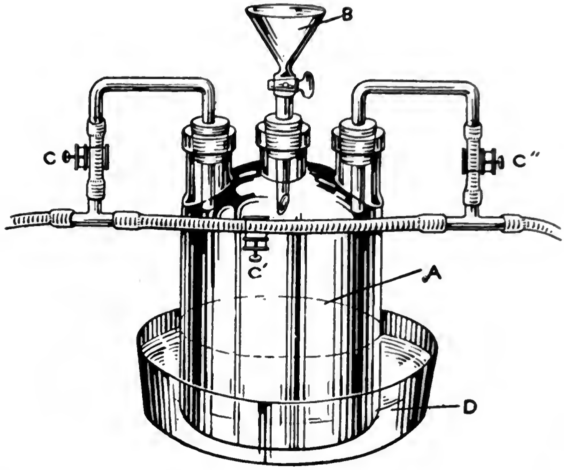


Fig. 21.—Surface Vaporizer. A, Wolff bottle, containing ether; B, filling funnel; C, C', C'', control clamps; D, basin of water.

## Intravenous Administration of Ether

**Introduction.**—The object in the intravenous administration of ether is to saturate the blood to proper anesthetic tension, obtaining the physiological effect on the neuron in pure form, without those side effects which are dependent on the stimulation of high percentage of ether in the respiratory tract. By this method the blood may be brought to solution of about 1/4 per cent. ether or an ether tension of 50 mm. without the vapor pressure in the respiratory tract ever reaching an irritating degree. Buckhardt first adapted the method to man.

The ether is dissolved 5 to 7.5 per cent. by volume in normal saline and is introduced by intravenous infusion.

**Special Physiology.**—On establishing an intravenous flow of about 50 c. c. per minute of 5 per cent. ether in normal saline, the patient becomes drowsy within 2 or 3 minutes, and there is slight excitation of respiration and of pulse rate. The pulse grows full and slightly increased in tension. The skin becomes flushed and moist.

Usually with very little or no mental excitement, the patient drops off into a state of quiet narcosis. Shortly the breathing becomes roughened or even stertorous and the muscular system perfectly relaxed. The stage of full surgical anesthesia has now been attained. This requires about 5 minutes, administering about 250 c. c. of 5 to 7 per cent. solution to the average individual.

After arriving at the stage of full anesthesia this is maintained by such dosage as will balance that ether which is being excreted by the respiratory tract, plus that which by diffusion is bringing about an equilibrium over the entire body.

The stage of recovery is attended by the usual phenomena of a smoothly induced and maintained ether anesthesia. The vomiting is much reduced over the rougher methods of pulmonary administration. Occasionally with robust alcoholics the excitement is as troublesome as by other methods.

With the onset of stertor the upper airway of the respiratory tract must be adjusted and held open and the depth of anesthesia gauged by a competent anesthetist.

The advantages of this method are those of a rapidly and smoothly induced pure ether anesthesia, without pulmonary stimulation. Also the region of the face is rid of inhalation apparatus. The disadvantages are those incident to ordinary infusion of saline in excessive bulk when no saline is physiologically needed, plus the destructive solvent action of ether in high percentage on the blood at the point where it first commingles and before it has been diluted by the general blood stream. The solvent effect of ether on the red blood cells in such solution in the plasma as is needed for anesthesia (i. e., 1/4 per cent.) is negligible, but the lipoid solvent and laking effect of ether in a far larger percentage (i. e., 5 to 10 per cent.) necessary in the infusion is a menace. Hematuria, excretion of lipoids, and postoperative anemia are seen. This effect, together with the accidents of air embolism, thrombosis, pulmonary embolism, and edema of the lungs, which are dependent on the infusion procedure, will no doubt relegate this method to the realm of physiological experimentation and not that of a useful surgical method. Approximately equal smoothness of anesthesia is attainable by proper pulmonary and rectal dosage. The danger of overdosage does not exceed that of other methods, if reasonable care and deliberation be exercised during the infusion and the physiological effect be closely watched by a competent anesthetist.

**Technic of Administration.**—Apparatus such as is commonly used for saline infusion suffices. The solution is prepared by dissolving 75 c. c. pure, clean ether in 925 c. c. of cool normal saline, or Ringer's, solution. If the solution must be prepared in advance it should be kept cold and tightly corked to prevent loss of ether. For use the solution may be poured into a graduated glass irrigation jar covered by a flat glass dish to inhibit the diffusion of ether into the air. The jar is elevated about 3 feet. The delivery tubing should be guarded by a small screw pinch clamp and should have in continuity below the irrigator a glass drip tube, so that each drop of solution may be seen as it feeds as for rectal drip. Near the patient the tube may be coiled through a water bath or placed beneath a hot-water bag to take the chill off the solution. Very hot water is objectionable, as it distills out the ether.

With the patient under light alkaloidal narcosis (see page 102), any convenient vein, preferably a large vein in the forearm, is exposed by dissection under infiltration anesthesia. A cannula is inserted and tied in place as for saline infusion. With all air ejected except that residual at the sight feed, the tube is connected to the cannula and the infusion allowed to run into the vein, about 50 c. c. per minute. When light anesthesia is induced the amount delivered is cut to about 20 and then to 10 c. c. per minute, i. e., 2 or 3 drops per second. Gradually a level is found on which an even grade of anesthesia continues by a slow, even drop. The depth of anesthesia may be controlled by the rate of the drop. If anesthesia deepens unduly administration is checked for a few minutes and the cannula and vein kept free meanwhile by a very low stream of normal saline from a second jar. Anesthesia may also be lightened by increasing the tidal volume of breathing by means of a breathing tube, or it may be deepened by muffling the face with toweling. Administration is checked about 10 minutes before the termination of the operation, and the wound sutured as the surgical operation terminates.

### Rectal Administration of Ether

**Introduction.**—Ether is administered by the colon for the purpose of eliminating the undesirable effects of the drug on the respiratory tract, such as cough, disturbance of respiration, and reflex excitement. Pure liquid ether cannot be used for injection into the intestine, since at body temperature it boils and may distend and rupture this viscus. Nor can ether vapor mixed with air be delivered into the intestine in sufficient strength to saturate the blood to anesthetic tension, since the absorptive surface is here so much smaller than that of the lung. The nearest approach to success was that of Sutton, who, by substituting for the inert nitrogen of the air, oxygen passed through warm liquid ether, increased the absorption. The various previous attempts have recently given way to what gives promise to be a successful method—the oil-ether method of Gwathmey.

**Oil-Ether Anesthesia.**—When ether is mixed with olive oil in a percentage of 75 the boiling point is above the body temperature and the danger of rupturing the intestine is eliminated. The vapor tension remains high (almost boiling) and the ether rapidly diffuses throughout the content and through the walls of the intestine into the blood stream. Gradually in the course of 20 to 30 minutes the blood and nervous system of the body may be brought to proper anesthetic tension. A certain amount of ether volatilizes into the gases of the intestine, increasing their bulk and moderately distending the intestine. Gradually the tension of the mixture first introduced falls, as the oil loses its ether, until the rate of absorption into the blood from the gut no longer balances excretion from the lungs, whereupon the patient emerges from anesthesia.

The depth of anesthesia must be gauged and the upper respiratory tract kept open by a competent anesthetist.

TECHNIC.—The colon is first thoroughly cleansed by catharsis and enemata. One hour before operation 1/6 to 1/4 grain of morphin with atropin, grain 1/100, is given hypodermically. Fifteen minutes later 10 grains of chloretone in ½ ounce each of ether and oil is administered by rectum. Fifteen minutes later through a small rectal tube, with the patient in the Sims' position, the following dose is administered: a solution of ether 75 per cent. by volume in olive oil, the amount being 1 ounce of the mixture to each 20 pounds of body weight, in total not to exceed 8 ounces.

Almost immediately ether may be detected on the breath; in about 10 minutes the patient becomes drowsy and somewhat incoherent. In about 20 minutes unconsciousness supervenes, soon passing into the stage of light anesthesia. If the patient becomes excited and breathes deeply elimination of ether is so rapid that anesthesia may not appear. By this slow induction the specific relaxant action of ether on the voluntary muscle and other desirable anesthetic effects are satisfactorily obtained.

To lighten the anesthesia the tidal volume of respiration is increased and elimination of ether is hastened by inserting a Connell breathing-tube (see Fig. 28). To deepen anesthesia diffusion of ether is checked by muffling the face in loose layers of toweling. Should anesthesia grow too deep the oil mixture may be in part withdrawn by a rectal tube, and the diffusion of the remainder checked by cold saline irrigation.

Anesthesia usually lasts about 60 minutes, after which, if required, 2 ounces of fresh mixture should be given, or this method supplemented by inhalation. Ten minutes before the termination of the operation the residual mixture should be withdrawn by insertion of rectal tube, and replaced by 4 ounces of olive oil.

The objections to the method are the occasional discomfort and tenesmus before anesthesia appears; evacuation of the mixture; the impossibility of anesthetizing deeply breathing patients; occasionally an uncontrollable depth of anesthesia; distention of the intestine; gas pains; and, rarely, paresis of the anal sphincter following operation.

## Miscellaneous Methods of Ether Administration

Ether has been injected into the *muscle* of the buttocks and thigh and *subcutaneously.* Also it is rapidly absorbed from *serous surface* such as the peritoneum, as proved by deepened anesthesia where ether is used to cleanse a tuberculous peritoneum. None of these methods promise to be widely used.

## Agents Used as Adjuncts to Ether in Anesthesia

**The Alkaloidal Narcotics.**—Morphin and scopolamin used as preliminaries to ether permit the initiation of the ascending stages of ether anesthesia with markedly diminished excitement. The patient may be carried through an operation under lighter anesthesia than is possible without supplemental narcosis, and may be more readily carried repeatedly from the light subconscious into deeper zones of ether anesthesia without cough or respiratory difficulty. However, for the abolition of muscular rigidity and for the protection of nerve centers from the harmful stimulus of severe operative trauma the same tension of ether is required as without the adjunct of such narcotics.

These narcotics smooth the course of irregular, inexpert administration of ether, but by combination with nerve tissue more stable than that of ether and by prolonged depression of the respiratory center, they desensitize the respiratory center in the higher zones of ether anesthesia. These drugs are particularly badly borne in the partial asphyxia which usually accompanies the inexpert administration of ether. The more efficiently ether is administered the less advantage can be derived from these narcotics. They are rarely employed by the skilled anesthetist.

Atropin, while not a narcotic, is of distinct advantage in inhibiting the mucous secretion when increased by the stimulus of concentrated ether vapor. However, with the expert and continuous administration of ether, stimulating concentration need be maintained only for a short period in the preliminary stage of ether anesthesia. The greatest utility of atropin, therefore, is to nullify the vicious effect of unevenly administered ether.

DOSAGE.—The usual dosage of preliminary narcotic is 1/4 grain of morphin with 1/100 grain of atropin, administered hypodermically 1 hour before anesthesia.

THE USE OF NARCOTIC ALKALOIDS FOLLOWING ANESTHESIA.—There can be no question of the value and advisability of alkaloidal narcosis to supplement and continue ether analgesia, i. e., that partial analgesia which lasts into the third hour of recovery from the ether zone of confusion. For this purpose morphin is the customary analgesic, administered hypodermically in 1/6 to 1/4 grain dose, as ether analgesia wears off and the patient becomes cognizant of pain.

**Nitrous Oxid.**—Nitrous oxid as a preliminary anesthetic to ether is the most rapid, pleasant, and effective means of inducing ether narcosis. It is the safest method barring one risk, namely, that of asphyxia. Asphyxia frequently arises in the inexpert management of the transition from one anesthetic to the other.

TECHNIC.—The *Bennett inhaler* is a popular type of apparatus for this sequence. It is a modification of the Clover type of inhaler. In this apparatus the gas bag is filled with nitrous oxid, the gauze in the ether chamber is charged with about 1 ounce of liquid ether. With the ether and the nitrous oxid closed off, the mask is adjusted to the face. After a few breaths of air with the expiratory valve open the air supply is cut off and nitrous oxid substituted. After 3 breaths of this gas the expiratory valve is closed and to and fro breathing into the bag is instituted. At the first quickening of respiratory rhythm the ether chamber is very gradually opened, so that the gas becomes charged with ether.

This is the stage which marks the skilled anesthetist from the bungler. After a few of the rapid breaths which indicate the onset of nitrous oxid anesthesia a small whiff of air must be allowed, or the patient will become cyanosed and respiratory rhythm will be upset. This small proportion of air is added by momentarily opening the air valve during inspiration. Leaking apparatus or defective face adjustment of the mask may allow too great dilution of the gas and upset the smoothness of the transition. The stage of asphyxia should be held in abeyance and nitrous oxid breathing continued until the percentage of ether vapor mounts to such height that the arterial blood goes to the nervous system constantly charged to proper anesthetic tension.

Thus 90 seconds suffices to put a patient to the peak of the induction curve without consciousness of the odor or irritation of ether vapor and without excitement or halt in breathing.

The ether chamber must be recharged after a minute, else the vapor pressure will fall. When the ether vapor is on to the full capacity of the apparatus the gas bag is removed and the air rebreathing bag is substituted. The dosage of ether must be maintained until the onset of surgical relaxation, otherwise the arterial blood and nervous system drop into the zone of confusion. If the percentage of ether be diminished excitement and irregular breathing and poorly achieved induction of anesthesia result.

A method by which nitrous oxid anesthesia is merged into ether narcosis with less risk of asphyxial symptoms even in inexperienced hands is that of *Gwathmey*. The essential feature is that ether is added to the nitrous oxid by the vapor method. For this method the mask is adjusted and nitrous oxid anesthesia instituted. By a hand bulb or foot pump air is forced through an ether bottle and, becoming laden with strong vapor, is delivered by tubing into the gas bag. Ether is thus added more gradually and is under better control than with the Bennett apparatus, and at the same time air is introduced in any desired quantity, thus avoiding asphyxia. Not less than 3 liters of fresh air per minute should be supplied, and after the first few minutes 5 to 8 liters.

**Nitrous Oxid-Oxygen.**—*Best Method.*—Nitrous oxid-oxygen anesthesia is fully established, then gradually full ether anesthesia is substituted. Thus the advantages of both anesthetics are secured and the disadvantages of each are eliminated. If the substitution be gradual, over 15 minutes, the vapor pressure of ether need not exceed 90 mm.; a toxic zone of ether is at no time entered; the oxygen percentage may be kept high, i. e., 12 to 16 per cent., and there is no stimulation of mucous secretion by high levels of ether vapor. When anesthesia reaches that stage where 20 per cent. of oxygen causes no return of sensibility then air may be substituted for the nitrous oxid-oxygen gases, and ether anesthesia continued by any method, preferably vapor delivery by pharyngeal insufflation.

**Chloroform.**—Since anesthesia can be secured more rapidly, quietly, and with less discomfort by chloroform than by ether, chloroform is occasionally chosen to institute primary anesthesia, and this is gradually merged into full ether anesthesia.

Such dangers as attend this method are those incident to the early stage of pure chloroform anesthesia, but these may be in some measure obviated by an early substitution of the stimulative action of ether for the depressing effects of chloroform on the heart muscle.

This method is simpler but is much less agreeable, less rapidly effective, and not so safe as the nitrous oxid-ether sequence. (However, the statistics of Gwathmey show a lower mortality than for nitrous oxid-ether.)

TECHNIC.—The administration of chloroform is begun by the drop method on an open mask. After the first few drops ether is added; gradually the proportion of ether is increased and that of chloroform diminished, until by the end of 6 to 8 minutes full anesthesia has been achieved with expenditure in total of not more than 2 drams of chloroform and of 1 to 2 ounces of ether.

A more effective method is by vapor delivery into a closed inhaler. This, however, requires great care in controlling the chloroform vapor from overconcentration, i. e., in excess of 3 per cent.

**Ethyl Chlorid.**—To carry the patient rapidly and quietly over the period of cortical disassociation this very effective lipoid solvent may be employed. Before the dangers of ethyl chlorid were fully appreciated this sequence was carried on in a closed inhaler by rebreathing. The only relatively safe method in the average hands is the open method.

TECHNIC.—An open inhaler of the Esmarch type is seated on the face and well enveloped at the periphery in toweling. On the gauze 1 or 2 c. c. of ethyl chlorid is sprayed over the first five inspirations. A few drops of ether are now added. Gradually the ether is increased with an occasional momentary spray of ethyl chlorid. After 2 minutes the ethyl chlorid is discontinued and ether anesthesia progresses into the higher zones as by the drop method. A total of 4 c. c. of ethyl chlorid usually suffices.

## CHLOROFORM

**Introduction.**—Chloroform in physical properties is a most effective agent for inducing complete, controllable general anesthesia. It volatilizes well, diffuses rapidly from pulmonary air to blood, and from blood to nerve tissue, and is so active a solvent in the neuron that a low vapor content in the pulmonary air establishes and maintains a proper state of anesthesia. Were it not for certain limitations in chemical stability and toxic action, chloroform would be the anesthetic of universal choice. Thus, in chemical structure, chloroform is unstable, being decomposed by light, heat, and age into highly toxic products; in physiological action it is an early and cumulative paralyzant of heart muscle and a primary depressant of blood pressure; and in remote toxic effect on the parenchyma of important organs, such as the liver and kidney, it results, after prolonged or repeated dosage, in late destructive degeneration of the cells of these organs. Therefore, despite the ideal physical qualities in vaporization, diffusion, and solvent action, because of inherent vicious properties chloroform has been largely supplanted for full general anesthesia by ether, and for transitory and for shallow general anesthesia by nitrous oxid.

According to the best substantiated theory, chloroform acts by a solvent action on the lipoid content of the neurons, similar to the action of ether. In this solvent action it is much more powerful than ether, having a partition coefficient between oil and water of about 33, as against ether, 4.5. Chloroform is, therefore, 7 1/3 times more powerful than ether. For full anesthesia in man it must be present in the plasma of the arterial blood to the extent of 1/40 to 1/60 per cent. The lipoids of the red cells hold a much higher percentage at the same vapor tension.

The amount of chloroform that must be present in the tidal air, to establish and maintain this percentage in the blood, rises during the induction stage from 2 to 3 per cent. by volume in the air, or a vapor pressure of about 20 mm. The amount necessary after anesthesia is established gradually falls, as the anesthetic tension of the body is established, to about 1½ per cent., or 11 mm., gradually scaling down through prolonged anesthesia to slightly less than 1 per cent., or about 7 mm. of vapor pressure.

## Physiological Action of Chloroform

**Chloroform as an Irritant Compared with Ether.**—Chloroform is locally a marked irritant to epithelium. If liquid chloroform or the concentrated vapor be held in contact with normal skin, blistering and continued inflammation result. In this lasting irritant action chloroform differs markedly from ether.

In the maximum vapor concentrations (i. e., 3 per cent. by volume) needed to institute anesthesia chloroform does not stimulate the secretion of mucus so much as do those percentages of ether which are necessary to induce anesthesia (i. e., 15 to 24 per cent. by volume). Chloroform in amounts required for anesthesia probably causes no lasting damage to the epithelium of the respiratory tract. As with ether, those pulmonary sequelæ occasionally observed are resultant not so much from direct irritation as from various aspiration accidents and from the exposure and depression of general anesthesia and of operative trauma.

When the parenchyma of other vital organs, prominently the liver and kidneys, is considered, chloroform in anesthetic dosage is found after long-continued or repeated administration to be a drastic cell poison inducing excessive degeneration. On the other hand, ether at its worst causes only a transitory parenchymatous degeneration.

**The Effects of Chloroform on Body Function.**—RESPIRATION.—Chloroform, like other volatile irritants, in the respiratory tract causes depth and frequency of respiration continuing into the stage of full surgical anesthesia. The respiratory center then becomes gradually depressed and the respiratory movement grows more shallow. This stimulation and subsequent depression are not so marked as with ether.

CIRCULATION.—On first inhalation chloroform induces an increase in the force and frequency of the heart beat and a slight rise of blood pressure, largely because of the volatile irritant action of the drug. Soon the characteristic effect of chloroform is manifested, namely, that of a primary paralyzant of heart muscle. The pulse becomes full and soft, the blood pressure falls about 20 mm., the heart remains slightly accelerated or drops back to normal rate, and the beat of the heart is less forcible. The heart in light chloroform anesthesia is more readily inhibited by vagus stimulation than the normal.

In toxic gradual overdosage the pulse becomes weak and small. The rate may be increased or fall below normal. The blood collects in the splanchnic area, the heart becomes slow and feeble, the jactitation marking tissue asphyxia may appear. Then the pulse becomes imperceptible, respirations become shallow and cease. Finally the automaticity of the heart muscle is at an end. Death is primarily one of circulatory failure.

In sudden overdosage caused by breathing concentrated vapor the heart may be arrested within a few breaths, the color blanches, the patient gasps and dies (see Accidents: Heart Failure).

SENSORIUM.—Nerve activity is suspended in the various levels in the same order as in ether anesthesia. Consciousness is abolished with less excitement and slightly more rapidly than with ether. In chloroform dosage the same zones of anesthesia exist as with ether, but the low zones, i. e., the subconscious zones, are more dangerous on account of sudden cardiac inhibition by vagus stimulation, and the high zones, the deep and profound, are more dangerous than those equally anesthetic in ether dosage on account of low blood pressure, circulatory insufficiency, and cardiac failure. The medium zone yields a quiet relaxed anesthetic state with protection from harmful traumatic stimuli of operative procedure, but without the sustaining stimulation of ether and nitrous oxid.

**Excretion of Chloroform.**—Chloroform is excreted largely by diffusion into the air of the pulmonary alveoli. A small amount is broken up in the body.

## Clinical Course of Chloroform Anesthesia

**First Stage or Stage of Conscious Excitement: Period of Cortical Disassociation.**—The mild sweetish taste and agreeable odor of dilute chloroform vapor cause no unpleasant sensation as do the taste and odor of ether. The breathing grows more full, the skin is flushed and moist, and articulation becomes slightly incoherent. Usually with very little excitement the patient becomes unconscious within 3 to 5 minutes from the first inhalation. Athletic subjects and those accustomed to the various narcotics may, however, show marked excitement.

**Second Stage or Stage of Involuntary Excitement: Period of Subconscious Disassociation.**—The skin may become less or more flushed, it remains moist. There is slight acceleration of pulse and of breathing. The pupil is apt to be dilated and reacts actively to light. Spasm of the muscles of the jaw or glottis and fixation of the chest and abdomen may be noted in resistant subjects. This irregularity of breathing must be met by free allowance of air, as the patient under chloroform bears asphyxia badly and about half the fatalities occur at this stage. It is imperative for safe chloroform induction that the anesthetist should know the theory and practice of relieving obstruction in the upper airway.

A period of false anesthesia is occasionally noted, i. e., the patient becomes quiet, the muscles relax, the color becomes pale, and the pulse small. Vomiting usually follows, after which the color returns and induction of anesthesia may proceed.

Soon the breathing grows roughened or slightly stertorous, the muscles relax, and the patient passes into the third stage of anesthesia.

**Third Stage or Stage of Surgical Anesthesia: Period of Spinal and Basal Disassociation.**—This differs in no wise from the stage of full surgical anesthesia with ether, except that the skin is less flushed and less moist, the breathing is more quiet, and respiratory obstruction in the upper airway less in evidence. The pupil uniformly remains moderately contracted, the pulse is slower, and blood pressure 20 to 40 mm. lower than with ether.

**Fourth Stage or Stage of Overdosage: Period of Medullary Disassociation.**—The pupil dilates and becomes insensitive to light, the tension of the eyeball diminishes, the color of the skin and mucous membranes grows pallid, with slight cyanosis, blood pressure drops and the pulse becomes imperceptible. Finally the circulation becomes insufficient to maintain life, breathing ceases and in a few minutes the automatic action of the heart is at an end. This stage may rapidly follow slight overdosage, namely, a half minute of concentrated vapor.

**Fifth Stage or Stage of Recovery: Period of Inverse Reassociation.**—The various levels are passed through in the same order, though more rapidly than after ether administration. After full chloroform anesthesia the light zone is entered in about 3 minutes, the subconscious zone in about 6 minutes, the light subconscious zone in about 15 minutes, and the zone of confusion in 20 to 30 minutes. Somnolence and analgesia are less marked than with ether.

## Technic of Administration of Chloroform

Chloroform should be administered only by the open drop and by the vapor methods. Closed rebreathing methods in chloroform are dangerous and have been largely abandoned, since toxic concentration by the closed methods quickly occurs, and the asphyxia from rebreathing is ill borne by the circulatory mechanism.

**Open Drop Method.**—The simplest inhaler is in the form of a wire mask of the Esmarch type covered by several layers of gauze.

The eyes are protected by a pad of gauze, the face and lips are greased with petrolatum, the mask is adjusted loosely. Administration is begun by the drop, at first a drop every few seconds, increasing as soon as the patient becomes used to the pleasant sweetish odor, first to 1 and finally to 2 or 3 drops per second. The rate depends on the volume of tidal air of the individual respirations, and on the loss by diffusion, which is determined by whether the mask is loosely or tightly seated, and whether it is free or enveloped in a layer of gauze or toweling.

The delivery must be even in rate and by the drop. Chloroform should never be douched onto the mask. *It is imperative that the dosage be not increased in periods of excitement.* With ether the anesthetic may be safely crowded at such periods, but with chloroform the margin of safety is small. A toxic percentage suddenly overcoming the circulatory mechanism may result in its abrupt cessation. With the onset of slight inspiratory roughening the dosage is gradually diminished, until a level is reached on which the state of anesthesia remains unchanged. With the average respiratory capacity and by the Esmarch mask this level is usually about 1 drop of chloroform every 2 to 4 seconds. With children or others of small tidal capacity the dosage is proportionate. The delivery should not be entirely suspended until recovery is desired, as the patient finally reaches a tension of anesthetic equilibrium, as with ether, on which even anesthesia proceeds for many hours.

**Vapor Methods.**—In this method the chloroform is vaporized at a distance from the patient by a current of air and is conveyed to closed or open face mask. After anesthesia has been established, the vapor may be insufflated directly into the pharynx or trachea of the patient. This delivery has the advantage over the drop method of being more controllable, particularly if the delivery be continuous and the chloroform vapor be diluted with a bulk of air sufficient for the tidal volume.

The methods of vapor delivery are two, the *interrupted* and the *continuous.*

INTERRUPTED METHOD OF VAPOR DELIVERY.—In the interrupted method of vapor delivery a small quantity of air is blown over or through liquid chloroform. The air is impelled by a hand bulb or small foot pump. The impregnated air is then delivered to and accumulates in an open mask over the patient's face. The small volume of concentrated vapor is here diluted by the tidal volumes of respiration. The anesthetist governs the quantity and concentration delivered by the reaction of the patient to the dosage. After anesthesia is established, the delivery may be made, for head cases, into the nose, or into the pharynx by nasal or by mouth tube and the vapor here diluted and mixed with the tidal air. Except for the convenience of ridding the operative field of the cumbersome face mask in head cases, this delivery has no advantage over the drop method.

The usual vaporizer is patterned after that of Junker, i. e., for the air supply a double atomizer bulb; for the vaporizer a graduated bottle with two-way stopper through which the air passes either over or through chloroform, and, third, the delivery tubing. The vaporizing capacity of each apparatus must be learned by experience.

For induction in the first 5 minutes usually 1½ drams of chloroform is vaporized, in the second 5 minutes ¾ dram, through the second 10 minutes about 1 dram and through the next ¼ hour about 1 dram. This amount is modified to fit various exigencies of changing tidal volumes.

CONTINUOUS METHOD OF VAPOR DELIVERY.—The continuous method employs a constant stream of air or other gas, such as oxygen, flowing over chloroform. Any portion of the air stream may be shunted around the chloroform, securing thereby any desired modification in the percentage of vapor borne by the air.

The method becomes more efficient the larger the volume of air delivered and the greater the dilution of the chloroform vapor. At the point where all air needed for tidal volume is charged with the minimal amount of chloroform needed to induce and maintain full anesthesia this delivery becomes the most even and efficient method of chloroform delivery.

APPARATUS.—As a source of air supply, a foot bellows, or preferably a mechanically driven small air compressor, is the most efficient portable apparatus. As a vaporizer, the Gwathmey bottle is useful since with this any portion of the air may be blown across or be shunted around the chloroform. Compressed oxygen may be used as the vehicle. The smoothness of anesthesia seems to depend upon an even flow of oxygen to deliver an even percentage of chloroform, rather than upon any effect of the gas itself.

TECHNIC.—For induction, any type of closed face mask may be connected to the delivery apparatus. The breathing bag is filled with dilute vapor, i. e., less than 1 per cent. A flow of fresh vapor and air at the rate of 5 liters per minute is established and the percentage soon raised to between 2 and 3 per cent. The volume of delivery is increased to at least 8 liters or a volume sufficient to fill a 2-gallon bag within 60 seconds. This quantity of fresh air should flow continuously, otherwise an element of asphyxia enters into the chloroform anesthesia. Exact strengths of chloroform vapor may be automatically prepared and measured by the anesthetometer. With the onset of anesthesia the vapor strength is lessened until a line of equilibrium is reached. With chloroform this is not so well established as with ether, but is somewhere between 5 and 11 mm. of vapor pressure.

After induction, if desired, the delivery may be changed, as with ether, to the pharyngeal or intratracheal type, delivering a volume of 18 liters per minute of the same strength of vapor as by face mask methods.

## NITROUS OXID

The anesthetic value of nitrous oxid gas was discovered by Wells in 1843. Since that time it has become the anesthetic of choice for short operations, when safe, light, transitory anesthesia is desired. In the last 2 decades the use of nitrous oxid has been extended to anesthesia for prolonged operations, by adding to the respired gas a proper percentage of pure oxygen.

Nitrous oxid ($N_2O$) is a stable, non-irritating, non-toxic gas, of sweetish taste and odor. It is formed in the decomposition of ammonium nitrate by heat. Small plants for the manufacture of the gas are on the market. The gas so obtained is somewhat cheaper and less liable to contain toxic by-products than the gas of commerce. The commercial product is obtainable as a liquid, stored in portable steel cylinders under vapor tension of about 760 pounds.

### Physiological Action of Nitrous Oxid

**Introduction.**—Nitrous oxid is supposed to act as an anesthetic chiefly by decreasing the oxygenation of the nerve tissue. It accomplishes this both by displacing oxygen from the respiratory tract and possibly by loose combination with the hemoglobin of the blood. Additionally there is a direct anesthetic interference of unknown nature with the functional activity of the neuron.

The objective in the administration of nitrous oxid is that the highest tension of the gas possible be maintained in the body. Of necessity, at the same time so much oxygen must be allowed to reach the blood and neuron as will keep the flame of subconscious existence alight, and such a fresh tidal volume must be supplied as will adequately wash from the respiratory tract gaseous excrement such as carbon dioxid.

**Physiological and Toxicological Action of Nitrous Oxid Undiluted.**—On inhaling the pure gas, one experiences within 2 full breaths a general sense of expansion and a desire to inflate the lungs. Then come a peculiar, pleasurable "thrill" and a ringing in the ears. Within 4 to 6 breaths, consciousness is lost. A transitory period of subconscious excitement is now passed through, which gives way, within from 10 to 15 inspirations, or usually within 1 minute, to rapid, full breathing, followed in the second minute by deepening cyanosis, partial relaxation, and complete general anesthesia.

Full anesthesia is usually established by the thirtieth breath or within 2 minutes, although no rule as to time can be laid down, since many variable factors enter, such as the depth and frequency of respiration and the reserve oxygen capacity of the blood. The most reliable indication of anesthesia is the quickened, irregular rhythm and deepening of respiration together with the onset of stertorous inbreathing. Deep snoring occasionally occurs, or the breathing may become slow and shallow with labored expiration. In this stage the pulse is quickened about 20 to 40 beats per minute, and the blood pressure increased 30 to 60 mm.

At the first sign of anesthesia, a short surgical operation may be proceeded with. For dental operations the subject is allowed to proceed about 4 breaths into the stertorous and asphyxial stage.

If atmospheric air or oxygen be now breathed, the color rapidly becomes normal. The state of anesthesia persists for about 40 seconds after discontinuing the anesthetic. This is followed by a period of confusion and excitement (the "laughing gas" stage), which may last 20 seconds to 2 minutes. Nausea, vertigo and headache may now follow, usually being of transitory character.

OVERDOSAGE OF NITROUS OXID.—If the undiluted anesthetic be continued, the color becomes livid, the muscles stiffen, jactitation of asphyxia appears, respiration grows more labored and stertorous. The pupil dilates widely, the rapid pulse becomes slow and the heart action irregular and labored, the blood rises 60 to 100 mm., then begins to fall, the color turns a dark bluish gray, the jaws and thoracic muscle become fixed in tonic spasm, the epiglottis is aspirated tightly over the glottis aperture, and the thoracic muscle becomes fixed in tonic spasm. The heart becomes dilated, but continues forceful work for a few minutes, during which time resuscitation may be accomplished if the asphyxia be relieved, otherwise death rapidly ensues. Even in the first stage of overdosage, cardiovascular strain may result in permanent lesions to heart and arteries.

If air or oxygen be allowed before the heart action ceases, resuscitation takes place spontaneously, since the respiratory mechanism usually makes the last gasp which relieves the asphyxia, and results in return of the respiratory rhythm. However, the epiglottis may be sucked tightly by violent inspiratory effort into the chink of the glottis. Death from asphyxia follows if the condition be not relieved. The relief is afforded mechanically by raising the epiglottis, preferably by grasping the linguo-epiglottic ligament between 2 fingers and carrying the entire base of the tongue forward. But this maneuver, as well as artificial respiration, is difficult on account of the tonic spasm of the jaw and thorax muscles. This respiratory spasm is less marked in asphyxia of gradual onset.

By proper admixture of air and anesthetic the asphyxial stage is held in abeyance. This requires 30 per cent. of air. However, by this large dilution, chiefly with inert nitrogen, the tension of nitrous oxid in the blood is so lowered that irregular and unsatisfactory anesthesia results. If, however, pure oxygen gas be the diluent in place of air, the tension of the nitrous oxid may be kept much higher and at the same time oxygenation is more perfectly controlled. For continuance of life only 6 or 7 per cent. of oxygen is required by normal man in the tidal gases, against 30 per cent. of air.

**Physiological Action of Nitrous Oxid-Oxygen Mixture.**—On inhaling nitrous oxid mixed with 6 to 8 per cent. by volume of oxygen, the normal man experiences less sense of general expansion than on inhaling pure nitrous oxid. All the symptoms of anesthesia come on less rapidly, and the anesthetic stage is reached without the symptoms of asphyxia which mark the inhalation of pure nitrous oxid. Memory is lost in about 12 inspirations. Analgesia is now present even before the subconsciousness zone is entered. Next a slight stage of subconscious excitement is passed through, which gives way in about 4 to 6 minutes to light surgical anesthesia. Superficial reflexes may be present for 15 minutes or persist through prolonged operation. The deep reflexes are never abolished, and muscular relaxation does not become complete. Suspension of function in the lower reflex motor and sensory centers is not to be achieved in normal man by nitrous oxid, unless supplemented by a basic narcotic, by a hydrocarbon anesthetic, or by an undesirable degree of asphyxia.

The breathing under nitrous oxid oxygen is full, regular, and of moderately increased rate, with slight inspiratory roughening. It becomes exaggerated under stimulation of the trauma of operative procedure, or by carbon dioxid accumulation resultant from repeatedly rebreathing expired gases. The breathing may also become of excited character in very light anesthesia.

The pulse is of moderately increased rate, of full quality and usually of 5 to 20 mm. increased pressure. The pressure is increased, not by the action of nitrous oxid itself, but by slight asphyxia and retention of carbon dioxid so commonly present. With full oxygenation and with a sufficiency of fresh gases, there is little or no rise in blood pressure. Under this anesthetic the pressure remains well sustained despite hemorrhage, trauma, and other depressants of blood pressure, so long as the anesthetic be continued. The blood vessels are engorged and bleed excessively in the operative field. The blood is dark. The skin is usually moist and slightly cyanotic to pink, depending on the degree of oxygenation. The suffusion of the skin and heat loss by the evaporation are not so great as with ether.

Anesthesia deepens through the first half hour. Usually the oxygen may be gradually increased up to 11 per cent. in the tidal volume (about 13 per cent. in a delivery of 10 liters per minute) without altering the physiological state of light surgical anesthesia.

On withdrawal of the anesthetic, after full anesthesia for an hour or more, complete consciousness is usually regained within 5 minutes, and with very little nausea, headache, or the other sequelæ of the hydrocarbon anesthetics. The more prolonged and intense the anesthesia, the longer the stage of recovery.

The stage of recovery occasionally lasts for an hour or more, and is sometimes accompanied by vomiting of a nature more acutely distressing than that of hydrocarbon anesthetics. The patient occasionally continues cyanotic or of greenish or reddish hue for several days. This has been ascribed to impurities in the gases, notably nitrogen dioxid.

Pulmonary complications, such as bronchopneumonia from aspiration, or lobar pneumonia from exposure and lowered vitality, are less common than after ether or chloroform anesthesia. Circulatory complications—hemiplegia, cardiac dilatation and cardiac decompensation—have been noted after skilled administration, although not with frequency as after the asphyxial anesthesia of undiluted nitrous oxid. These cardiovascular complications, together with the light degree of true anesthesia and the ever imminent asphyxia, constitute the physiological objections to this anesthetic.

**Zones of Nitrous Oxid Anesthesia.**—Zones of anesthesia may be differentiated, each with a definite symptom-complex according to the percentage of oxygen in a given mixture. The percentage of mixture inspired in each zone is in the average constant and basic for the animal kingdom. In man it requires about 5 minutes to establish an anesthetic equilibrium in any given zone. Individual requirement toward higher percentage of oxygen is common when there is present any abnormal condition of tidal volume or of quality or rate of blood flow. For example, diminution of tidal volume from obstruction or breath holding, diminished oxygen-carrying capacity of the blood by low hemoglobin, and diminished rate of blood flow, all require higher percentage of oxygen than the average for that zone of anesthesia. The carrying capacity of the blood for oxygen is much diminished by anemia and by septic conditions; second, the capacity seems to be lessened and the necessity for higher per cent. of oxygen is evident in rapidly growing children and in patients of rapidly increasing weight; third, the carrying capacity, being in direct ratio to the rate and volume of the blood flow, is lessened in asthenic states, such as old

| PERCENTAGE IN TIDAL GASES | | ZONE | DEPTH OF ANAESTHESIA | DEGREE OF ASPHYXIA | DEGREE OF RELAXATION | COLOR | UTILITY |
|---|---|---|---|---|---|---|---|
| NITROUS OXIDE | OXYGEN | | | | | | |
| 100%<br>97% | 0%<br>3% | LETHAL | COMPLETE | GREAT TO FATAL | TONIC & CLONIC SPASM | BLUE BLACK | EXTRACTION OF TEETH INCISION OF ABSCESS (USE CONDEMNED) |
| 95% | 5% | PROFOUND | COMPLETE | CONSIDERABLE (DANGEROUS) | ASPHYXIAL RIGIDITY | DEEP CYANOSIS | |
| 94% | 6% | DEEP | COMPLETE | PARTIAL (DANGEROUS) | PARTIAL | MODERATE CYANOSIS | |
| 92% | 8% | MEDIUM | COMPLETE | PARTIAL | PARTIAL | SLIGHT CYANOSIS | INDUCTION |
| 89% | 11% | LIGHT | PARTIAL | SLIGHT | SLIGHT | FAINT CYANOSIS | ABDOMINAL SURGERY |
| 86% | 14% | VERY LIGHT | PARTIAL | 0 | 0 | NORMAL "ROSE COLOR" | SURFACE SURGERY (OR ABDOMINAL SURGERY WITH SUPPLEMENTAL NARCOSIS) |
| 84% | 16% | SUB CONSCIOUS | PARTIAL COMPLETE ANALGESIA | 0 | 0 | NORMAL TO PINK | |
| 80% | 20% | LIGHT SUB CONSCIOUS ANALGESIA | ANALGESIA | | 0 | PINK | |
| 50% | 50% | CONSCIOUS ANALGESIA | EQUAL PARTS OF AIR ALLOWED | | | NORMAL | DENTISTRY |

Fig. 22.—Zones of Nitrous Oxid-oxygen Anesthesia in Normal Man without Supplemental Narcosis.

age, cardiac decompensation and conditions of disease. Any of these factors which decrease the oxygen intake by a lessened tidal volume, or decrease the oxygen-carrying capacity of the blood by lessened hemoglobin or rate of blood flow, must be compensated for by increase of oxygen in the mixture administered to that patient.

The zones charted in Figure 22 were determined in routine anesthesia at the Roosevelt Hospital, except the most dangerous zones which were determined by insufflation on the dog. For the analgesia zones I am indebted to Dr. C. K. Teter.

The percentage of the lethal zone is used for short operations such as extraction of teeth. The asphyxial mixtures of this zone should be abandoned for those which induce anesthesia more slowly and safely. Anesthesia induced in the lethal zone subjects the patient to severe cardiovascular strain, and carries him to within a minute or two of death from asphyxia. The profound and deep zones are frequently invaded by error during the routine administration and are rapidly retreated from, by raising the percentage of oxygen when oncoming asphyxia is observed. By intratracheal insufflation a dog may be kept alive in the profound zone for half an hour. Man may be carried in the deep zone if the tidal volume is large and no asphyxial obstruction or thoracic fixation presents, yet the margin of safety is small. The medium zone is useful only for the first few minutes of induction, as an undesirable degree of asphyxia is soon induced. Some anesthetists utilize the physiologically disadvantageous asphyxia of this zone for an additional degree of anesthesia on resistant subjects. It is much safer to utilize the lighter zones and supplement the narcosis by ether.

The light zone is the one desirable for abdominal surgery. The perfect relaxation of the hydrocarbon anesthetics is never present, but if relaxation is desired, it may be secured in part by supplemental narcosis or local anesthesia. The very light zone is the desirable one for surface surgery, such as amputation of the breast. Both this and the subconscious zone may serve for all degrees of operative work when supplemented by ether. In fact, these are the ideal zones, since in these zones the blood pressure is not raised, the color is normal, the breathing is not exaggerated and there is no asphyxia.

On the usual volume of delivery of 8 to 10 liters of gases per minute, the percentages in the gases delivered must be about 2 per cent. higher than those charted above on account of dilution with expired gases from which the oxygen has been in part absorbed. In patients who are anemic or toxic from disease or whose respiratory volume is small or who have diminished blood flow, a higher percentage of oxygen is required to maintain the same oxygenation of the tissues. The percentage of oxygen needed in the inspired gases is approximately in direct ratio to the degree of anemia or intoxication. For example, a patient with 50 per cent. hemoglobin or half the normal oxygen-carrying capacity requires for the zone of light anesthesia 20 per cent. of oxygen in the tidal volume of respiration, instead of 10 per cent. mixture, as does normal man.

The stimulus of operative trauma elevates the blood pressure 10 to 30 mm. in all zones, even in the zone of profound anesthetic asphyxia. Nitrous oxid has not the ether effect in blocking efferent sensations by direct action on the nerve ends. Therefore, it provides no zone which protects against harmful stimuli, as do the hydrocarbon fat-solvent anesthetics.

### Apparatus for Nitrous Oxid-Oxygen Anesthesia

**Inhaler.**—As it is essential to exclude dilution by air the face mask should fit snugly. To the mask should be connected in close proximity a light rubber reservoir bag of 1 or 2 gallon capacity for the gas. The inhalers supplied by dental houses for pure gas administration are ineffective for surgical anesthesia. For surgical work the Gatch, Boothby, Gwathmey, Coburn and Teter inhalers may be mentioned as excellent types. A proper mask should have the following features: A metallic or celluloid mask enclosing the area of the nose and mouth, the edge of the mask being properly shaped to the average contour and rendered gas-tight on slight pressure by an inflating rubber ring; a series of valves, so that the gases on exhalation may be wasted into the outer air, or be returned into the original reservoir bag for rebreathing. Other valves may provide for inhalation of atmospheric air as desired.

**Gas Supply.**—The most convenient supply of gases is that compressed in commercial cylinders.

**Apparatus for Control of Gases.**—CRUDE APPARATUS WHICH DOES NOT MEASURE.—In the simplest form of apparatus both cylinders are connected by a Y tube to the inhaler bag, and the flow of each is controlled by a valve at the cylinder head. An efficient apparatus may be improvised by strapping 2 tanks together so that they sit securely and leading the outflow by Y connection into a common tube which runs to an inhaler. As each gas is required, the cylinder cock is opened; the oxygen, being in gaseous form, flows smoothly, but the nitrous oxid, being liquefied, boils and sputters. The flow becomes more even and controllable when a reducing valve is attached to the tank. These reducing valves with proper pressure gauges are common articles of commerce supplied by the manufacturers of nitrous oxid and oxygen gas. A good form of stand for holding and controlling the raw cylinders is the Gatch apparatus.

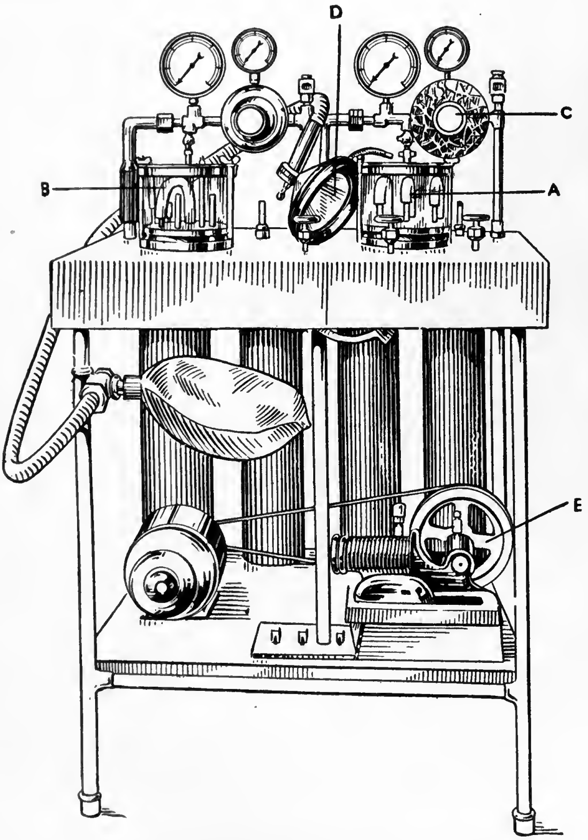

FIG. 23.—THE BOOTHBY APPARATUS FOR NITROUS OXID-OXYGEN, AIR AND ETHER MIXTURES. A, Water chamber, a sight feed for the different gases, bubbled through the water; B, ether vaporizer; C, reducing valves and pressure gauges; D, face mask; E, air-pressure generator.

An extensively commercialized type of delivery apparatus, mentioned to be condemned on account of the misinformation which it yields, is that which depends on the simultaneous opening of valves or ports of different sizes, as a means of measuring the relative volume of the two gases delivered. Dependence on this inaccurate type of measurement may lead to distressing misjudgment and asphyxial death, especially in inexperienced hands. Simple apparatus, with alternate manual opening and closing of valves and visual or auditory estimation of the proportion of gases delivered, is much to be preferred to these inaccurate instruments.

APPARATUS WHICH MEASURES.—The Teter apparatus measures the gas

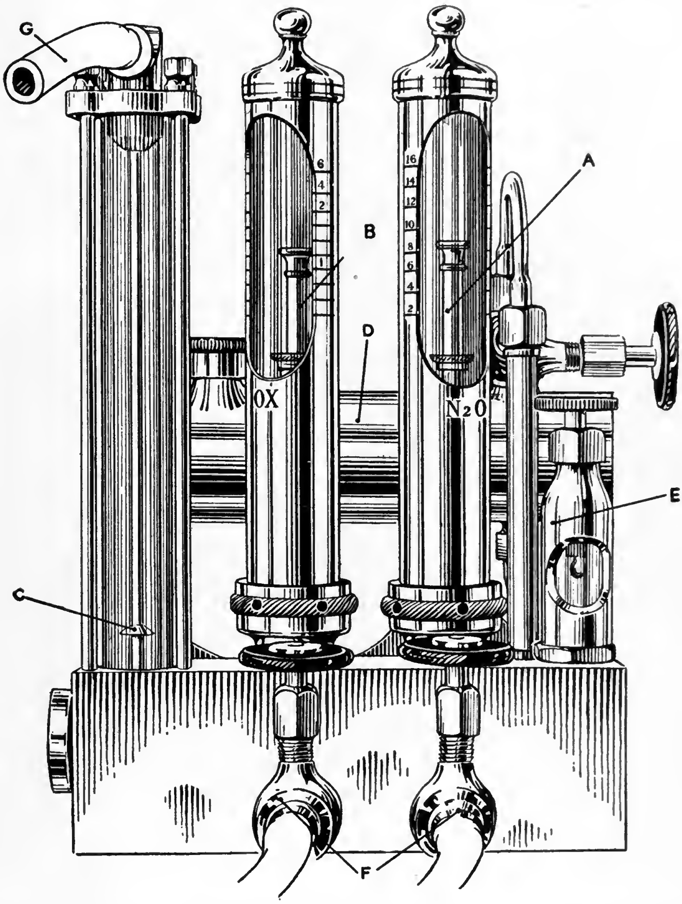


FIG. 24.—CONNELL NITROUS OXID, OXYGEN, ETHER FLOW CONTROL. A, Nitrous oxid instantaneous gas-flow gauge (piston type); B, oxygen gauge (piston type); C, parachute gauge, combined gases; D, ether tank; E, ether dropper; F, gas-control cocks; G, outlet.

flow by gradual opening of a graduated valve. It is approximately correct so long as the valves remain unworn and true, and if the pressure is accurately controlled.

The Boothby apparatus (see Fig. 23) depends for measurement on the bubbling of gases through water as a means of estimating the rate of flow. It is much more elastic and accurately adjustable than the foregoing, since the parts do not wear nor does the pressure need to be constant.

The McKesson apparatus depends on the suction effort of inspiration, open adjustable parts and the aspiration of oxygen and nitrous oxid from 2 bags of balanced pressure. The apparatus is accurate in measurement but has the fault of requiring for its operation aspiration effort on the part of the patient.

The Connell apparatus (see Fig. 24) is a measuring unit of the instantaneous gas flow gauge type. It is designed for use between the gas supply and the inhaler and permits of accurate constant measurement of each gas. It consists of two Connell instantaneous gas flow gauges of the piston type. Each gauge may be connected, one to nitrous oxid, the other to the oxygen supply under any pressure from 1 up to 150 pounds. By opening a pin valve the piston rises and accurately reads the volume of gas flowing each instant. The oxygen gauge reads in quarter liters of gas per minute up to 6 liters. The nitrous oxid gauge reads in 2 liter steps up to 16 liters per minute. These gauges are mounted on an aluminum base containing a small electric stove. Ether may be fed by the drop into the gases from a 2-ounce tank through a sight feed. The combined gases find exit through a third gauge, the Connell parachute gauge, reading from 6 to 24 liters per minute. The entire apparatus weighs about a pound.

## Technic of Administration

**Nitrous Oxid.**—For short operations such as incision of abscess, the inhaling bag is filled with 8 liters or 2 gallons of pure gas. The face mask is securely fitted and the valves so adjusted that the first 4 exhalations of the gas are discarded together with the nitrogen and oxygen that were present in the respiratory tract as tidal and residual air. The exhalation valve is then closed and the gas is rebreathed to and fro until sudden increase of the depth and frequency of respiration marks the onset of the stage of anesthesia. The mask may now be removed and the anesthesia will persist for about 40 seconds. If a longer operation be contemplated, a proportion of atmospheric air must be allowed by occasionally opening an air inlet, or by raising the mask for an instant during inspiration. Fresh nitrous oxid must be supplied as this is lost or becomes too diluted with air.

To and fro rebreathing of the gases, for anesthesia of short duration, is of advantage because in this way anesthesia is secured with less muscle twitching, thoracic fixation, and cardiac strain than when each tidal volume is of fresh nitrous oxid.

The usual anesthesia quickly achieved with pure nitrous oxid depends in large measure on the state of partial asphyxia induced. While for small dental procedures this short asphyxia is attended with little danger other than that incident to the cardiac strain, yet for the more prolonged anesthesia required in surgery, even for procedures of 1 minute's duration, the asphyxial anesthesia of undiluted nitrous oxid should be abandoned for the true, non-asphyxial anesthesia secured by nitrous oxid-oxygen mixture.

**Nitrous Oxid-Oxygen Mixture.—General Consideration.**—The preferred mixture for induction is 6 to 8 per cent. of oxygen in nitrous oxid administered in quantity of about 6 to 10 liters a minute. The first few exhalations are discarded. Thereafter the exhalation may be mixed with the fresh gases and to and fro breathing is permitted. The rebreathing bag may be emptied of old gases and filled with fresh every 1 or 2 minutes or preferably a slow even delivery and discharge are established. Within 2 minutes the percentage may be raised to 9 per cent. If no reliable measuring apparatus is available, these percentages are approximated by guess work, using the patient as an index. Any respiratory embarrassment or deepening cyanosis calls for higher percentages of oxygen. The stage of slight excitement lasts usually about 3 minutes. Light surgical anesthesia comes on in about 5 minutes and gradually deepens. The color, the respiration and the pulse must be carefully watched, and signs of asphyxia quickly noted and relieved by higher percentages of oxygen or air. The color should never show more than the slightest tinge of blueness and preferably no cyanosis whatsoever. The pulse should be of moderately increased frequency and of increased force and volume. A slow, asthenic pulse or a rapid one of weakened quality shows danger to the circulation and imminent asphyxia, as do shallow, jerky respiration, muscular twitching, or an ashy-gray cyanosis. Much exaggerated breathing may mean too superficial anesthesia, or, on the other hand, carbon dioxid retention. This latter is met by more freely washing out the lungs with a larger supply of fresh gases. The upper respiratory tract must be efficiently open. If there is any obstruction to the ebb and flow of tidal volume, the intrapulmonary gases become so rapidly depleted of oxygen that asphyxia shortly appears. Nasal obstruction demands that the mouth be kept open by gag or by breathing tube.

When relaxation is unsatisfactory it cannot be secured by deepening the asphyxia; to the contrary, relaxation is accomplished by increasing the oxygen percentage and the total gas flow, or by supplemental ether anesthesia.

Occasionally the percentage of oxygen may be increased as high as 12 per cent., or under conditions of shallow respiration and asthenic states even higher. When the gases are excessively rebreathed and the total supply is small, as high as 15 to 20 per cent. of oxygen is required in the fresh supply to yield in the tidal gases the proper anesthetic mixture of from 8 to 11 per cent. of oxygen. Percentages lower than these may be used in short procedures of 5 minutes' duration, since the blood carries for some minutes of anesthesia a reserve supply of loosely combined oxygen. However, when the reserve supply becomes depleted after 3 or 4 minutes, any depression of the oxygen below 6 per cent. is fraught with danger of sudden collapse of the respiratory center from asphyxia. Percentages of oxygen higher than 11 are useful only for very light anesthesia or when nitrous oxid is supplemented by other anesthetics or alkaloidal narcotics. The operatoı must work in harmony with the anesthetist, and not expect the complete and continuous anesthesia and relaxation of the other general anesthetics.

**Methods of Delivery in Detail.**—The two basic types of delivery are the *interrupted flow* and the *continuous flow* method of administration.

THE INTERRUPTED FLOW OR REBREATHING METHOD (GATCH METHOD).—This method requires the least apparatus and is the most effective of crude methods. It is economical of gases and in the hands of the inexpert anesthetist working with crude apparatus it is the method of choice.

The rebreathing bag is filled loosely with nitrous oxid and 1/12 part of oxygen is added. The first 4 breaths are exhaled, washing out the residual air. The exhaling bag is then closed, and the patient rebreathes the remainder of the gases. Fresh nitrous oxid is now added and is slightly diluted with oxygen (1/10 part). The patient is allowed to rebreathe these gases so long as the color shows only a tinge of blueness. After a minute a small amount of oxygen is added to replenish that which has been absorbed into the blood. The breathing soon shows marked stimulation in frequency and in tidal volume because of excitement and carbon dioxid accumulation. After 2 to 4 minutes the expiratory valves are opened and the rebreathing bag almost emptied, to be filled again with fresh gases. As little as 40 gallons of gas and 12 gallons of oxygen may be consumed in 1 hour, yet better anesthesia is achieved by 120 gallons of nitrous oxid and 15 to 20 gallons of oxygen per hour.

The anesthetist is constantly on guard against asphyxia. The patient may rapidly turn blue and begin to twitch. More to be dreaded than this acute asphyxia is the asphyxia of the asthenic type. In this type the pulse loses its force, the respiration grows shallow with labored inspiration followed by a short expiratory jerk, and the skin turns a dirty gray. When either of these types of asphyxia appears the percentage of oxygen is immediately increased or pure oxygen is substituted. For the asthenic type of asphyxia, showing as it does circulatory danger, the effort to induce anesthesia by nitrous oxid alone is abandoned and, with a liberal allowance of oxygen, ether narcosis is gradually superimposed, or substituted entirely for that of nitrous oxid.

THE CONTINUOUS FLOW METHOD (BOOTHBY METHOD).—This is a more rational method and yields a safer and more even grade of anesthesia. The same outfit of face mask, rebreathing bag and valves is utilized, but the delivery apparatus is of such nature that a continuous flow of adjustable volumes of the 2 gases may be established. To yield the best results the gases should flow uninterruptedly at the rate of at least 8 liters per minute (120 gallons per hour). Smaller volumes and intermittent flow result in carbon dioxid accumulation, rapid breathing, cyanosis and poorly maintained degree of anesthesia.

The gases may be set flowing by guesswork from tank pressure preferably reduced to at least 4 pounds, but some method of approximately accurate estimation is far more satisfactory. As previously noted, the common commercial cocks and ports, alleged to be minutely graduated in percentage and quantity, are grossly inaccurate. The best crude determination is that of Boothby, namely, bubbling each gas through water from graduated holes. With the Boothby apparatus and its more portable modification, the Gwathmey-Woolsey apparatus, the anesthetist soon learns at what rate each gas should bubble. The total flow should fill a 2-gallon bag in 60 seconds. Thus a constant fresh delivery of 8 liters per minute is established. Escapement of breathed gases is permitted best by an automatic pressure release valve at the mask. One or 2 mm. or more of positive pressure at the face mask ensures against aspiration of air into the mask, and yields, therefore, a more even grade of anesthesia than if no pressure is maintained. After the first 10 minutes it becomes practicable to strike such an even rate of flow that the apparatus need scarcely be further adjusted through subsequent hours of anesthesia.

Only in case of respiratory obstruction or other accidents of anesthesia need the nitrous oxid be cut off and the oxygen flow increased. Cyanosis should at no time be present. If deeper anesthesia or muscular relaxation for abdominal surgery is desired, this is best obtained by a slow continuous dropping of ether, beginning at 2 or 3 drops per second and gradually decreasing to 1 drop every 3 seconds (see Nitrous Oxid Adjuvants).

With the Connell instantaneous gas-flow gauge apparatus, the gases may be measured with accuracy and the ether added in definite proportion. The apparatus is connected to any pressure of gas from 1 to 450 pounds, but most conveniently to a flow reduced from tank pressure to about 4 pounds.

CONNELL TECHNIC OF NITROUS OXID ADMINISTRATION. — For all cases, children and adults, nitrous oxid is set flowing at 8 liters per minute, with the single exception of large muscular men of active metabolism, who receive 10 liters per minute. The oxygen is adjusted to 3/4 liter per minute. This volume is fed into any proper type of face mask and breathing bag, where it mixes with the expired gases. As soon as faint cyanosis appears, usually within 2 minutes, the oxygen flow is raised to 1 liter and shortly thereafter to 1 1/4 liters per minute. This results in a mixture of about 13 per cent. oxygen, which, when mixed with expired gases, yields about 11 per cent. of oxygen constantly present in the breathing bag. On this mixture nearly all patients come to anesthetic equilibrium in light anesthesia. If sufficient anesthesia cannot be secured by nitrous oxid, ether is added as indicated (see Nitrous Oxid Adjuvants). After 20 minutes the oxygen may usually be increased to 1 1/2 liters per minute. For anemic and septic cases the oxygen must be rapidly increased as need arises, until the level of the patient is found. Rarely are more than 2 liters of oxygen per minute required, unless the tidal volume of respiration be very small.

OTHER METHODS.—INSUFFLATION.—Nitrous oxid-oxygen mixture may be administered by pharyngeal and intratracheal insufflation by the technic already described under these methods. This administration is wasteful, requiring 20 to 26 liters of fresh gas per minute, and is less advantageous than ether-air mixture.

PARTIAL INSUFFLATION, FOR AUTOMATIC OR POSITIVE PRESSURE ANESTHESIA.—After anesthesia has been induced by face mask, a flow is established into the pharynx by the nasal route, delivering 8 to 10 liters per minute. The gases are expired through a pharyngeal breathing tube (see Fig. 25). The patient receives a constant supply of fresh gas into the pharynx, and breathes back and forth through this mouth tube. The expired gases are trapped in and spill from a rubber breathing bag attached to this tube. This establishes an automatic delivery, keeps the upper airway open, and relieves the anesthetist

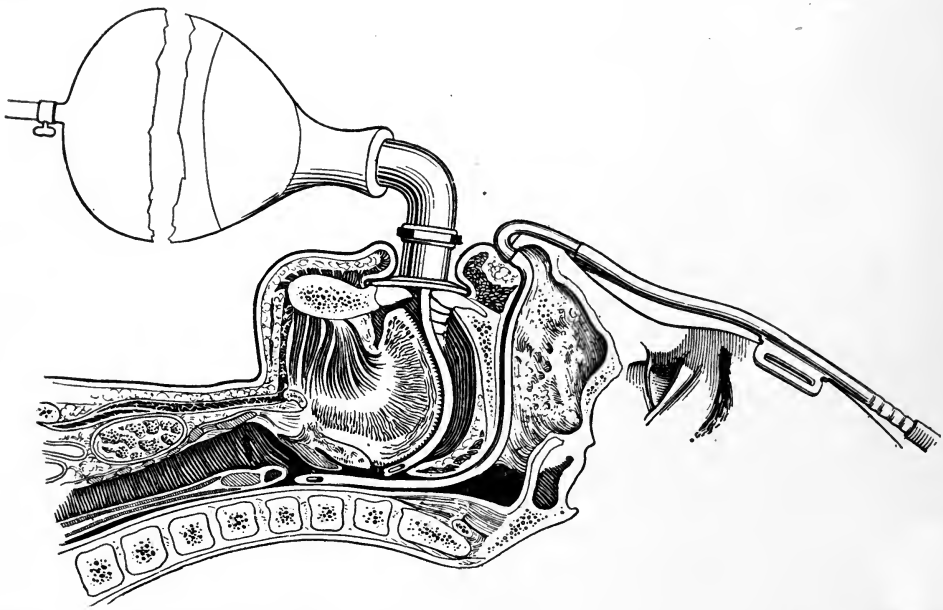

FIG. 25.—PHARYNGEAL INSUFFLATION WITH REBREATHING. Connell method for differential pressure in ether anesthesia, or for automatic delivery and economy of gases in nitrous oxid-oxygen anesthesia. (For the usual method of pharyngeal insufflation without rebreathing, the nasopharyngeal catheters alone are inserted. See pages 95 and 96.)

from holding a face mask in place. If positive pressure is desired, the spill cock from the breathing bag is partially closed until the bag is distended to the desired pressure.

## ADVANTAGES AND LIMITATIONS OF NITROUS OXID-OXYGEN ANESTHESIA

Nitrous oxid-oxygen mixture is the safest of all anesthetics for short operations. For long operations it is as safe as ether only when skillfully administered. Death from asphyxia may rapidly occur, and since the extensive introduction of this gas into general surgery the reported and unreported deaths have probably far exceeded those from ether. The anesthetic should be given only by anesthetists thoroughly familiar with the required apparatus and quick to recognize the symptoms of asphyxia in all its phases.

Anesthesia is induced rapidly and pleasantly and without irritation or excessive secretion of mucus. Bronchopneumonia, which follows the inspiratory accidents of ether, is rarely seen, and the "exposure" lobar pneumonia occurs less commonly than after ether and chloroform.

Nitrous oxid has no known immediate nor remote toxicology other than from asphyxia. It is the anesthetic of choice in acute pulmonary and renal inflammation.

The after-complications of general anesthesia are minimized, nausea and vomiting are somewhat less common than after ether and chloroform anesthesia of equal duration, and are usually transitory in character. The stage of recovery of sensibility is shortened. This rapid recovery of pain sensibility may be classified as a disadvantage in major surgery.

Nitrous oxid is unsatisfactory to the surgeon who has been trained to work unhampered because of the physiological limitations of this anesthetic, namely, light anesthesia, incomplete relaxation, changed color value and excessive congestion of tissue. Nitrous oxid often fails to hold in proper anesthesia vigorous young adults, vigorous fat subjects, and those accustomed to narcotics, such as alcohol, tobacco, morphin and cocain. To yield an anesthetic state approaching in depth that of full ether and chloroform anesthesia, nitrous oxid must be supplemented in action by preliminary narcosis of such undesirable narcotics as morphin and scopolamin, or must be reinforced during the administration by light ether anesthesia, or by efficient local analgesia.

Nitrous oxid is unsafe when respiration is restricted or obstructed in any way. The narrow and collapsible gas way of the upper respiratory tract in infancy and childhood renders nitrous oxid an unsafe anesthetic for children under 8. It is unsafe where strain on the heart or high pressure may result in decompensation, or arterial strain may result in apoplexy.

The increased cost of nitrous oxid-oxygen over ether anesthesia is a question of hospital economics, the cost averaging not less than 2 dollars per hour of anesthesia.

## Nitrous Oxid Anesthesia Adjuvants

**Introduction.**—Owing to the intrinsically light character of nitrous oxid-oxygen anesthesia, as said above, it must frequently be supplemented for general surgery by alkaloidal narcosis or by light ether anesthesia, or both. Morphin with atropin or with scopolamin is the recognized alkaloidal adjuvant. Without these adjuvants it is impossible to hold in surgical anesthesia robust athletic individuals and those of alcoholic, tobacco, and other narcotic habits without dangerous degrees of asphyxia.

**Ether Anesthesia Supplemental to Nitrous Oxid.**—By proper combination, the best points of both of these anesthetics may be secured. By combining the very light zone of nitrous oxid anesthesia, i. e., 11 to 14 per cent. of oxygen, with the light subconscious zone of ether anesthesia, i. e., a vapor pressure of 15 to 25 mm., a physiologically ideal state of general anesthesia may be induced, for the light transitory anesthesia of nitrous oxid is secured together with the relaxation, sensory nerve-end paralysis and postoperative analgesia of ether. The asphyxial zones of nitrous oxid may be avoided, also such concentration of ether vapor as actively stimulates mucus secretion in the bronchi. Nor do the after-effects exceed those of unsupplemented nitrous oxid administration.

TECHNIC 1.—The patient is primarily anesthetized by nitrous oxid oxygen. Ether is now slowly added, increasing the vapor pressure to approximately 86 mm. by adding 65 drops of ether for each gallon of gas, usually 2 drops per second. At the same time the oxygen percentage may be increased to 12 per cent. When anesthesia is complete and general relaxation has been established, usually within 6 minutes, the anesthetic state may be readily continued by nitrous oxid-oxygen alone, usually without further recourse to ether.

TECHNIC 2.—At any time during the course of nitrous oxid-oxygen anesthesia, when it becomes necessary to secure efficient anesthesia or to establish relaxation, the administration of ether is desirable. This is a far safer procedure than to persist in attempting to get complete anesthesia in unsupplemented nitrous oxid anesthesia by reducing the oxygen supply.

About 86 mm. of ether vapor pressure (i. e., 65 drops of ether per gallon of gas) is necessary to establish an efficient state of anesthesia within reasonable time, i. e., 3 to 5 minutes. When relaxation is secured, the ether is discontinued or reduced to minimal dosage, i. e., 20 mm. of vapor pressure or 15 drops of ether per gallon of gas.

TECHNIC 3: THE BEST METHOD.—By starting the administration of ether immediately in nitrous oxid administration, adding less than 22 drops of ether per gallon of gas, the dosage of ether vapor may be kept constantly below 30 mm. of ether vapor pressure. The oxygen content in the gas may be gradually increased to 15 per cent. Thus the safest, most satisfactory state resultant from any general anesthetic is obtained, a state combining the light subconscious zone of both ether and nitrous oxid into one of deeper yet controllable anesthesia. A proper ether flow is a drop every 2 seconds for the first half hour, thereafter a drop every 3 seconds. The gases are best delivered continuously, 10 liters per minute. Thirty grams of ether per hour and 150 gallons of gases are used.

**Alkaloidal Narcosis Supplemental to Nitrous-Oxid.**—Preliminary alkaloidal narcosis renders the course of nitrous oxid anesthesia smoother, increases the depth of anesthesia, allows an increase of 1 to 3 per cent. in the oxygen percentage, and renders the necessity for ether less frequent. However, these narcotics desensitize the respiratory center and increase the danger of respiratory collapse from asphyxia. Scopolamin or hyoscin also occasionally exercises rapid powerful depression on the circulatory mechanism.

TECHNIC 1.—The usual procedure is to administer, 1 hour before anesthesia, 1/4 grain of morphin with atropin, grain 1/150. Or the dose of morphin may be 1/8 grain given 1 hour before anesthesia, and if no narcotic effect is manifest the dose may be repeated 1/2 hour later. With athletic, robust individuals the dosage may be doubled. In total not more than 1/2 grain of morphin nor 1/75 grain of atropin should be administered.

TECHNIC 2.—Morphin, 1/4 grain, with scopolamin, 1/100 grain, is administered 1 hour before operation. If no narcotic effect is evident, the dose is repeated in 1/2 hour.

With these narcotic adjuvants a susceptible patient may easily be carried in satisfactory light surgical anesthesia on a 10 to 12 per cent. oxygen delivery, but the physiological state is not so safe or satisfactory as with ether as an adjuvant.

**Postoperative Narcosis.**—Unless a preliminary narcotic has been given, postoperative alkaloidal narcosis is a necessity following nitrous oxid anesthesia, as no merciful after-period of somnolence and analgesia is present as with ether.

The usual technic is to administer hypodermically morphin, 1/4 grain, 5 minutes before discontinuing nitrous oxid anesthesia.

## ETHYL CHLORID

**Introduction.**—Ethyl chlorid is a rapidly acting, intense yet transitory anesthetic. For practical purposes it may be considered as a very rapidly acting chloroform. It has such properties of rapid volatilization and diffusion, and such intense action as a lipoid solvent as to be controlled with difficulty in its anesthetic effect.

For a time it was vaunted in England as possessing the quick action and safety of nitrous oxid, but a series of fatalities brought disillusion to its advocates. As a prolonged anesthetic it has had extensive trial and been found so uncontrollable as to be dangerous in the deeper stages of full surgical anesthesia, and to induce in exaggerated form the evil after-effects of the hydrocarbon anesthetics.

At present it is used, with the same indications as nitrous oxid, for transitory anesthesia where the gas is not available. It is occasionally employed to hasten the induction of ether anesthesia. Its use for the maintenance of anesthesia beyond 5 minutes has been largely abandoned. In the light stages of primary anesthesia it is less dangerous than chloroform, but in the stage of recovery death from cardiac collapse is more frequent. It is not a safe anesthetic to use in a sitting posture as is nitrous oxid.

**Physiological Action.**—Ethyl chlorid is locally a refrigerant by rapid vaporization. It has very little odor and in the required percentage is not an irritant to the respiratory tract. On the circulation it has the same effect as chloroform, being a primary paralyzant of heart muscle and depressant of blood pressure.

RESPIRATION.—After a few inhalations respiratory movement grows full and more rapid. Within 15 breaths slight stertor marks the onset of anesthesia. In the stage of light anesthesia with excitement there may be respiratory embarrassment, cyanosis, and asphyxia from spasm of the jaw or the glottis, or from thoracic fixation. With this anesthetic asphyxia is badly borne and must be promptly relieved.

SENSORIUM.—Consciousness is lost with remarkable rapidity. By closed methods and with rapid admission of the vapor, consciousness may be abolished within 4 breaths, and as a rule without noticeable discomfort or resistance. By the open methods and in resistant subjects a stage of excitement may be present, with some respiratory halting and slight general muscular rigidity.

ZONES OF ANESTHESIA.—Without doubt the same zones of anesthesia exist as with ether and chloroform, but it is impracticable to maintain continuously any desired level of anesthesia, since the changes are so rapid with this volatile drug.

**Period of Recovery.**—The period of recovery is brief. After a short administration the patient may regain consciousness within a few breaths, after longer administration recovery may take 5 minutes. At times when sudden overanesthetization occurs, the degree of anesthesia may dangerously increase for an instant by absorption of the anesthetic residual in the alveolar air. The period of recovery largely depends on the duration of anesthesia and the relative tidal volume of respiration.

Recovery of consciousness is not infrequently followed by severe headache, nausea, repeated vomiting and severe prostration. Late in this period even several hours after the administration, a delayed collapse has added a number of fatalities to the score of this anesthetic. This late collapse is more liable to occur after prolonged administration, also when, for purpose of economy and to deepen the anesthesia, a state of chronic asphyxia has been occasioned by excessive rebreathing.

**Technic of Administration.**—There are two methods, the closed and the semi-open.

CLOSED METHOD.—Into the inflated 2-gallon air bag of any closed face inhaler, such as the Ormsby or the Bennett, liquid ethyl chlorid is sprayed through any convenient vent, in dosage of about 1 to 2 c. c. for the child, up to 3 to 5 c. c. for the adult. Rebreathing is judiciously allowed for about 15 breaths, when a period of available anesthesia ensues, lasting a minute or more after removing the mask. For more prolonged anesthesia fresh air must be allowed by partially opening the air vents of the inhaler and adding fresh anesthetic as indicated, in dosage of ½ to 2 c. c. per minute.

SEMI-OPEN METHOD.—Either an Esmarch inhaler, well swathed in gauze and moist toweling, is employed, or a special ethyl chlorid inhaler consisting of rubber face mask with a 1 in. gauze-covered opening is selected. Onto the mask is sprayed a continuous stream of ethyl chlorid, 4 to 5 c. c. per minute until anesthesia ensues, when the dosage is decreased to ½ up to 2 c. c. per minute.

The Esmarch inhaler is the simplest and safest mask, but involves the largest wastage of the drug. Unless it is well swathed over the face with moist toweling, proper anesthetic pressure of ethyl chlorid in the tidal air is secured with difficulty.

For prolonged anesthesia it is far safer to superimpose light ether anesthesia than to continue the ethyl chlorid alone. On the whole, ethyl chlorid meets no necessity in anesthesia which cannot be better supplied by ether, nitrous oxid or chloroform.

### The Ethyl Chlorid Group of Drugs

A series of drugs has at various times been tried with the high fat-solvent power and rapid action of ethyl chlorid. These have been found more objectionable than ethyl chlorid, because either less stable, less controllable, or intrinsically more dangerous. Among these are ethyl bromid, ethidene dichlorid, amylene and pental, and many recent proprietary mixtures and compounds, for the most part dilute ethyl chlorid and bromid mixtures put forth with somniferous names and unsubstantiated claims. The anesthetist should not be lured into the use of these mixtures, but use only the 4 standard anesthetics of the highest purity obtainable, either singly or in deliberately planned combination or sequence as the exigencies of anesthesia demand.

## ANOCI-ASSOCIATION

**Introduction.**—Systematic effort has been made by Crile to exclude from the central nervous system of a patient, the various afferent stimuli of fear and pain. Crile believes that these stimuli exhaust the cell through the rapid discharge of nervous energy and thereby predispose to shock during and after the operation, and to postoperative neurasthenia. A series of measures to disassociate the nerve cell from these noxious stimuli has been termed by Crile *anoci-association.*

The method deserves mention in detail despite its complexity and the toxic agents employed, because of the widespread beneficial influence which the accumulated facts, systematized procedures, and engaging hypotheses of anoci-association have had on modern surgical technic; particularly toward increasing the efficiency with which general anesthetics are now administered and toward emphasizing the necessity for gentle, considerate, surgical manipulation even under ether and chloroform anesthesia.

**Technic.**—The first measures deal with the preoperative stage. Apprehension on the part of the patient is lessened by the reassuring attitude and the efficiency of the surgical attendants throughout this period. Acute fear and excitement at the time of operation are lessened by a small dose of morphin (grain 1/6) and scopolamin (grain 1/120). With especially nervous cases, such as those suffering from exophthalmic goiter, even the time of operation is unknown to the patient, and the anesthetic (nitrous oxid) is administered under the guise of inhalation therapeusis.

For anoci-association during the second or operative period, Crile employs nitrous oxid as the anesthetic agent, believing that the anesthetic effect of nitrous oxid more efficiently protects the nervous system than even the fullest action of ether. (This is not supported by general opinion and is in direct divergence from more recent and carefully controlled observation.) In addition he employs a method of terminal nerve block by local anesthesia (see Novocain and Local Infiltration Anesthesia for Major Operations, believing that centripetal stimuli constantly bombard the nervous system, even during efficient general anesthesia.

In the third or postoperative period, the after-pain of operation is blocked by the long-continued local anesthetic effect of weak alcohol (50 per cent.), or quinin and urea injected into the most sensitive tissues when the wound is about to be closed and before general anesthesia has ceased. Thus, in celiotomy the peritoneal suture line is widely blocked by subperitoneal infiltration, also the field of fascial and cutaneous suture.

The technic of the "shockless" operation by anoci-association is largely based on the assumption that centripetal stimuli of operative trauma continued under general anesthesia; that merely the consciousness of pain is removed. This is true only for the lightest grade of general anesthesia, whereas the deeper grades slowly induced and fully maintained block all except the most vital stimuli, such as have to do primarily with blood flow, aeration and splanchnic control. (For order of disassociation by efficient general anesthetic, i. e., ether and chloroform, see Figure 16.)

## DIFFERENTIAL PRESSURE METHODS IN ANESTHESIA

**Introduction.**—For certain intrathoracic operations it is desirable to establish an atmospheric pressure within the lung greater on the average than that which exists on the chest wall. Such a differential pressure may be maintained either by decreasing the pressure outside the lung (negative pressure or suction method), or it may be maintained by increasing the atmospheric pressure within the lung (positive pressure method). The purpose in establishing differential pressure is to overcome the tendency of the lung to collapse and become immobile when the pleural sac is opened. To overcome this tendency, it is necessary to maintain a differential pressure within the alveoli at least 5 mm. (mercury column) greater than that which exists in the opened pleural sac. By this pressure the elasticity of the lung is balanced and the lung remains in partial or full distention and follows more or less completely in a normal manner the movements of the thorax. Thereby, even if both pleural sacs be opened, the normal ebb and flow of tidal air and aeration of blood continue. The differential pressure maintained must not be too great, for a pressure continually in excess of 20 mm. retards the return of blood and lymph to the thorax, and within 3 to 5 minutes a condition of shock is induced.

So long as the tidal volume is adequate to ventilate the lungs it matters little in the physiological effect whether the necessary differential pressure of 5 to 20 mm. of pressure be maintained by gentle suction from without (negative pressure method) or by moderate pressure from within (positive pressure method). Mechanically, however, the positive pressure methods have proved so much more simple and generally applicable, and in addition the insufflation methods have provided such an effective artificial ventilation of the lungs, that these methods alone are in general use.

**Negative Pressure Method in the Sauerbruch Chamber.**—APPARATUS.—The chamber is an air-tight room built to withstand a negative pressure of a pound or more. This room is of sufficient size to accommodate the operating table, the operating staff and the equipment. The atmosphere of the room may be exhausted, under control of the anesthetist, by a large rotary air pump. The air exhausted is continuously replaced by the inflow of fresh air through valves, which are released automatically at a given pressure. The patient's head projects from the chamber through a hole, the margin of which is adjustable by a membrane and a collar snugly fitting the patient's neck.

TECHNIC.—The patient is anesthetized by the usual routine methods. At that stage of the operation when differential pressure is desired all ingress into the room is closed off except the inflow valves, and the room is exhausted by the air pump. By adjusting the inflow valves the interior pressure of the chamber may be kept at any desired degree of exhaustion, usually about 10 to 20 mm. of negative pressure. Anesthetization may be carried on by the usual face mask methods by the anesthetist outside the room.

The only advantage of this method over the face mask method of positive pressure is that the anesthetist can more freely adjust the mouth and upper air tract than when the face is covered by a tight pressure mask. The mechanical disadvantages of the method are obvious, in extensive and complicated equipment. It has been almost entirely superseded by positive pressure methods.

**Positive Pressure by Face Mask.**—By delivering the anesthetic mixture under pressure into a snugly fitting face mask, the rubber breathing bag becomes gradually distended and maintains by its elasticity a constant pressure against the alveolar air. Thus when the pleura is opened the lung does not collapse, but tends to follow the movements of respiration in a normal manner.

APPARATUS AND TECHNIC.—As suitable masks the Gwathmey, Boothby, and Teter masks may be mentioned, although any snugly fitting face mask will suffice. Masks fitted with an adjustable escape valve, which opens and discharges when the pressure becomes excessive, are preferable; or to control the escapement, a tube may be led from a face mask and discharged into water at a depth from 5 to 10 in. beneath the surface. This maintains the necessary 10 to 20 mm. of pressure within the face mask.

For apparatus to generate and deliver the anesthetic mixture under pressure, see page 97. A quantity not less than 8 liters per minute of fresh mixture should be delivered, and preferably 15 to 20 liters. Usually 10 to 20 mm. of pressure at the face mask results in the necessary average increase of 5 mm. or more of pressure within the lungs. The lungs are kept only in gentle distention, and this is maintained only for such period of the operation as is necessary. The degree of positive pressure is lowered every few minutes, since long-continued high pressure tends to produce shock.

To ensure an open upper air tract and avoid accident, a pharyngeal breathing tube (see Fig. 28) should be placed and the depth of anesthesia should be full and continuous, well beyond the vomiting stage.

**Positive Pressure by Pharyngeal Insufflation.**—Pharyngeal insufflation is much more effectual than face mask methods, since the mixture is delivered not only where it can be more freely inspired and pressure more dirctly applied, but also the upper airway may be kept widely opened. The anesthetist is relieved from holding a face mask in place. (See Fig. 25.)

**Positive Pressure by Intratracheal Insufflation.**—The most effectual method is the Meltzer method of intratracheal insufflation. Not only is positive pressure easily maintained, but also an effectual artificial ventilation of the lungs (see page 91). This is the only method whereby life can be continued with both pleural sacs opened, and both lungs immobile or partially collapsed.

## THE NEWER MECHANICAL METHODS OF ARTIFICIAL RESPIRATION

**Intratracheal Insufflation.**—The efficiency and technic of this method of artificial respiration have already been considered (pages 91, 92). The objection to the method lies in the fact that, with absolute suspension of respiratory movement, a phase of negative pressure is at no time created to assist by aspiration the return of blood and lymph to the thorax. To render insufflation as thoroughly effective on venous flow as it is on aeration, the air current should be interrupted about 4 times a minute and an inspiratory movement carried out by extending the arms and lifting the short ribs, as in the Sylvester and other standard methods of artificial respiration.

**Pharyngeal Insufflation.**—Air blown into the pharynx will be carried into the lungs if the mouth and nose be held shut and the epiglottis be raised by carrying the tongue and jaw forward. The best instrument for this method of artificial respiration is the pharyngeal tube of Meltzer. This tube is a cylinder about 1 in. in diameter, flattened on the under side and presenting a large fenestrum at its proximal end. This tube is thrust against the posterior pharyngeal wall and obturates the nose and mouth. The tongue is pulled out to raise the epiglottis, and air is insufflated by a foot bellows or other apparatus. The current of air is interrupted about 15 times a minute by alternately opening an inflow and an exhaust valve. The air flows into the lungs under pressure and is expired by the elastic recoil of the thorax. If the stomach becomes distended, this is deflated by a small stomach tube passed through a space provided in the Meltzer cylinder.

**Pulmotor.**—The pulmotor is an apparatus operated by compressed oxygen which alternately exhausts and increases pressure in a face mask for purpose of artificial respiration. The apparatus is started by opening the valve of an oxygen cylinder. A face mask is attached to the apparatus and is securely adjusted to the face, the patient's tongue having been drawn well forward.

The motive power—namely, the compressed oxygen—flows from a cylinder through a Sprengel pump. This pump first sucks air from the face mask, then blows air into the mask, the current being changed automatically by certain mechanical devices, when a set degree of suction or of pressure is created in the face mask. A full tank of oxygen usually furnishes motive power for about 40 minutes of respiration.

The objections to the apparatus are: First, the limited motive power in the compressed oxygen; second, the complexity of the automatic mechanism; third, the excessive degree of pressure and of suction to which the mechanism may be adjusted; fourth—not however inherent in the apparatus—the average inefficiency with which the upper respiratory tract is held open in the novice's attempts at resuscitation. Properly used it is a very valuable apparatus for artificial respiration as well as an aid to venous circulation.

**Lung-Motor.**—The "Lung-motor" substitutes for the above, as the motive mechanism in creating positive and negative pressures in the face mask, a double acting piston pump operated by hand. Thus, motive power is more reliable and the degree of suction and of pressure is less severe than with the pulmotor. Otherwise the general utility and mode of use are the same. In neither apparatus is the small amount of oxygen which may be added to the sufficiency in normal atmosphere of any material advantage.

## THE CONNELL ANESTHETOMETER

**Introduction.**—The anesthetometer is an apparatus to vaporize exact amounts of liquid ether and chloroform, and to accurately mix and measure anesthetic vapors and gases. It is developed from a commercial gas meter.

The apparatus as originally designed is the most accurate and practical working instrument yet devised for exact dosage by pulmonary diffusion of the various vapor and gas mixtures. It has made possible the standardization of ether vapor administration and of nitrous oxid-oxygen dosage (see tables under these subjects. The construction plan of the original instrument is shown in Figure 26. This original model has been supplanted for nitrous oxid-oxygen administration by a very small and flexible, although somewhat less accurate, instrument, the Connell instantaneous gas flow gauge (see Fig. 24). For ether-air administration, the original instrument, for use outside of large hospitals and experimental laboratories, has been modified into a smaller, more cheaply constructed, and less complex design, eliminating all unessential or complex parts. Since the latter model is more generally acceptable, it is described herein.

**Description.**—The simplified anesthetometer (Fig. 27) consists of three assembled units: an air meter, an ether measuring unit, and a vaporizer. The first unit, the air meter (A, Fig. 27) is a small commercial "dry gas-meter." This is a necessary unit. In fact, by no other mechanism than an accurate meter can air be sensitively measured and a liquid, such as ether or chloroform, be simultaneously and automatically fed into the air current, and thus accurately correlated to the bulk of air passed by the apparatus.

Air under light pressure from any generator, such as a foot bellows or preferably a motor blower, is driven through the meter. This moves not only the measuring and recording mechanism, but also a mechanism which feeds into each 3 1/3 liters of air any desired amount of liquid ether from zero to 5.8 c. c. Thus the air may be impregnated by any vapor percentage from zero to 28 per cent. by volume, or better expressed as partial pressure of ether vapor ranging from 0 to 210 mm.

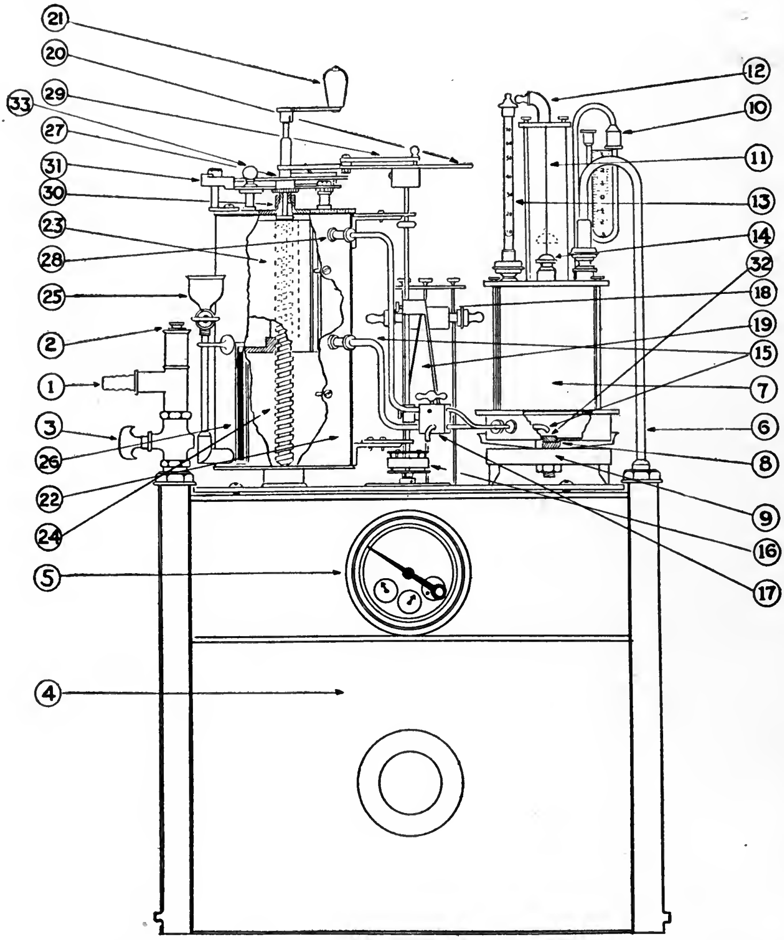


FIG. 26.—THE ANESTHETOMETER, ORIGINAL HOSPITAL AND LABORATORY MODEL. 1, Inflow; 2, safety valve; 3, cock; 4, meter; 5, dial; 6, outlet of meter; 7, glass vaporizing chamber; 8, absorption disc; 9, electric heater; 10, manometer; 11, instantaneous gas-flow gauge; 12, outlet; 13, thermometer; 14, loose piston of gas-flow gauge; 15, ether feed pipes; 16, function clutch; 17, ether cock; 18, 19, gas-oxygen mixing unit (abandoned); 20, revolving disc; 21, piston crank; 22, ether chamber; 23, displacement piston; 24, screw spindle; 25, filling cup; 26, window; 27, 28, 29, 30, 31, ratchet mechanism.

The second unit of the apparatus (B, Fig. 27) measures out the ether into the third unit, the vaporizer (C). This second unit consists of several parts; first a small glass ether cup (4, Fig. 27), on which a can of ether may be inverted. The ether drips out from the can as needed into the cup when the level of the ether in the cup becomes lower than the mouth of the can. This eliminates the necessity for a large reservoir. The second part of this unit is a compound three-way cock. By movement of this cock, ether flows from the cup into a horizontal hypodermic syringe. By a return movement of the cock, the ether thus measured into the chamber is emptied into the vaporizer. The cock is moved by the meter through a simple connecting mechanism at each revolution of the meter and thus a definite quantity

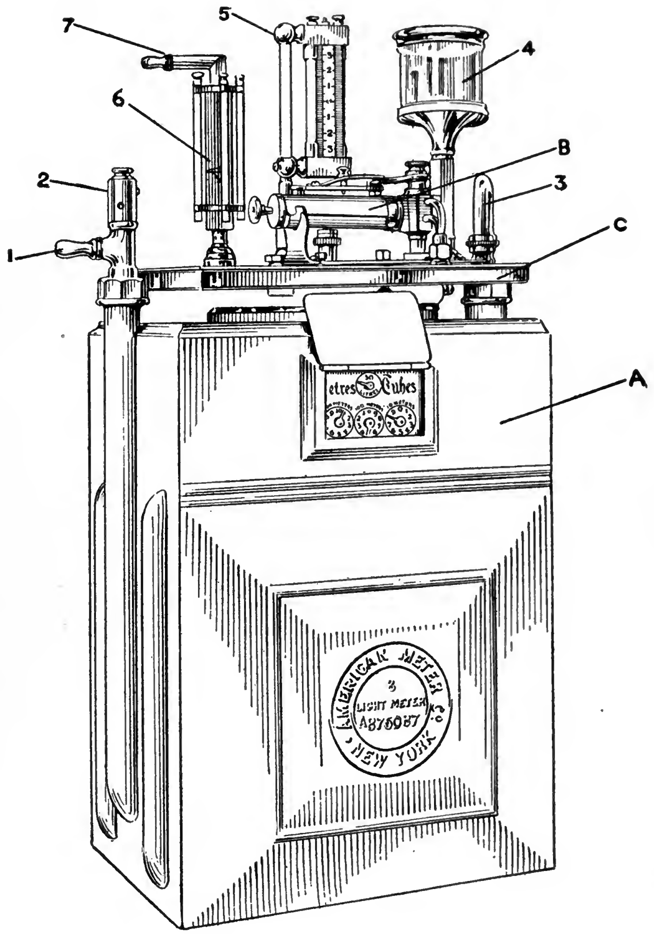


**Fig. 27.—The Connell Anesthetometer.** Simplified model for ether vapor. A, Gas meter; B, ether-measuring apparatus; C, vaporizer. 1, Air inflow; 2, pop safety valve; 3, outlet from meter to vaporizer; 4, ether cup; 5, U pressure gauge; 6, instantaneous gas-flow gauge; 7, outlet of vapor mixture.

of ether is measured into a definite amount of air. The capacity of the syringe is modified by moving the piston in or out by a screw, diminishing or increasing the amount of liquid ether measured off at each revolution of the meter.

A scale of measurement is attached to the glass barrel of the syringe with graduations, expressed in millimeters of ether vapor pressure. The available percentage or pressure of ether vapor ranges from zero to 210 mm. Thus the piston may be set to the 50 mm. graduation, and by charging the ether cup and supplying compressed air to the meter the apparatus automatically measures 1.14 c. c. of liquid ether into each 3.39 liters of air. The resultant output of vapor mixture from the apparatus contains 50 parts of ether vapor in each 760 parts of mixture, physiologically a strength of mixture on which the entire animal kingdom may be safely held in full surgical anesthesia for many hours.

The third unit (C) is the vaporizer, a thin metal double bottom on which is set the foregoing unit. The liquid ether from the measuring unit and the air measured from the meter flow through this bottom in a tortuous course. The surface of this channel is so devised that the metal acts as a radiator and supplies in total from the atmosphere of the room the heat necessary to evaporate and warm the mixture to room temperature. This obviates the necessity for artificial electric heat. The resultant mixture finally emerges from the vaporizer without material loss of heat or moisture. The mixture flows out through an instantaneous gas flow gauge, an aluminum piston moving in a vertical glass tube calibrated so that the operator may observe at any moment at what rate the mixture is being delivered. The apparatus also embodies a pressure gauge (No. 5) and an adjustable safety valve (No. 2).

**Advantages.**—The desirability and utility of such an instrument as will automatically deliver any quantity and strength of anesthetic mixture, under full control of the anesthetist, have been sufficiently set forth.

By the use of such an accurate instrument and with the theoretical knowledge of the underlying facts of ether administration, the average novice anesthetist rapidly acquires facility in properly inducing and maintaining a perfection of anesthesia by these accurate vapor methods, which is attained in an empiric way only by exceptionally adept individuals and after years of training in the cruder methods.

## ACCIDENTS OF ANESTHESIA

**Accidents from Decomposition and Ignition of the Anesthetic Agent.**—*Chloroform* should not be administered in a closed room in the presence of a naked flame, since the free vapor is decomposed into highly irritating fumes (phosphagon and hydrochloric acid), which are detrimental to the patient and may be overpowering to the surgical attendants.

*Ether* should be used with precaution against ignition particularly from the thermocautery and from sparking electric apparatus. When the cautery is used in the region of the head or neck, the ether should be withdrawn for a minute or two prior to the use of the cautery. The expired breath highly charged with ether may ignite with a blue flame and burn at the lips. Fortunately this does not flash back into the respiratory tract, but becomes extinguished by the cooling effect of the mucous membrane. When the cautery must be used in the region of the mouth, chloroform is the anesthetic of choice. When the cautery is used elsewhere, care must be taken that it is not held below the level of the table (since the heavy ether vapor sinks) and that the current of ether exhalation from the patient is deflected away from the cautery by a moist towel over the patient's face.

**Obstruction to Respiration.**—Of the various factors contributing to irregular anesthesia and often leading to respiratory and cardiovascular disaster, the most common is respiratory obstruction. This obstruction is usually at the base of the tongue and in the deep pharynx and is due to relaxation of muscular support, but may be at any of the following sites:

A. NASAL OBSTRUCTION.—The alæ of the nose may collapse on inspiration. For this the nostril may be held open by a bent hairpin or probe.

Obstruction may be occasioned by insufficiency of the nasal passage. As a remedy, mouth breathing must be instituted. If in the preliminary examination any nasal obstruction is evident, it is well to impress on the patient the necessity of breathing through the mouth during induction. With pure nitrous oxid asphyxial anesthesia, it is best to have a rubber mouth gag between the teeth as a preliminary measure to induction.

B. MOUTH OBSTRUCTION.—Occasionally the relaxed lips of elderly people and of those from whom false teeth have been removed act as a double flapper valve obstructing inspiration. To hold the lips open and gums apart a small wad of gauze may be tucked into an angle of the mouth.

Close set teeth clenched from excitement or from asphyxia may obstruct respiration. It is difficult to unlock these jaws by a mouth gag. The best remedy lies in the prevention of such manifestations of asphyxia. The quickest relief is afforded by passing a size 22 F. soft rubber catheter with multiple lateral eyelets a distance of 14 cm. through each nostril. When the condition of acute asphyxia has been relieved, and the jaws relax sufficiently to be easily pried open, a pharyngeal breathing tube should be inserted.

C. PHARYNGEAL OBSTRUCTION.—The base of the tongue may drop into the pharynx from the relaxation of muscular support. This is the most common of all obstructions. It can usually be met by adjusting the head and jaw of the patient. The head must usually be extended and thrown slightly to one side and the lower jaw thrust forward until absence of stertor and full movement of the chest wall and abdomen indicate an unobstructed airway. Occasionally the jaw must be held forward continuously by the anesthetist through a gentle pressure with his fingers beneath the body of the jaw at about the bicuspid teeth. Occasionally a rather forceful forward thrust must be exercised by well-distributed pressure behind the angle of the jaw, throwing the lower jaw into an "undershot" position. Prolonged and forceful pressure on one spot may incite a subsequent painful traumatic parotitis.

If the obstruction can be cleared in no other way, the tongue must be pulled forward directly by the thumb and forefinger or by a tongue clamp or traction suture passed through the tongue. The tongue may be seized by opening the mouth and depressing the chin. On the next attempt at expiration the tongue will be found to protrude and may be seized in a piece of gauze between the thumb and forefinger.

These barbarous methods of tongue traction and the forceful holding forward of the jaw may be obviated by the introduction of an artificial airway reaching from the lips into the lower pharynx. A convenient improvised form is a ¾ in. rubber tube, 5 in. long with two lateral eyelets at the pharyngeal end. The Coburn breathing tube is of this pattern. A useful procedure of Bennett to hold the tongue forward is to wrap the shaft of this breathing tube with fluff gauze so that it will adhere to the rugæ of the palate and to the tongue. By drawing out the tongue it will be held forward and leave free the pharyngeal airway. The best device is the Connell breathing tube, a flattened copper tube, accurately fitting the curve of the palate and pharynx, incompressible by the bite of the teeth and providing an abundant airway with mineral displacement of oral structures (see Fig. 28). This may be easily inserted at the first indication of obstruction and guarantees against many of the embarrassments of faulty airway and faulty administration of the anesthetic.

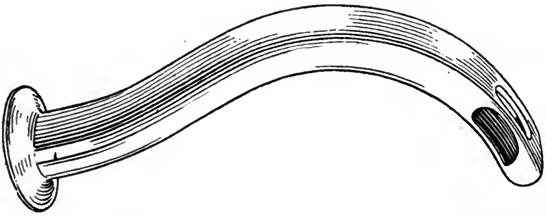

Fig. 28.—The Connell Pharyngeal Breathing Tube. A flattened metallic tube, easily inserted, fitting the curve of the palate and pharynx, not compressible by the bite of the teeth, and providing an abundantly free airway into the lower pharynx

D. OBSTRUCTION OF THE GLOTTIS.—The epiglottis may fall over the aperture of the glottis by the same muscle relaxation which allows the tongue to fall back. It is raised by the same maneuvers which carry forward the tongue.

Occasionally, as the result of powerful inspiratory efforts in the course of asphyxial obstruction, the epiglottis will be sucked tight as a cork into the aperture of the glottis. Pulling forward the tip of the tongue does not relieve this obstruction. For relief, the base of the tongue as a whole must be carried forward by 2 fingers in the pharynx or by forceps which grasp the linguoepiglottic fold and carry forward the whole base of the tongue.

During light anesthesia the glottis may be thrown into tonic spasm by overconcentrated vapors. This passes off spontaneously, but may render the subsequent course of etherization more stormy.

The glottis may be obstructed by a foreign body, such as false teeth, chewing gum and tobacco. This should be prevented by preliminary search for loose foreign bodies in the mouth. The treatment is by digital removal, or by tracheotomy in the face of impending dissolution.

E. TRACHEAL OBSTRUCTION.—The usual cause of tracheal obstruction is collapse of diseased tracheal walls during inspiration, or pressure of a tumor in the region of the thyroid or of the thymus gland. If pathological conditions are known to exist which may cause such sudden obstruction in the course of anesthesia, this disaster may be forestalled by the intratracheal insufflation method of anesthesia. Obstruction once developed must be promptly relieved by passing a large urethral catheter, size 26 F., or other tube by way of the larynx or through a tracheotomy wound, well past the obstruction. Suddenly developed obstructive asphyxia from an enlarged thymus and from thoracic goiter may be thus relieved. Diagnosis is difficult unless the pathological condition be suspected before anesthesia. The above measure for relief of obstruction should be employed when acute obstructive asphyxia has not yielded to the opening of the upper airway, and death is impending.

F. BRONCHIAL OBSTRUCTION.—The finer bronchi become obstructed by mucus and vomitus. Oversecretion of mucus is the more common and results from concentrated and irritating vapors, particularly from rapid and irregular induction and irregular maintenance of very light anesthesia. The condition is indicated by rattling and moist râles and slight cyanosis.

TREATMENT.—Bronchial obstruction should be avoided by smooth induction and full, continuous anesthesia. Excess of mucus may be relieved by lowering the head of the table and by allowing the patient to emerge from anesthesia until coughing clears the obstruction. Recurrence is prevented by full anesthesia or by hypodermic administration of atropin, grain 1/100.

Inspiration of vomitus is another factor in obstruction. It may be obviated, first, by anesthetizing only when the stomach is empty; second, by full continuous anesthesia; third, by the proper management of the head when vomiting occurs, i. e., turning the head to one side and allowing the propulsive mechanism of vomiting and coughing to evacuate the mouth and pharynx before the anesthetic is again resumed. The obstinate vomiting of intestinal obstruction is to be relieved during the operation by repeated lavage.

**Vomiting.**—Irritability of the vomiting center is physiological at a certain level in the subconscious zone of general anesthesia. At this level the vomiting center is undergoing disassociation or reassociation. If the induction of anesthesia is smooth and continuous the vomiting center usually becomes anesthetized without excitation. If the anesthetic is irregularly administered or the intake of the anesthetic is delayed by breath holding or by small tidal volume, as when abdomen is rigid, then vomiting more commonly ensues. Vomiting does not occur in the stage of full surgical anesthesia.

In the stage of recovery subconscious vomiting to the extent of slight retching frequently occurs in all general anesthesias. After this the patient lapses again into sleep.

Vomiting in the progress of anesthesia is judged to be impending when on light dosage of the agent anesthesia seems suddenly to deepen, the pulse diminishes in volume, the skin grows pale, and increased lacrimation appears. The most reliable sign is a long inspiration followed by a pause, a moment after which, if the anesthetic be not immediately increased, vomiting may be expected.

TREATMENT.—Vomiting may frequently be inhibited when threatening, by rapidly and repeatedly stimulating the pupillary light reflex by opening and closing the eyelid a dozen times or more. It may also be inhibited by chafing the face, by rubbing the lips, by administering a strong whiff of fresh cold ether vapor, or by a light tap over the epigastrium.

When vomiting occurs the face mask should be removed, the head turned to one side, and the mouth allowed to open. The anesthetic should not be resumed until the act has been completed and the pharynx sponged out, or emptied by coughing. The first subsequent deep inhalations are assisted by dragging the jaw forward. Repeated vomiting, as during anesthesia for operation on intestinal obstruction, should be relieved by gastric lavage.

**Pulmonary Edema.**—Pulmonary edema may result from cardiac decompensation occasioned by anesthesia and the shock of the surgical procedure. It has also been occasioned during anesthesia by flooding the cardiovascular system with an excessive quantity of saline infusion.

The symptoms are those of circulatory depression, a pale cyanotic color, the exhalation of watery and frothy material from the mouth in large quantity, and an abundance of moist râles.

TREATMENT.—Aside from the usual intravenous epinephrin and strychnin stimulation and the depletion of venous engorgement by phlebotomy when indicated, the most effectual treatment is that of Bennett. Bennett injects into the rectum 2 ounces of concentrated solution of magnesium sulphate. This is followed in favorable cases, within 10 minutes, by marked diminution or relief of the pulmonary edema.

**Respiratory Failure.**—ETIOLOGY.—The most common cause of respiratory failure is acute or chronic asphyxia of the respiratory center with consequent suspension of its automaticity. Acute asphyxia as a cause is commonly resultant from complete obstruction in the upper airway during the stage of induction. Chronic asphyxia as a cause is resultant from partial obstruction prolonged over the course of anesthesia, or from persistent rebreathing and oxygen starvation. Both forms are most commonly seen in nitrous oxid and in ether anesthesia and are usually due to blunders of an incompetent anesthetist.

A less common cause of respiratory failure is overdosage of anesthetic. This may be a sudden large dose or prolonged gradual overdosage.

To the third group of etiological factors belongs the toxemia of disease. This is rarely a primary, but usually an accessory, factor to the depression of asphyxia and overdosage of anesthetic.

SYMPTOMS.—In acute respiratory failure usually after a period of violent muscular effort at respiratory movement these efforts suddenly cease. The patient meanwhile turns bluish and then livid, jactitation of asphyxia appears, the eyes open and bulge, the pupil dilates, the blood pressure first rises and the pulse slows, then becomes rapid and irregular with sharp fall of blood pressure. This form is seen several times a year in any large hospital training novice anesthetists and usually results from obstruction, less commonly from spasm, and least commonly from acute overdosage of anesthetic.

In the chronic form of desensitization of the respiratory center the respiration grows more shallow and irregular, tending toward the Cheyne-Stokes type of rhythm. The color becomes pale with pronounced cyanotic tinge, the heart action becomes more rapid, the blood pressure falls, and finally the respiration stops. This is far more serious from the standpoint of resuscitation than an acute form of failure.

TREATMENT OF FAILURE FROM ACUTE OBSTRUCTION.—If obstruction be relieved or the anesthetic be withdrawn the condition usually rights itself automatically, probably from cumulative carbon dioxid stimulation of the respiratory center. A size 22 F. catheter is passed through each nostril a distance of 12 to 14 cm. If this does not relieve the asphyxia the mouth must be pried open and the base of the tongue and epiglottis carried forward by 2 fingers down the throat, and artificial respiration instituted. The crisis arising from such obstruction is usually passed within 60 seconds.

TREATMENT OF FAILURE FROM ACUTE OVERDOSAGE.—From acute overdosage of anesthetic recovery is more gradual and the respiration must be carried on by artificial means sometimes for a period of 10 or 15 minutes before automaticity of respiration is reëstablished. If in addition the circulatory center has been asphyxiated or intoxicated, measures directed as in cardiac failure must be instituted.

TREATMENT OF FAILURE FROM CHRONIC OBSTRUCTION.—For the slow and chronic type of respiratory failure the best measure, as with the acute type, is preventive, in keeping the airway open and relieving the respiratory center from overwork in the early stages of anesthesia. The same treatment must be instituted as with acute asphyxia, namely, opening of the upper airway, withdrawal of anesthetic, and institution of artificial respiration. The most effective means of artificial respiration is by intratracheal insufflation of air or oxygen mixture, using about 20 liters of air per minute and interrupting the current about 15 times a minute.

The presence of carbon dioxid up to 10 per cent. in the air acts as a marked stimulus in starting the respiratory center.

**Cardiac Failure.**—ETIOLOGY.—Predisposition to cardiac failure may be due to fatty and other degenerative myocardial changes. The intoxication of disease, such as sepsis and uremia, and pathological states, prominently *status lymphaticus,* are contributing factors.

The exciting causes are: first, nervous inhibition; and, second, intoxication of the muscle by the anesthetic agent. From nervous inhibition, even before the anesthetic is inhaled, the patient may die from psychic shock. Similarly sudden arrest of the heart from nervous inhibition may be induced early in chloroform and in ethyl chlorid anesthesia by the irritation of too strong anesthetic vapors and by the psychic influence of trauma, such as the movement of a painful joint, when the patient is not sufficiently anesthetized. The heart may also be stopped early in chloroform and in ethyl chlorid anesthesia by actual overdosage of anesthetic. This commonly occurs by inhaling concentrated vapors during a period of excited breathing. Thus a wave of toxic blood passes to the left heart and overwhelms the heart muscle, even before the nervous system is affected. Ether, being less toxic to heart muscle and requiring much higher concentration, practically never causes this sudden cardiac death. Cardiac failure from gradual overdosage is rarely seen, even in chloroform anesthesia, since the signs of gradually deepening anesthesia and falling blood pressure serve as a warning. In ether anesthesia the respiratory center fails so long before the heart that arrest follows respiratory failure only when the resultant asphyxia is unrelieved.

PROPHYLAXIS.—Chloroform and ethyl chlorid should especially be avoided in the lymphoid conditions of childhood, also where adult status lymphaticus is suspected, or degenerative or toxic changes of the heart are present.

TREATMENT.—After sudden stoppage by nervous inhibition the heart beat may again become active, either spontaneously or by external stimulation, as by pressing with a hot towel about 60 times per minute over the precordia. From cessation of heart beat by acute chloroform intoxication the heart is only to be resuscitated by massaging the toxic blood out of the heart muscle and cavities. Thus in intra-abdominal operations the heart has been resuscitated by transdiaphragmatic massage several minutes after rhythmical motion had ceased. This method, as well as transpleural pericardotomy for purpose of cardiac massage, may be practiced with some slight hope of resuscitation up to 12 minutes after death. The usual drug stimulants are of no avail in cardiac failure, since circulation has ceased. As shown by Meltzer, electric stimulation by weak faradic current at the auriculoventricular sinus is the most effective stimulus in resuscitating the heart.

A method of retrograde arterial dosage with epinephrin has been suggested by Lieb. The radical artery is exposed and divided and the proximal end cannulized, as for intravenous infusion. Normal saline, 500 to 1,000 c. c., is injected into the artery under a head of 4 feet of gravity. When the flow is well established 10 minims of epinephrin solution 1:1,000 is administered by slowly injecting it by hypodermic syringe through the wall of the infusion tubing. This dose is repeated 4 or 5 times during the infusion in the hope that the epinephrin saline solution may back up and out into the coronary artery, and thus stimulate the heart muscle to again resume rhythmical contraction.

For failure of gradual onset the anesthetic, if excessive in dosage, must be diminished and an abundance of air supplied and the usual cardiovascular stimulants employed.

**Surgical Shock.**—The obscure condition known as surgical shock, characterized by a persistent fall in blood pressure, by accumulation of blood in the splanchnic area, and by lowering of all body functional activity, may arise as one of the complications of anesthesia.

ETIOLOGY.—Predisposing to this condition is any depletion of body activity such as exhaustion from pain or from disease. The exciting causes from the surgeon's side are: first, inadequate preparation of the patient physically and nervously for the operation in hand; second, excessive blood letting; third, excessive surgical trauma, particularly by rough manipulation of great joints, of periosteum, of peritoneum, and of pleura, and by traction on viscera, especially in the splanchnic area. From the anesthetist's side the exciting causes are: first, too light a degree of anesthesia during the foregoing severe surgical manipulations; second, long-continued strain on the respiratory apparatus by partial respiratory obstruction; third, chilling; fourth, a bad position of the patient during anesthesia, such as the high inverted (or Trendelenburg) position, or the sitting posture; fifth, continuously maintained intrathoracic pressure in excess of 15 to 20 mm.

TREATMENT.—Measures to be effective must lie not so much in treatment as in prevention of shock, since when the shock is fully developed active treatment is of little avail. External heat should be applied by hot blankets and hot-water bags. The various adverse or etiological factors should be so modified as to be no longer operative. The body should lie horizontally, the head slightly lowered.

The only drugs of proved value are strychnin and epinephrin administered intravenously, strychnin in dosage up to 1/20 grain, and epinephrin solution in dosage of 10 to 70 minims. Epinephrin is best administered with 500 to 1,000 c. c. of saline by intravenous infusion, injecting the drug gradually as it is needed by hypodermic syringe into the rubber tube which carries the saline infusion. When hemorrhage has been the principal factor in the causation of shock a large infusion of normal saline up to 1,500 c. c. should be administered, or 500 to 1,000 c. c. of heterologous blood may be transfused. Artificial respiration by the Sylvester method, so as to obtain a pumping effect on the blood sinuses, may be employed where respiration is much depressed. When the state of anesthesia begins to lighten, the nervous system should be blunted to psychic impressions and sensations of pain by a moderate dose of morphin. However, this drug must be used with caution, since it is an undesirable depressant of respiration when shock is acute. An effective respiratory stimulant is carbon dioxid administered by inhalation, 1 volume to 10 of air or oxygen. This also tends to relieve the venous congestion present in surgical shock.

**Nerve Lesions.**—During anesthesia various nerves may be compressed or stretched, with subsequent anesthesia or paralysis. The most common lesion is wrist drop. This occurs from compression of the musculospiral nerve in the middle third of the arm by allowing the middle third of the humerus to hang against the edge of the table. A less common paralysis is the flexor palsy of the forearm from continuous stretching of the median and ulnar nerve in the axilla by hyperextending the arm above the head during anesthesia.

PROPHYLAXIS.—The anesthetist should be ever watchful lest the arm hang over or be dropped sharply against the edge of the table. The hyperextended position of the arms should never be induced. The arms preferably are adducted at the sides, forearm extended parallel to the axis of the body, and are folded into a sheet or other band passing beneath the patient. A common position, less desirable because of restriction to respiratory movement, is with the forearms folded across the chest, the sleeves pinned together at the wrists.

With a patient in the lateral posture the arm should not lie directly beneath him. In this position care should also be taken that no edge of furniture or apparatus presses against the external popliteal nerve where it lies superficially below the head of the fibula.

## CHAPTER IV

### PREPARATION OF PATIENTS FOR OPERATION

Charles E. Farr

To prepare a patient for operation various factors must be considered, such as the age, sex, mental condition, the physical state of the various organs, and, lastly, the part to be operated upon. The preparation itself has two sides, a mental and a physical, and its object is to bring the patient to the operating table in as nearly a normal condition in each respect as may be possible.

From a superficial point of view the less mental preparation we have the better, but a certain amount of it is a necessary evil except in the mentally incompetent, such as children, idiots, and the unconscious. Worry and fear unquestionably sap the vital powers of resistance to shock and infection, while **the smooth convalescence of the emergency case is proverbial.** However, it must be kept in mind that here, as in children, we are dealing with a local lesion in tissues otherwise presumably sound. When conditions are not so favorable unpleasant sequels are only too common.

A frank discussion of the case can do no harm and, indeed, is necessary in order to obtain a legal consent, based upon a reasonable degree of knowledge. Fearful descriptions of operative details must be avoided, but there should be a clear, though brief, statement of what is to be done, giving the advantages and the disadvantages of the operation and comparing its dangers with the dangers or discomforts of the diseased condition. **The statement that an operation is without danger should never be made, as it is not true.** Even the pulling of a tooth has resulted fatally more than once. However, one may honestly say that the danger is very slight, or remote in the average case, and is far outweighed by the benefits to be attained.

Aside from this one necessary discussion all reference to operation should be studiously avoided and the atmosphere and environment of the patient should be kept as cheerful, diverting, and encouraging as possible. In particular, doleful friends and relatives, with gruesome tales of other operations of a similar kind and always with an unfavorable or fatal ending, must be excluded.

Once an operation has been determined upon nothing is to be gained by delay unless the physical or mental state of the patient can surely be improved thereby. In many conditions, however, operations which are not urgently indicated would best be postponed until every resource of medical treatment has been exhausted to bring impaired tissues or organs back to normal or as near normal as may be possible in the given conditions. Obesity, arteriosclerosis, and high blood pressure, cardiac and renal disease, intestinal toxemia, acidosis, tuberculosis, syphilis, etc., are strong contra-indications to all but the most imperative operations. Much may be accomplished, however, by intelligent medical supervision toward rendering a bad operative risk a relatively good one. Carefully regulated massage, bathing, graduated exercises, dieting, and, above all, copious water drinking, will accomplish wonders in properly selected cases. Of drugs, the tonics, cathartics, and the arterial dilators are the most useful. Specific treatment for such diseases as syphilis and malaria must not be forgotten, nor iron for anemia. All of these measures not only render the operation safer, but make the convalescence smoother and far pleasanter for the patient.

If an operation must be done in a region or in tissues partially devitalized by trauma or disease, and is not urgently indicated, it is the part of wisdom to wait for reaction to set in, if such may reasonably be expected to occur. Similarly, if the skin of the operative field is abnormal, particularly if eczema or any inflammatory condition is present, every effort must be made to cure the disease before operation. No amount of preparation can possibly obviate the danger of an established infectious process.

The preliminary preparation of the patient consists in making every effort to render him in mind and body as nearly normal as may be under the circumstances. It is only by such efforts that occasional disasters may be avoided and the final, as well as the immediate, operative result be made the best attainable.

The days preceding an operation should, so far as possible, be ones of rest, relaxation, and diversion, and the latter should be of the simplest nature. Exercise must be moderate, and nothing should be allowed to fatigue the body or mind. Business worries and household cares are especially to be avoided.

The immediate physical preparation of the patient consists in the care of the alimentary tract, the respiratory tract, the genito-urinary tract, and the skin. Cleanliness, simplicity, and safety are the main indications to be met. To begin with the alimentary tract, the first part to require attention is the mouth, including those ever-ready sources of infection, the teeth, the tonsils, and the pharynx. When time permits, too much attention cannot be given to these structures, especially if the operation is to be upon any part of the alimentary or respiratory tracts. Carious teeth should be filled or removed, deposits of tartar cleaned out, and any pyorrhea treated as effectually as possible.

Next in importance to the teeth, the tonsils ought to be examined, the crypts cleaned of any plugs, chronic abscesses opened, and, if infection still persists, the tonsils should be enucleated as a preliminary to the main operation. The pharynx also is to be inspected and any acute or chronic affection must receive appropriate treatment, consisting of mild gargles, douches, or applications of astringents, such as 10 per cent. silver nitrate solution. An excellent wash for the mouth and throat is the peroxid of hydrogen, one-half strength, with the addition of a little lime water. If this is followed by a one per cent. watery solution of thymol, or a saturated solution of boric acid, surgical cleanliness will be approximated as nearly as may be.

The nose and its accessory sinuses, the nasopharynx, the larynx, trachea, and bronchi, are prolific sources of postoperative trouble, especially when inhalation anesthesia is used. The thorough use of an oil spray, such as albolene, containing 1 per cent. thymol or menthol, will render the discharges somewhat less infectious. Any of the more serious lesions should be put in charge of a specialist.

The preparation of the alimentary tract proper is comparatively simple. The diet up to the day of operation should be light, nutritious, and easily digested, leaving slight residue. If the operation is to be upon the stomach or bowel the food and drink may well be sterilized, with the addition of buttermilk or some one of the lactic acid bacilli preparations. None of the numerous intestinal antiseptics is of any value, unfortunately. Aside from this simple regulation of the diet, the only precaution necessary is against intestinal stasis. For this a simple laxative is all that is required, or, at most, a mild purge, such as an ounce of castor oil. This should be administered on the night preceding operation and in the morning a low enema of a quart of soapsuds is given, followed, if needed, by an irrigation of plain warm water. The latter is especially indicated in operations on the rectum and vagina. These simple measures are enough. The days of prolonged fasting, violent purging, and repeated exhausting enemas are, happily, over. The patient should have at least two hours' rest before the anesthetic is administered. **In emergency cases it is better to omit the enema than to bring an exhausted patient with a half emptied bowel upon the table. The process is only too sure to be completed on the table, to the discomfiture of everyone concerned.**

The evening meal on the day preceding operation should consist of a moderate allowance of toast, cocoa, a chop or poached egg, or any other similar food of an easily digested nature. In the morning, if the operation is to be during the forenoon, nothing but a cup of coffee without milk or sugar is allowed. For an afternoon operation coffee, a roll or toast, and a soft-boiled egg may be given, but no food is to be taken within six hours of operation. The drinking of water in small quantities frequently repeated up to within a half hour of the administration of the anesthetic is an excellent thing. It allays nervous excitement, flushes the kidneys, and tends to prevent operative shock.

No hypnotic or sedative drugs, such as chloral, the bromids or morphin, should be given without the consent or expressed wish of the anesthetist. Certain conditions, great restlessness and nervous excitability, for example, require their exhibition, but in general they are much better omitted.

The preparation of the genito-urinary tract is in general very simple. The kidneys should be flushed by copious water drinking and the bladder emptied just before operation. Catheterization is needed only if retention exists. If any part of the urinary tract is infected, or if the operative attack is to be upon or near it, urinary antiseptics should be administered. The best are salol and urotropin, either of which may be given in 0.3 gm. (5 gr.) doses every four hours, or in much larger doses if deemed necessary. It must be remembered, however, that urotropin is of no value in alkaline urine. In addition to the above, the bladder and urethra, and, in the female, the vagina, should be irrigated at least every four hours with warm saline or saturated boric acid solution.

**In emergency cases if food has been eaten within six hours, in vomiting cases especially if the vomitus be of a fecal nature, and in cases of suspected gastric stasis or dilatation, the stomach should be washed out until the return is absolutely clear. The omission of this simple precaution has cost many lives. Warm water or a weak solution of the bicarbonate of soda should be used.**

Preparation of the skin has been the great stumbling block of surgical technic ever since the early days of Listerism. Practically every other detail in the aseptic technic can be absolutely relied upon, as instruments, gloves, sutures, and gauze can be boiled or sterilized by live steam under pressure, but as yet no way has been found to render the skin aseptic. Beginning with phenol, there has been a constant search for more and more powerful antiseptics and germicides, each new discovery being seized upon and exploited as the perfect antiseptic, only to be discarded in a few years at the most as too irritating to living tissues or as lacking in germicidal properties. The latest of these is iodin, now in almost universal use, and considered the acme of perfection of the antiseptic technic. Only a few of the more conservative surgeons have held aloof or, having given the iodin technic a more or less extensive trial, have returned to one of the older forms of preparation. Here and there, also, are met signs of dissatisfaction and the reaching out after something newer and better.

It is an obvious fact that skin sterilization must depend upon two factors, mechanical cleansing and chemical disinfection, as thermal sterilization is out of the question. Moreover, the amount of mechanical cleansing which the skin can bear without injury is decidedly limited. This, however, is no excuse for its omission, because undoubtedly, within its limitations, it is of great value. It is one of the great faults of the iodin technic that this important factor cannot be efficiently used.

Since, then, thermal disinfection of the skin is impossible and mechanical cleansing, although important and useful, is limited in its applicability, our main resource must be chemical disinfection. Unfortunately, our knowledge of the action of the various antiseptic and germicidal drugs on living tissues is very limited. The inhibition of the growth of the ordinary pathogenic bacteria in test tube media is a very simple thing, as the innumerable present-day antiseptics prove. The killing of these same bacteria, however, is a very different matter and is not so easy, even in fluid media. Many of the most highly vaunted antiseptics have little or no germicidal power and a number of pathogenic bacteria are highly resistant to the strongest of the germicides. It is self-evident, then, that in living tissues which are themselves extremely susceptible to the irritant action of all the chemical germicides and whose vital resistance must be preserved at any cost, the action of any antiseptic or germicide in a concentration compatible with the life and function of the tissues is very problematical. Undoubtedly, the pyogenic organisms on the surface of the skin can be killed by the more powerful germicides, such as iodin, alcohol, and the bichlorid of mercury, while those in the upper layers of the epidermis can be temporarily inhibited, during the time in which the chemical is still present, but the deeper layers of the skin, to say nothing of the underlying tissues, are entirely unaffected.

An aseptic skin is unattainable by any means at present known, and what is true of the skin is even more true of mucous membranes with their infection-harboring folds and crypts. **It may be taken for granted that all wounds are infected and that the only reason so-called aseptic wound healing occurs is that the tissues are able to overcome a certain amount of infection and that healing takes place in spite of this infection.** Unquestionably the great majority of surgical wounds would heal without gross infection if the skin received no preparation at all except simple cleanliness, provided the tissues were reasonably sound, that only aseptic materials were introduced, the wound was dry and free from devitalized tissue, and that the sutures were not drawn too tightly. The skin technic is only one, and not the most important one, of the many factors entering into wound healing. This alone makes the relative value of the various skin technics extremely hard to judge. The best clinics in this country report from 1 to 5 per cent. of infections in the so-called clean cases, regardless of the technic employed, and, although most of these are of minor consequence, their occurrence is not thereby justified.

A number of more common methods of preparing the skin will be enumerated below, but the following precaution applies to them all: Do not place implicit reliance on any skin technic, but protect the underlying tissues and the viscera from any contact with the skin or anything which has touched it.

## GENERAL DIRECTIONS

Unless special contra-indications exist, a prolonged warm bath should be taken the evening before operation, using plenty of soap and scrubbing the operative field with a coarse wash-cloth or piece of gauze. Lather and shave if necessary. This latter cannot be done with too great care, as careless shaving, abrading and cutting the surface of the skin, is a prolific source of infection. The inhumanity of the average nurse or orderly in this respect, due, of course, to ignorance or carelessness, is one of the chief minor ills of the patient's operative ordeal. After wiping the field dry with a soft mop of gauze any one of the following methods may be employed:

**The Iodin Method.**—Cleanse the skin with alcohol (95 per cent.) and apply a dry sterile dressing. After anesthesia is induced remove the dressing, dry the field, if necessary, with 95 per cent. alcohol, and apply one coat of tincture of iodin (U. S. P.). Allow to dry three minutes and cover all but the line of incision with dry sterile sheets or towels. After the incision in the skin is made fasten the towels to its edges with sutures or suitable clips.

PRECAUTIONS.—Use only freshly prepared tincture of iodin. The alcohol evaporates rapidly, increasing the irritating properties of the solution.

Apply only one smooth coat, without pressure or friction.

Avoid excess of iodin. It may collect in a pool or run into a crease in the skin and cause a burn.

Avoid soap on the field. It will prevent the efficient penetration of the iodin.

Do not use wet towels or solution of bichlorid of mercury on the skin. They increase the irritant effect of the iodin.

DANGERS.—Burns or dermatitis, due to the iodin, may result from idiosyncrasy or from careless use of the solution. They are generally of no serious importance, but are very annoying and at times quite painful. No preventive treatment seems of any great value, although it is claimed by some that by removing the excess of iodin with alcohol, either three minutes after its application or at the end of the operation, the probability of burns is nearly obviated. The alcohol must be carefully mopped on, as brisk rubbing will only increase the irritation. The treatment of an established iodin dermatitis is like that of any other similar lesion, a bland sterile dusting powder, such as zinc oxid, or aristol, usually sufficing.

One other danger noted by some surgeons is the production of extensive peritoneal adhesions by the iodin which unavoidably reaches the peritoneal cavity to a greater or less degree. This is strongly denied by others, who even go so far as to use iodin freely to prevent adhesions. The question is still undecided, but it would seem wiser to avoid unnecessary contamination.

DRAWBACKS.—Aside from the dangers noted above and from its probable inefficiency, two minor drawbacks may be noted, that it cannot be used in certain situations safely and that it obscures the landmarks of the skin. As to the former, certain parts of the anatomy, such as the eyes, are too sensitive for the efficient use of any antiseptic, and on others, such as the scrotum or perineum, a half strength solution of the iodin, using alcohol as a diluent, may be used. As to the second, the skin markings, if they are of any importance, may be preserved by tracing them on the day preceding operation with a 10 per cent. solution of silver nitrate.

**Modifications of the Iodin Technic.**—There are many variations from the above preparation, of which the most important are as follows: (1) Omit all preliminary treatment of the skin, dry shave on the table, one coat of full strength iodin. This is almost universally used as an emergency preparation, is simple, and apparently fairly safe. With many it is the method of choice. (2) Dry shave and one coat of iodin on the day preceding operation with the usual technic on the table. (3) As in (2), using one half strength iodin. (4) Like the preceding, with a preliminary treatment of a weak solution of iodin in benzin.

**The Alcohol-Ether-Bichlorid Technic.**—After the preliminary washing with soap and water and the shaving the field is cleansed with alcohol, ether, and a watery solution of bichlorid of mercury, 1:1,000. A soap poultice is then applied for a half hour or more, the field again cleaned with alcohol and ether, and a moist dressing applied of 1:10,000 bichlorid. On the table the dressing is removed and the field again vigorously scrubbed with soap and water followed by alcohol, ether, and one in one thousand bichlorid.

PRECAUTIONS.—Use only cotton, soft gauze, or a very soft brush, as the skin is very easily irritated by too much scrubbing. The soap must be very bland. A solution of castile soap is better than the tincture of green soap. The action of the soap poultice on the skin must be watched, as it may be very irritating. The bichlorid solution must not be too strong, for it may set up a severe dermatitis.

DANGERS.—The only danger is that of causing a dermatitis by too vigorous scrubbing or too strong bichlorid.

MODIFICATIONS.—There are many variations of this technic, consisting of changes in the strength of the bichlorid solution, the number of times the dressings are changed, and the scrubbing performed. A strong alcoholic solution of bichlorid may be used in the final preparation, if the skin is not too irritated.

DRAWBACKS.—This method is probably as efficient as the iodin preparation, but is far more tedious and exhausting to both the patient and the nurse. It is sloppy, uncomfortable, and irritating.

**The Lime and Soda Technic.**—This is used for the most part as a step in the preceding and consists of the application of a freshly prepared and moistened mixture of chlorinated lime and sodium carbonate. The nascent chlorin formed is a very powerful germicide, while the alkali of the mixture dissolves the superficial epithelium and allows a deeper penetration of the antiseptic. The main drawback to its use is its irritant action on the skin. It is a very useful adjuvant to other forms of preparation, especially on thick, tough, or very dirty skins.

**The Benzin Technic.**—Benzin, gasoline, and naphtha, although rather weak in germicidal power, are excellent cleansers of the skin and have been extensively used for the entire preparation of the skin. The method is very simple, consisting of a single application on the day preceding operation, dry dressing, and another application on the table. The results in a fairly large number of cases observed by the writer were excellent. Care must be taken that the agent does not collect in pools or run into creases in the skin, and that the latter is perfectly dry before it is covered, or severe burns will ensue.

Many other chemicals, notably carbon tetrachlorid, thymol, and picric acid, have been enthusiastically advocated for the preparation of the skin, but are as yet in the experimental stage. Carbon tetrachlorid has one decided advantage over benzin in that it is not inflammable. Inhalation of its fumes is very dangerous. Thymol, 5 per cent. in 80 per cent. alcohol, is a powerful antiseptic and germicide, not very irritating, and is a splendid deodorant. It does not obliterate the natural or artificial markings of the skin. Picric acid in 1 per cent. watery or alcoholic solution has about the same advantages, and the added one that it can be applied to irritated and inflamed surfaces, on which it has a decidedly soothing and anesthetic action. As applied by the writer in quite a large number of minor surgical cases it has proved exceedingly useful and reliable.

Alcohol, which forms the menstruum of many of the best germicides, is itself a powerful antiseptic and germicide and it is an open question whether or not alcohol is not the principal ingredient in some of them. A few operators have relied upon it alone, using from 50 to 95 per cent. solutions. The question of germicidal power in the various strengths is not yet settled.

Many attempts have been made to apply an impervious aseptic or antiseptic coating to the operative field, through which the incision is to be made. No great success has as yet been attained, but it may well be that the next step in advance will be in this direction. Certainly if a sheet of rubber dam or other similar substance could be firmly and evenly cemented to the skin and the incision made through it, contamination of the wound by the skin would be nearly impossible. We now use sheets of gutta-percha to protect clean wounds from infected areas, cementing them to the skin with chloroform, but we cannot be sure of the sterility of the tissue itself.

Certain regions require special methods of preparation. Thus in the eye only saline, boric acid solution (watery), or argyrol is permissible. In the external ear alcohol or an alcoholic solution of boric acid may be used. In the mouth and nose solutions of menthol or thymol in water or liquid vaselin, of about 1 per cent. strength may be of some value. The rectum will tolerate only saline irrigations, while in the bladder, saline, boric acid, or weak permanganate solutions may be used. Iodin can be safely used in the vagina if it is wiped dry afterward, but it is very questionable if irrigations of weak bichlorid or iodin solutions are not more efficacious.

In conclusion, one other most important subject remains to be touched upon, namely, the attempt to increase the resistance of the tissues to infection. If by serum, by vaccine, or by drugs we could confer even a fleeting immunity to infection by the various pathogenic organisms, all our elaborate technic of preparation, not only of the patient, but of the surgeon's hands, dressings, and instruments could be entirely discarded. In this direction lies the real path of progress, not in attempting the impossible task of destroying the innumerable infective organisms themselves. The three great sources of danger from operations are hemorrhage, shock, and infection. Of these hemorrhage is practically overcome by modern operative technic, shock bids fair soon to become so, and infection remains, conquered only in part by diligent efforts at asepsis.

# CHAPTER V

## RELATIONS OF MEDICAL DISEASE TO SURGERY

ALEXANDER BRYAN JOHNSON AND JAMES H. KENYON

## PART I

ALEXANDER BRYAN JOHNSON

Commonly, surgical operations are grouped under two heads: operations of necessity and operations of choice, expediency, or election. There can be no two decisions in regard to the wisdom of opening an acute abscess whenever practicable and as soon as may be; nor of evacuating a full bladder, somehow; whereas a man with Dupuytren's contraction of the palmar fascia may well think twice or even several times before submitting himself to a surgical operation.

Our task in this chapter will, however, be to try to help those who are perhaps less experienced than ourselves, and to jog the memory of others who desire this sort of aid in deciding in a given case and under a variety of local and general pathological conditions whether to operate or not, and also to tell in what way the preparation and after-care of an operative case may be modified to advantage in the presence of acute and chronic diseases and other local and general changes that give the surgeon pause. The task is no light one, and perhaps the title of the chapter might better have been "Surgical Judgment Made Easy or Everyman a Good Surgeon."

### ANEMIA

A profound degree of anemia from any cause adds a serious risk to any considerable surgical operation. In simple anemias, such as we see from acute hemorrhage or from repeated small bleedings—uterine bleedings, for example—the more acute the condition the more serious the effect upon the prognosis of a surgical procedure. In the most acute cases where shock and hemorrhage are combined the shock element is an absolute contra-indication to any serious operation.

**Shock.**—Active external bleeding may and should be controlled at once. This can usually be done in a few moments without anesthesia. But any formal operation, such as amputation or an abdominal operation, should be postponed until the shock has passed. Every young surgeon left to his own devices learns this from sad experience. Until this lesson has been brought home to him more than once he fails to realize that a muscular man of 30 whose shoulder has been amputated by the wheels of a locomotive, who has lost but little blood, whose pulse is slow, though not full, who says cheerfully that he has no pain and "is quite comfortable," and who is pale and bathed in a clammy sweat, is the worst possible surgical risk. Some 24 or 48 hours later he may be able to endure a formal amputation or disarticulation at the shoulder joint with but little risk. Now, while in shock, the same operation is murder pure and simple.

**Chronic Simple Anemia.**—Chronic simple anemia uncomplicated is, on the other hand, by no means so serious an added risk. The common rule has been that less than 30 per cent. hemoglobin contra-indicated a serious operation.

One of the most common types of this sort is seen in women reduced to severe anemia by uterine bleeding from causes other than cancer. In these cases it is astonishing that hysterectomy may be done successfully with a percentage of hemoglobin of 20 per cent., and even, as in one case that came under my observation, of 12 per cent. To be sure, the reparative power of the tissues is much reduced, and in these cases the operative wound takes much longer to form a solid scar. There is, I think, also more danger of infection, slight or severe, than in persons in ordinary health.

When similar grades of anemia are caused by or accompanied with a cancerous cachexia or a septicopyemia death follows any serious operation with great regularity.

In some anemic cases, more especially when uncomplicated, transfusion from a suitable donor may be a very valuable preparatory measure indeed.

In some cases of chronic sepsis combined with anemia repeated transfusions have rendered successful operations possible.

## TYPHOID FEVER

Typhoid fever during the active course of the disease is a contra-indication to surgical operations, except those of necessity.

The complications often call for surgical interference, either immediate, as in cases of perforation and of acute suppurative processes, wherever situated, or, later, after the fever has run its course and the patient is suffering from one or more of the numerous sequelæ, such as a typhoid joint, osteomyelitis, cholecystitis, abscess in the skin and deeper soft parts, middle ear disease, or some other of the lesions left after the intestinal ulcers have healed.

It may be understood that, since in a large proportion of cases, 85 to 90 per cent., the typhoid bacillus is circulating in the blood and often causes purulent inflammations wherever it may lodge, the list of surgical complications of the disease is a long one. The more common ones are here enumerated; their treatment will be found in other sections of this work under appropriate headings.

1. Perforation of the bowel.
2. Hemorrhage from the bowel.
3. Typhoid appendicitis.
4. Typhoid infection of the biliary passages and of the liver.
5. Typhoid cholecystitis with perforation.
6. Typhoid rupture of the spleen and typhoid abscess of the spleen.
7. Stricture of the esophagus following typhoid.
8. Typhoid inflammation of the bones and periosteum.
9. Typhoid arthritis.
10. Typhoid spine.
11. Typhoid larynx.
12. Bed sores.
13. Typhoid gangrene of the extremities.
14. Typhoid abscesses, subcutaneous or in special organs other than those mentioned.
15. Typhoid inflammation of any mucous membrane.

During the early days of the disease it has happened that a diagnosis of appendicitis has been made, and the appendix removed. As a rule, these patients have done well, the operative wound has healed, and the disease has run its course without apparent modification.

**Perforation.**—In regard to operation for typhoid perforation. Success depends upon: (1) Early diagnosis; (2) early operation; (3) rapid operation; (4) simple procedures; (5) the general condition of the patient as affected by the typhoid, and by the added effects of the septic peritoneal absorption. Within the past few years the results have been much improved. Thus, in the Montreal General Hospital during the year 1909 and up to May, 1910, Armstrong reported 22 typhoid perforations, 19 of which were operated upon and 9 of whom, or 47 per cent., recovered.

**Other Acute Abdominal Conditions.**—Other acute abdominal conditions may simulate perforation during typhoid; among them may be mentioned acute appendicitis, typhoid perforation of the appendix, intussusception, mesenteric thrombosis, volvulus, acute obstruction by bands, and strangulation or perforation of Meckel's diverticulum, also spontaneous rupture of the spleen and rupture of the gall bladder. All these conditions are indications for immediate operation since in all delay is fatal.

Intestinal hemorrhage may be an indication for operation in exceptional cases. Transfusion of blood may be indicated.

**Typhoid Gangrene.**—Typhoid gangrene of an extremity is not a very frequent complication. The mortality is high, amputation of the lower extremity having been fatal in nearly half of the cases. An effort on the part of the tissues to form a line of demarcation should be encouraged in every way—by dry heat, dry antiseptic dressings, elevation of the limb, etc.—in the hope of improving the general vitality before amputation is done.

## TYPHUS FEVER

The depression of vitality in this disease is extreme. Operation for its surgical complications are, therefore, attended by a high mortality. These are by no means so frequent and varied as in typhoid. The most common are gangrene, usually of a lower extremity; ulceration of the fauces with possible edema and mechanical dyspnea; and empyema.

Gangrene, when it occurs, is due to the lowered vitality of the tissues, followed by arterial or venous thrombosis, or both, less often by embolism. Preexistent diabetes or arteriosclerosis or both are believed to be predisposing causes. The popliteal is the artery most often involved, next the femoral, the aorta, and the iliacs. In the lower extremities a line of demarcation may form, or none. In the latter group amputation must be done early and well above the advancing area of necrosis to be effective. The mortality is very high, probably nearly 75 per cent. Edema of the larynx demands tracheotomy and empyema drainage of the pleura.

## SMALL-POX

The relations of small-pox to surgery consist merely in the treatment of the suppurative complications and of the sequelæ of the disease.

The most frequent are furuncles, deeper abscesses, erysipelas, and ulceration of the larynx and fauces; less frequent are bed sores, progressive and fatal gangrene of the skin and subcutaneous tissues, noma, and suppurative or gangrenous parotitis. Empyema is not common. Cicatricial deformities of the eyelids may require plastic operations. In certain epidemics diphtheria is a complication. These several conditions demand appropriate treatment described elsewhere in this work.

## CHICKEN-POX

(*Varicella*)

Surgical complications are rare in this disease. As in all conditions furnishing open atria for infection through the skin, local and general septic processes are possible, and may be severe or fatal. Thus, in rare instances, streptococcus septicemia, erysipelas, localized gangrene of the skin, and joint lesions have been noted. Death resulted in a few instances. The treatment is that of similar lesions whatever their origin.

## SCARLET FEVER

*(Scarlatina)*

Surgical complications during or after an attack of scarlet fever are by no means rare. They demand watchfulness on the part of the medical attendant lest they escape notice until far advanced, and when recognized may require immediate surgical treatment. Some of them are of grave import and some only annoying.

The disease itself is a septicemia of a specific sort, and seems to invite a secondary invasion, local or general, of the common pyogenic microbes. Indeed, streptococcus septicemia complicating the disease is the cause of death in not a few cases.

Scarlet fever as a complication after surgical operations, other wounds, burns, and during the puerperium is of occasional occurrence and may render the prognosis grave. The infection may precede or follow the trauma. In the latter group both the lowered vitality and the raw surfaces may favor infection. These conditions were formerly spoken of as "surgical scarlet fever." In earlier days septic rashes, after surgical operations, were more common than at the present, and were doubtless mistaken for scarlet fever in some cases. At present the above term is rarely used.

**The list of pyogenic processes complicating or following scarlet fever is long. The most frequent is otitis media. Deafness and chronic middle ear disease only too often mark the individual for life. In the statistics of various observers infection of the middle ear occurs in from 10 to 50 per cent. of the cases.** It is usually bilateral with a purulent or mucopurulent exudate. Mastoiditis is not very common. The antrum of Highmore and the sphenoidal sinuses are rarely involved.

**Otitis Media.**—Otitis media may occur as early as the third day of the disease, or at any time until complete convalescence. It occurs more often and is of a more severe type when the throat symptoms are marked. When it occurs early it is more apt to be masked by other symptoms and to pass unrecognized until the ear drum bursts and a discharge appears at the meatus; when it occurs later severe pain in the ear and a rise of temperature are present.

**Early incision of the drum head is indicated in all cases, followed by frequent irrigations with warm boric acid solution,** in order to wash out the sticky discharge and keep the drainage free. Cessation of this discharge, with return of pain and fever, demands examination of the ear and reopening the drum if the former incision is closed. Mastoiditis demands operation.

**Affections of the Lymph Nodes.**—The lymph nodes of the neck are regularly enlarged in scarlet fever, the increase in size may be slight or marked, in the latter group the swollen glands may gradually subside or suppurate.

*Suppuration* may occur early or be delayed for weeks. It is indicated by the usual signs: Pain, tenderness, fever, and leukocytosis. Suitable and liberal incisions for drainage are indicated.

**Paronychia.**—Pyogenic infection at the root of the nails is frequent during desquamation. Scratching and picking with infected finger nails is the cause. In some cases small incisions and suitable dressings may be required. Painting the finger tips with iodin may prevent infection of the other fingers.

**Albuminuria and Nephritis.**—Albuminuria is almost regularly present during scarlet fever. It is not necessarily accompanied by marked organic changes in the kidney and usually ceases during convalescence. Nephritis is not a rare complication and may terminate fatally from uremia. *Chronic nephritis* following scarlet fever occurs once in 250 cases.

In selecting the anesthetic to be given to an individual who has recently had scarlet fever, *examine the urine.* If nephritis is present local anesthesia or gas and oxygen in suitable cases may be safer than ether or chloroform.

**Arthritis.**—Arthritis is a complication of scarlet fever: the joints rarely suppurate, but if they do they must be drained. The streptococcus is the most frequent organism found in the pus.

ACUTE POLYARTICULAR ARTHRITIS (ACUTE ARTICULAR RHEUMATISM).—Acute polyarticular arthritis may occur and demands suitable treatment: rest, local applications of methylsalicylate, and internal medications.

**Peritonitis.**—In bad cases of scarlet fever diffuse peritonitis may occur, apparently without discoverable localized origin. The patients are septic and the outlook is grave.

## MEASLES

Much the most common medical complication of measles is bronchopneumonia. Lobar pneumonia may occur and be followed by empyema demanding operation. Among the other pyogenic complications are boils and noma. Osteomyelitis and arthritis are rare, as is also otitis media.

## DIPHTHERIA

Laryngeal diphtheria demands intubation or, if this cannot be done, tracheotomy. The general use of antitoxin has diminished the frequency and severity of this complication.

Otitis occurs in about 4 per cent. of the cases and demands incision of the drum head. Cervical adenitis is a regular concomitant of diphtheria, the swelling may be moderate or excessive, and may end in resolution or in suppuration. Incision for drainage is indicated in the latter group.

## WHOOPING-COUGH

The presence of a spasmodic cough from any source is a contra-indication to operations of expediency, notably on the abdomen—for example, hernia—since, during violent coughing, the suture line may be weakened or even broken open.

If an abdominal operation becomes *necessary* especial care should be used in suturing the aponeurotic structures of the abdominal wall. A continuous suture of chromic gut may be reinforced by a series of interrupted stitches of the same material. **It is never wise to use buried sutures of non-absorbable material under these conditions.** In addition, the wound edges and the entire belly wall should be supported by carefully placed masses of gauze so applied that the zinc oxid plaster strips placed over all shall really support and keep quiet the abdominal muscles.

## MUMPS

The surgical complications of mumps are chiefly two: otitis media and edema of the glottis. The complication orchitis does not proceed to suppuration, though it may lead to atrophy of the testis. Otitis is treated by early incision of the drum head. Edema of the glottis by inhalation of medicated steam from a croup kettle. For this purpose compound tincture of benzoin, one dram to a pint of water, answers well. Preparations for instant tracheotomy should be made and a cannula placed in the wind pipe when asphyxia threatens.

## INFLUENZA

In epidemics of influenza accompanied by pneumonia as a frequent complication, abscess and gangrene of the lung as well as empyema are observed. They demand operative treatment when the local and general conditions permit. (See Vol. II.)

## EPIDEMIC CEREBROSPINAL MENINGITIS

The surgical complications of this disease are otitis media, very common, and purulent arthritis, very rare. Panophthalmitis has been observed. The otitis may readily be overlooked; so common has been this complication in certain epidemics that puncture of the drum head has been recommended as a routine measure.

**Lumbar Puncture.**—Lumbar puncture has been used both as a diagnostic and therapeutic measure. As a means of treatment it has not given encouraging results. It may, however, be tried, 30 c. c. to 50 c. c. of cerebrospinal fluid being withdrawn in the usual manner. It can scarcely be considered an efficient method of drainage in these cases.

## ERYSIPELAS

Erysipelas is caused by a particularly active form of the streptococcus pyogenes.

During recent years the number of cases seen in our surgical wards, or, more properly, developing in patients who are recovering from operations in such wards, has greatly diminished. This is partly owing to better wound treatment and partly because, when a case of erysipelas comes to, or develops in, the ward of a general hospital, it is either isolated or transferred to a special hospital at once. No ordinary isolation will suffice. The patient should be placed in another building or in some specially arranged part of a building with a separate entrance. Medical attendants, nurses, and orderlies should be detailed for the care of the case and should not come in contact with other cases. During all handling of the patient special clothing and rubber gloves should be worn.

The patient himself should be bathed frequently, and should have frequent changes of body and bed clothing. The baths may well be of 3 per cent. boric acid solution after the use of soap and water. **Upon recovery he should receive several thorough baths.** The hands and hair should be thoroughly disinfected. All fomites should be disinfected either by steam or formalin solution, and the apartment disinfected with formaldehyd gas.

**Not only are persons with wounds likely to contract erysipelas, but also persons with medical diseases or healthy persons who may have some slight abrasion of the face or a fissure within the nostrils.** In cases of facial erysipelas this last is a very common portal of entry, the contagion being conveyed by the fingers.

The surgical complications of erysipelas are numerous: Abscesses, gangrene of the skin, lymphadenitis, phlebitis, pneumonia, empyema, septicemia, pyemia, otitis, edema of the glottis, arthritis, and delirium tremens.

James M. Anders, in Osler's "Modern Medicine" (Vol. II, Chap. XX), gives analyses of 1,674 cases with especial reference to complications, with results as follows: Abscesses, 105; arthritis, 20; delirium tremens, 10; lobar pneumonia, active delirium, phlebitis, pleurisy, each 7; acute nephritis, 6; synovitis and diarrhea, each 5; tonsillitis, 3; catarrhal pneumonia, otitis media, edema of the larynx, acute bronchitis, each 2. The most fatal complications are lobar pneumonia and delirium tremens.

**Abscesses.**—The most frequent site of abscess is the face (eyelids) and scalp. They give the usual signs of subcutaneous abscess and should be opened early. They may be single or multiple, and are usually of moderate size, but in bad cases they may attain large proportions and be followed by extensive sloughing of the skin and subcutaneous tissues.

When on duty in the erysipelas pavilion of Bellevue Hospital many years ago I saw a number of cases in which these abscesses were very large, took long to heal, in spite of free incisions, and left ugly scars. The most extensive were in the neck and scalp.

Several epidemics of erysipelas occurred in the surgical wards during the time I was surgical interne at Bellevue, and I saw others later in Roosevelt Hospital. The speed of transmission from patient to patient was striking. Thus, in a male surgical ward of 18 beds, a man was admitted with a severe scald of the genitals and abdominal wall produced by a bursting steam pipe. Within a day after admission the characteristic intensely red blush of the skin had appeared at the margin of the scald of the scrotum, the man had a chill and a high temperature, was removed to the erysipelas pavilion, became delirious, and died comatose in less than 48 hours thereafter. A man in the next bed had been operated upon for a fracture of the patella, he developed facial erysipelas, but survived. Across the ward lay a man with a simple fracture of tibia and fibula, and on the same day he developed erysipelas of the face. Three beds removed from the first case was a man with inoperable cancer of the neck, whose common carotid artery had been tied. Three days after the first case he had erysipelas in his wounds and then erysipelas of the pharynx, with edema of the larynx, and died in spite of early tracheotomy. Another patient near by had a perineal section for stricture of the urethra. Within a few days he had erysipelas and died. There were 8 deaths in this ward as the result of this epidemic, and the lesson has never been forgotten.

The disease is infectious and contagious. In those early days we knew nothing of proper precautions and the hands of orderlies and surgeons infallibly carried the infection from one patient to the other. I have heard eminent surgeons say that erysipelas in a ward caused them no anxiety. To them it was no more than any other infected wound. Such a view does not agree with my experiences. I have seen the disease recur after months of exemption and believe that the germ is a peculiarly resistant and enduring form, not to be regarded lightly, and that it should receive most careful attention from the beginning. Only in this manner can a hospital be protected from such infection. The use of rubber gloves for all examinations and dressings is the best means at our disposal to avoid this particularly unfortunate and disastrous type of wound infection. Infection with erysipelas may have a beneficial effect on sluggish wounds and on sarcomata—more rarely on carcinomata.

In the extremities the abscesses and necrotic processes may be localized, or diffuse. When circumscribed they resemble subcutaneous abscesses elsewhere, are easily discovered, and demand early incision. When diffuse, extending, for example, from the ankle to the knee, or from the wrist to the clavicle, they require, for the relief of tension and evacuation of pus, cuts of unusual length from the ankle to the knee or thigh, from the wrist to the clavicle. All tension must be relieved, all pockets drained. The operator must remember that a **cut in the skin two feet long** is as nothing compared to the life of the patient, and that such cuts are of no great consequence since they do not as a rule impair the usefulness of a limb and heal quite rapidly.

**Gangrene of the Skin.**—A peculiarly deadly form of streptococcus infection combined with putrefactive microbes may complicate cutaneous erysipelas or occur alone. This disease has been called "erysipelas alba." It results in a progressive necrosis followed by putrid decomposition of the subcutaneous tissues and connective tissue planes. **The skin may show no redness, but only a boggy edema.** The most fatal forms occur in the neck, and death from septic absorption or edema of the larynx may occur in two or three days.

The widest incisions and the use of antiseptics in the wounds and all pockets may stay the process. Tincture of iodin or Chlumpsky's solution may be used.

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|---|---|
| Camphor | 60 |
| Carbolic acid | 30 |
| Alcohol | 10 |

An excess of this solution must be carefully wiped away with gauze swabs gently applied. The wound cavities may be lightly packed with gauze saturated in the above solutions. Frequent changes of dressings are required, daily or twice or three times daily. Pocketing should be sought for, and all pockets laid open as soon as found. Most of these cases die in spite of every effort for their relief.

Stimulants in every form should be given in large doses; in young subjects alcohol in large quantities may be used with advantage, such as brandy, whiskey, or rum.

**Lymphadenitis.**—Lymphadenitis is seen most often in the neck and groin. If it ends in suppuration, incisions will be required, **not enucleation of the glands.** This is a conclusion arrived at after a long experience in the surgery of infected wounds.

**Phlebitis.**—Phlebitis is observed in the veins of the lower extremity. Rest, cotton, and bandaging, with slight elevation of the limb and absolute immobility, are indicated.

**To avoid the danger of embolism the quieter the patient is kept the better.**

**Pneumonia and Empyema.**—Pneumonia is, as stated, one of the most fatal complications of erysipelas. It may be a streptococcus pneumonia or a pneumonia due to the pneumococcus. It is followed in a small proportion of cases by empyema, giving the usual signs, and demanding the resection of a rib and drainage. The pneumonia in these cases is often a terminal phenomenon lasting only a short time and ending in death, and in most instances little can be done. Several portions of the lungs may be involved in succession—"wandering pneumonia."

**Delirium Tremens.**—The chronic alcoholic is peculiarly susceptible to infection with erysipelas. If the alcoholism has resulted in serious organic changes in the liver, kidneys, alimentary tract, heart, and blood vessels the prognosis is grave.

It is better not to withhold alcohol in these cases, but to give it in moderate quantities, to force the ingestion of milk, eggs, and broths at frequent intervals. (This is contrary to the opinion of good observers of large experience, notably Alexander Lambert. In delirium tremens uncomplicated with infection I agree with him.) (For the use of drugs and other measures, see Delirium Tremens, page 166.) Other stimulants, strychnin, digitalis, and camphor, may be given and an effort made to induce sleep. Paraldehyd seems to be as efficient as any drug for this purpose. When asleep these patients should on no account be disturbed.

These patients may require restraint, by a sheet passed across the body and by suitably arranged rolls of gauze or muslin tied to the wrists and ankles. A method in use for many years at Bellevue Hospital is efficient, easy to apply, and much easier to bear than a straight jacket. It is described as follows by Lambert.

> "There is no question that these patients should be confined to bed during the entire delirium stage, as in the wilder delirium it is often necessary to restrain them by a sheet tied around their ankles and then tied to the foot of the bed, and by another sheet which goes from the bed up over one shoulder, down through the axilla, across the back to the opposite axilla, out across the shoulder, up to the bed; the wrists, when necessary, can be restrained by a muslin bandage wrapped around over cotton wool, which thus prevents abrasions and holds them firmly; sometimes a folded sheet stretched across is sufficient to hold them in bed."

The other surgical complications of erysipelas will receive due attention elsewhere since they possess no distinctive peculiarities.

## STATUS LYMPHATICUS

Persons with status lymphaticus should not be operated upon if it is possible to avoid it. They are very bad surgical risks and often die merely from the administration of a general anesthetic. Unfortunately the condition may not be recognized until it is too late. These individuals are peculiarly susceptible to poisons of all kinds, **notably to ether and chloroform, and to acute infections, and they succumb to slight injuries and operations. If occasion arises where operation must be done it might be safer to use a local anesthetic, novocain, not cocain.**

So important is the recognition of this condition in order to avoid a fatal result from some relatively slight operative procedure that I quote from Johnson's "Surgical Diagnosis" (Vol. III, pages 705, 706, 708):

### EXTERNAL APPEARANCES

The body is graceful in its proportions, except in disease, well nourished, and rarely obese.

The conformation of the limbs is most characteristic, especially that of the thighs. These are well rounded, **arched anteriorly and laterally,** the latter being the most noteworthy feature. The lateral and anterior arching exists both in male and female, and in both sexes the pelvis may be small. The upper arms are rounded, the shape being graceful; the forearms are not rounded, except in marked cases. The muscular development, even when excessive, does not cloak these appearances, some of the most marked cases having occurred in muscular male cadavers. This configuration cannot be considered as a female type of build, but rather a persistence of the juvenile contour.

**The skin** most frequently has a glossy, less often a pasty, appearance, as was first brought out by Escherich and Daut.

**Hair.**—The hair upon the pubis is distinctly feminine in distribution, confined to the suprapubic fat pad, the superior edges being sharply marked off. The hair may be abundant, but it is never absent, except in the young. A few hairs may extend up the line toward the umbilicus.

Axillary hair in adults is usually scanty, although the individual hairs may be long. Hair on head may be abundant even in less marked cases. It is coarse, straight and lusterless.

Hair on Limbs.—Even in subjects having the usual amount of hair, the thighs are, except for lanugo, free of hair, even when the legs and forearms are hairy. The same is true for the upper arms.

**The head** is brachycephalic in type.

**The neck** is implanted squarely upon the upper thoracic opening. It may be either long, thin, and columnar, or short and thick.

**Genital Organs.**—A few of the marked cases present evidences of infantilism, the external genitals being small. This infantile type of the genital organs is, however, exceptional, even in those cases associated with a hypoplastic condition of the aorta and arterial system. The glans penis is frequently pointed like an acorn.

Many of the above characteristics may be absent, the most **constant** being the **peculiarity of the thighs.**

Thus, the pubic hair may be normal or excessive, running up to the linea in normal adult males. This is, however, exceptional.

Our experience at the morgue teaches us that the external appearances are of considerable importance in diagnosing the presence of the *status* cases, especially those which are recessive in type. It is certainly a striking fact that time after time, without clinical history, the diagnosis has been made before autopsy.

1. Status lymphaticus is characterized by hyperplasias of the lymphatic structures associated with persistence or enlargement of the thymus gland beyond the age of puberty, with arterial hypoplasia and possibly with hypoplasia of the chromaffin system.
2. Cases of this state have characteristic external appearances, especially in respect to general conformation of the body and distribution of the hair.
3. This constitution represents a constitutional anomaly, and not a mere persistence of the infantile type or an arrest of development. Infantilism is, however, not infrequently associated with it.
4. Individuals with this constitution have a special predisposition to disease, and increased susceptibility to various insults.

5. The frequency of the lymphatic constitution has not been sufficiently emphasized, nor has sufficient account been taken of it in its wide medical, surgical, and insurance aspects, especially its relation to prognosis and duration of life. We have found this condition in about 2 per cent. of over 2,000 autopsies.

6. Not all the individuals with the lymphatic constitution succumb to disease. Many survive to adult age. The various lymphatic structures thereupon tend to undergo recessive changes.

7. The lymphatic constitution is noted with especial frequency in diseases of the ductless glands (Basedow's, acromegaly, Addison's, and in tumors and diseases of the pineal gland) and in diseases such as epilepsy, which are probably due to disorders of internal secretion.

8. The thymus is an epithelial organ, and not a lymphoid structure.

9. More exact knowledge of the thymus, in its relation to general lymphoid hyperplasia, to the onset of spermatogenesis, and the development of the secondary sexual characters is vital to any further progress in the elucidation of important physiologic and pathologic consideration of health and of disease.

## LOBAR PNEUMONIA

Lobar pneumonia is a contra-indication to all operations except such as are rendered necessary by the complications of the disease itself. It is worthy of note that in earlier stages of pneumonia, before the physical signs are well marked, or in cases where the diaphragmatic pleura is first involved, errors in diagnosis are not very rare.

Pain may be referred to the abdomen, and abdominal rigidity may be well marked. Highly competent surgeons have opened the abdomen in search of an inflammatory focus and found nothing abnormal, and the signs of pneumonia have appeared the following day or later.

I came near doing this myself a short time ago in a case where a few days before I had removed a tuberculous testis associated with inguinal hernia. The patient developed a temperature with very severe pain referred to the left upper quadrant of the belly and back. A probable diagnosis of a tuberculous kidney was made. Within two days signs of pneumonia in the lower lobe of the left lung were recognized, and no operation was done. The patient survived and left the hospital apparently quite well.

The surgical complications of pneumonia are few but very serious. The most important are empyema, abscess of the lung, gangrene of the lung, pneumococcus arthritis, pulmonary embolism, and peripheral venous thrombosis.

**Empyema.**—In from 2 to 5 per cent. of the recorded cases pneumonia is followed by empyema. The exciting germ may be the *pneumococcus,* or the *streptococcus.* The percentage varies in children and adults. Ewart found that in children 75 per cent. of all the empyemata were caused by the pneumococcus, 25 per cent. by streptococcus pyogenes. In adults the percentages were reversed.

The treatment of empyema, as soon as the presence of pus in the pleural sac is verified by the aspirating needle, is drainage of the pleura by resecting an overlying rib and introducing one or more large rubber tubes. N. B. The tubes should have large safety pins thrust through their outer ends lest they slip in and be lost in the cavity, a most annoying accident. (See Vol. I, Chap. VII, "Aspirating Devices in Surgery.")

It is not wise to irrigate the pleura. If the patient is weak, is breathing badly, and is cyanotic, a rib may be resected under local anesthesia. The procedure is very painful and distressing. I seek to avoid it whenever possible.

**Abscess of the Lung.**—The treatment of abscess of the lung is drainage when practicable. (For technic see Vol. II.)

The other complications of pneumonia are rare, nor does their treatment require special mention here.

## ALCOHOLISM

The habitual use of excessive amounts of alcohol greatly increases the risk of surgical operations, and renders prognosis after an injury or in cases of any infection much more serious. The longer the individual has had the habit and the larger the quantity of alcohol he takes daily so much the worse, and yet, here, careful discrimination is necessary. Alcohol is a poison to all, but it acts differently on different individuals. There are men who have taken more than a quart of whiskey every day for many years, who yet recover from a serious injury or a serious infection requiring operation without much trouble, even though all alcohol be withdrawn at once. They are, indeed, the better for the withdrawal. They are, as a rule, men who have led active lives out of doors.

In other cases even a moderate alcoholic habit may cause the patient to become delirious after a surgical operation or to develop pneumonia and die. Among alcoholics in general, it is to be remarked that pneumonia is very fatal.

In some cases when alcohol is withdrawn, the patients, for a few days at least, are greatly depressed. If in this group an operation is believed to be necessary and there is no indication for immediate action, the best treatment I know of is as follows: Keep the patient in bed. Feed him with milk, eggs and broths at frequent intervals, keeping his stomach full of these things, given preferably *hot*. Keep his bowels open with, first, a large dose of calomel (℞ Calomel grs. ii, iii or iv with Sodium Bicarb., grs. x) followed by ½ to 1 ounce of magnesium sulphate, the following morning. Give him Tinct. Nux Vomica m. x, t. i. d. in water a. c. and every morning for two weeks. Carlsbad salts ℥ss in hot water before breakfast. Iron and other tonics may be given if indicated.

One of the best drugs I know of as a tonic and sedative is asafetida in doses of 3 grains four times a day; it is well combined with extract of nux vomica, $\frac{1}{8}$ grain, or $\frac{1}{4}$ grain of powdered nux vomica. It is astonishing to see how these patients will improve under this treatment. In a fortnight they may be so much better that any ordinary operation—for hernia, for example, or a stricture of the urethra—may be performed with good convalescence. The three cardinal points are:

(1) Rest in bed.
(2) The bowels open.
(3) Plenty of easily digested food.

When a man long dependent upon alcohol is put in bed and kept there with no necessity for physical or mental effort, when he is fully fed with simple food, and his bowels kept freely open, he loses quickly the craving for drink. He may lie more or less quietly, or for a day or two may be a little restless, but after a very few days, if not obliged to exert himself, the craving passes off and soon he becomes almost if not quite normal. These remarks apply to the average young or even middle-aged drunkard whom we see in the hospitals. He should be protected from the necessity of worry and mental or physical effort.

It is rarely necessary to give a sedative for more than two or three nights to induce sleep. Such sedatives as veronal, trional or paraldehyd may be employed. An old formula which agrees with most people is useful when these patients are very nervous. It may be varied to suit the individual case. It is as follows:

℞

Bromid of sodium....................................gr. xxx
Chloral hydrate .......................................gr. x
Tr. of nux vomica.....................................m. x
Tr. of capsicum........................................m. v
Water up to a drachm.

M. Signa, a teaspoonful every 4 hours in water.

This dose may be given well diluted with water every three hours until the patient is quieted, when the intervals may be increased. If the heart is dilated or weak, digitalis may be added.

In some cases, chloral in doses of this size seems to make the patients more excited. In these cases the dose of chloral may be doubled and caffein added or some other drug must be chosen. In my experience, much larger doses of chloral may be given to induce sleep if the heart is in good condition. After a few days these sedatives can be omitted; they tend to produce a certain degree of mental and physical depression.

In the treatment of alcoholism, A. Lambert places a high value on the hypodermic use of ergot, combined with strychnin. He warns against giving these drugs by the stomach, more particularly in delirium tremens, lest they accumulate in the stomach and later be absorbed suddenly and in dangerous quantity.

In deciding for or against a serious operation in the given case, the following conditions—one or all—will render the prognosis more serious or very serious: Marked arteriosclerosis, a rapid, feeble and dilated heart, i. e. a degenerated heart muscle, marked chronic gastritis, chronic nephritis, obesity, premature senility, well-marked cirrhosis of the liver.

No sane man would think of operating on a patient with delirium tremens, but, as the result of accidental trauma or infection, the surgeon is often called upon to treat these conditions, more especially in hospitals. When a patient who has an alcoholic habit is received in a hospital suffering from an accidental trauma, **it is wise in my opinion to give alcohol in moderate and diminishing quantities for about a week, together with the sedatives just mentioned.**

When delirium occurs it appears on the second or third day or may rarely be delayed until the sixth. When active delirium develops, the treatment already outlined in the preceding pages may be used.

The treatment used by Lambert in Bellevue Hospital is as follows:

Alcohol should be absolutely withdrawn in all cases.

First and foremost, all these patients must be treated from the standpoint of those having a degenerated heart muscle, and they therefore should be stimulated with strychnin (gr. 1/60-1/30, gm. 0.001-0.002) every four hours or oftener, or by caffein or camphor, and these are best given hypodermically. Strong coffee or tea can be given in mild cases instead of the pure caffein. The patient should be given a purgative such as compound cathartic pills, compound licorice powder, or calomel. In young, vigorous adults, without any appreciable change in their arteries, who have recently been drinking, an emetic such as copper or zinc sulphate is often an advantage. These should never be given to elderly persons or to those who appear old for their age.

In mild and abortive attacks a dose of a dram of paraldehyd, repeated if necessary in an hour, is all that is necessary to cause sleep, from which the patients frequently awake either clear-headed or with their delirium lessened. In the severer cases the paraldehyd may be given in dram doses, at hour intervals, even up to three doses. Other hypnotics, such as sulphonal, trional, etc., have in the hands of the writer usually failed utterly except in the mildest cases. Opium should be resorted to only as a last resort, and is especially contra-indicated with pronounced arteriosclerosis. Hyoscin (gr. 1/125, gm. 0.0005) and morphin (gr. 1/6-¼, gm. 0.01-0.015), hypodermically, should only be given to young and vigorous individuals in whom the motor symptoms are especially marked. Hyoscin alone tends to increase the delirium, especially in women. Often in the severest cases a mixture of hyoscin, gr. 1/100 (gm. 0.0006) with apomorphin, gr. 1/10 (gm. 0.006) and strychnin, gr. 1/30 (gm. 0.002), will quiet them and give at least a few hours' rest. Bromids are insufficient, and in the hands of the writer have been practically useless.

Chloral is one of the best drugs when properly administered; small doses are useless, and Lancereaux claims that they even tend to excite these patients. When the heart is properly stimulated chloral hydrate does not have any deleterious effects. Lancereaux recommends thirty to sixty grain doses (gm. 2-4); the combination of chloral and morphin is especially advantageous in that smaller doses of each can be given and the mixture be more effective than either singly. The mixture of morphin, gr. ⅛ (gm. 0.008), chloral, gr. 15-30 (gm. 1-2), with tincture of hyoscyamus, ʒss (2 c. c.), tincture of ginger, m. x (c. c. 0.6), and tincture of capsicum, m. iii (c. c. 0.2), and water to ℥ss. (c. c. 15) is very effective, and can be repeated at the end of an hour.

These hypnotics, while causing sleep, do not necessarily cut short the delirium, but after a sleep of some hours the delirium is often quieter and there is the further advantage of rest for the heart from cessation of motor excitement. Of late years the writer has used ergot hypodermically in Livingston's solution, which is as follows: One dram of the solid extract of ergot is dissolved in an ounce of sterile water and three drops of chloroform and three grains of chloretone are added, and the solution filtered; this is sterile and should be given straight into the muscles in the gluteal region or in the deltoid. It should never be given subcutaneously; if carelessly given, it will produce painful spots. The administration of thirty drops of this solution, hypodermically, every two to four hours, reduces the dilated blood vessels, lessens the various congestions, and brings about a better equilibrium of the circulation. After it there is a distinct tendency to a quieter delirium and less need of restraint; it reduces the tremor, less hypnotic is required, and it diminishes the tendency to "wet brain." The writer has never seen symptoms of ergotism, although thirty minims of this solution were given every two hours for ten days or longer. As soon as patients awake they must be given food, best in the form of milk or milk and eggs. This should be given regularly every two or three hours during the delirium, but if asleep they should not be awakened for any reason.

The treatment for the "wet brain" condition should be begun as soon as it is suspected. Strychnin, gr. 1/60 to 1/30, and ergot, 30 minims, both hypodermically, should be given every two hours, and caffein and camphor are also of use. The patient should be carefully fed every two hours with milk, broth, and eggs, and thorough purging is advisable. Alcohol seems to increase the effusion, and should not be given. During convalescence, however, a little alcohol in the form of eggnog, two or three times a day for a few days is often of benefit.

A treatment has been published by McBride of Toronto, which has proved very successful in his hands. The writer has tried it in a few patients, and so far the results have been all that could be desired. It is as follows: As soon as the patient is over the severe effects of his debauch, or if he is steadily drinking without any drunken outbreak, he should be given, hypodermically, three times a day, atropin and strychnin, of each gr. 1/100 (gm. 0.0006); these drugs should be gradually increased until the full physiological effect of the atropin is obtained and the patient is taking a thirtieth or even a twentieth of a grain of strychnin three times a day; when the mouth is continually dry and the pupils dilated, the atropin should be reduced slightly and held at this dosage for four or five days; then both the strychnin and atropin should be gradually reduced, and finally the patient should be given the drug twice daily, then once daily, and then cut off entirely; the length of time required for this treatment is about a month or six weeks. Often the compound tincture of cinchona is added, especially in the morning, when the craving for alcohol is greatest. It is a noticeable fact that after a few days, usually in less than a week, the desire for alcohol has ceased, and the thirst from the dryness of the mouth is easily satisfied with water. McBride reports that he has tried this for a number of years, and the patients whom he thus treated ten or twelve years ago have remained abstinent; this has not been universally successful, but in his hands it has succeeded in such a large majority of cases that it is worthy of the most extensive trial, and it has the special advantage that the patients need not be confined or absent from their homes or even daily work.

This treatment has now been in rather extensive use in New York City for some years and has furnished satisfactory results.

## USE OF OPIUM AND MORPHIN

Before the use of opium and morphin has produced marked deterioration of health and while the heart muscle is still in fair condition, the habit is not in my experience a serious contra-indication to a surgical operation. **The patient must by no means be deprived of his accustomed doses or disaster is sure to follow.** If the total quantity taken in 24 hours is large, it may be diminished somewhat and the bowels should be thoroughly emptied by purgatives and kept active.

**If the patient has long been habituated to the drug and it be suddenly and totally withdrawn he will wilt like a wet rag and pass into a condition of mental and bodily wretchedness which may speedily end in fatal collapse.** If to this is added the shock of a surgical operation, it is easy to understand that a fatal result is very probable. If, on the other hand, he gets his stimulant at stated intervals, even though somewhat less in quantity, his convalescence may be and often is as smooth as could be desired.

The difficulty in these cases often is that the patient does not confess his habit, perhaps does not realize how dependent he is upon the drug, or fears to suffer the shame which a knowledge of his slavery will entail among his friends, or in other cases the family will unwisely withhold their knowledge of the condition and permit the surgeon to operate in ignorance. Therefore, the symptoms of chronic morphinism, and more especially the symptoms of deprivation from the drug, should be well understood by every surgeon. In my experience those who take morphin habitually do not realize what abstinence means. They never abstain long enough to know more than the premonitory symptoms of deprivation. When any slight additional call is made upon their energies, they naturally think that it can better be met with just a little of the customary stimulant. The little must be increased to more, and that to still more, until a grain or two becomes just a small stimulating dose which scarcely counts in the day's allowance.

It is, therefore, important for the surgeon to seek the confidence of his patient in any suspected case of drug addiction in order that a proper understanding of the conditions may be known and proper measures may be taken. **This can best be done by placing the patient in a hospital, taking away everything in which the drug could be concealed and having him constantly watched for a day or two.** If he is addicted to opium or morphin, certain symptoms will certainly develop within twenty-four hours. They will vary in intensity, according to the duration of the habit and the quantity taken. They are yawning, violent and repeated sneezing, a profuse discharge of tears from the eyes and of mucus from the nose, cramps in the legs and back, profuse sweating. The skin is at first flushed, later cold and clammy, and **the sweating is often most marked upon the forehead and at the back of the neck.** The sweating may be preceded by chills alternating with flushes of heat up and down the spine. The yearning and craving for the source of peace, ease and comfort are such that the individual regards it as his right as though when thirsty he were deprived of water. As the hours pass, after the time of the habitual dose, the patient becomes pale, the face has an anxious drawn expression, extreme restlessness appears, he thrashes about in bed, and there may be violent jactitation of the limbs and an utter inability to lie still. A feeling of constriction about the chest is complained of, and the respiration is sighing. The patient becomes very weak, with a rapid, thready pulse. He can hardly stand or walk, nausea and vomiting are common, and within a day or two a profuse diarrhea. This last may still further weaken the patient and in bad cases the vomiting and purging may continue until he passes into a fatal collapse. He may become hysterical or even maniacal and attempt suicide, or murder; collapse with heart failure may suddenly follow and the patient may die, unless morphin be given, when the symptoms disappear like magic and he is himself again. If such symptoms occur and then suddenly cease without treatment, it is certain that the patient has obtained his drug somehow.

The suffering from abstinence is so great that patients will resort to any expedient to obtain the drug, and use great cunning and skill in hiding it, secreting it in the toe of a bedroom slipper, the inside of a sock on the foot, a cigarette case, between the leaves of a book, etc.

One of the most common results of the prolonged use of opium and morphin is *emaciation,* leading in the end to profound cachexia. Patients in this condition should not be operated upon if it be possible to avoid it. The condition of the heart and of the kidneys should be looked into carefully in such cases, since the heart muscle is often degenerated and the kidneys faulty. Loss of hair and teeth occurs during the advanced stages of chronic morphin poisoning, usually with extreme physical weakness and emaciation, and are signs of ill omen. In such cases the processes of repair and resistance of the tissues to infection are greatly diminished.

If operation be decided upon and delay is permissible, an attempt should at first be made to improve the general condition. Most important is it to get the alimentary tract in a state to absorb food. To this end, repeated doses of castor oil are useful, given daily for a week or longer, in 1-ounce doses, or ½-ounce twice or 3 times daily.

As a tonic, strychnin may be given subcutaneously in doses of gr. 1/30-1/60 several times a day. For patients in better general condition, tincture of nux vomica, citrate of iron and quinin and tincture of capsicum are useful. The subcutaneous use of ergot as in alcoholism is highly spoken of by A. Lambert. Tea and coffee, and for a time alcohol, in moderate doses may be given. Egg-nog made with milk, egg, and brandy, sherry or rum, given 3 or 4 times daily, helps greatly to make these patients more comfortable and to improve nutrition.

If the patient does well after operation and is anxious to be rid of his habit, an attempt may be made to cure him by the rather rapid method of withdrawal, i. e., the dose is reduced one-half each day until in a few days the drug is entirely withdrawn. The suffering is severe, but the very gradual withdrawal is tedious and trying in the extreme for both patient and his attendants.

**He will require constant watchfulness day and night** and is best placed in a hospital or special institution. The suffering for the first few days is severe, and the patient requires every possible aid and encouragement.

## USE OF COCAIN

The use of cocain as a local anesthetic, either subcutaneously or locally upon mucous surfaces, while still general, has been supplanted to a great extent by novocain usually combined with adrenalin. The latter combination possesses two advantages, i. e., it can be sterilized in solution without destroying its effects and is much less poisonous.

We are here concerned with the habitual use of cocain as a stimulant and what effect, if any, such use may have upon the individual considered as a surgical risk. Of the three intoxicants in most common use—alcohol, morphin and cocain—the last named is the most rapid in its destructive effects upon the body and mind of its victims. It is taken either by snuffing, by mouth, or subcutaneously. The doses vary, and may reach a maximum of gr. 30-60 daily. In those not habituated to its use ½-1 grain may be a dangerous subcutaneous dose in the adult and a much smaller quantity in children. Many persons take morphin and alcohol and to combat the depressing after-effects take cocain. Others take cocain as their principal stimulant and alcohol or morphin or other hypnotics to put them to sleep.

The primary effects of a moderate (non-poisonous) dose of cocain are an intense mental and bodily exhilaration, said to be more agreeable than any other form of intoxication. These effects are brief in duration, and are accompanied by an increased pulse rate, by an irrepressible mental and motor activity, and, if the drug is taken at night, are followed by insomnia. Sweating is also a symptom of cocain intoxication.

When taken habitually, cocain produces insanity. These patients early lose self-respect and all sense of responsibility. They become careless of their affairs and lie without compunction, later delusions of grandeur are present, the individual believes himself capable of wonderful feats of physical and mental strength. He may be furiously industrious in his profession, but his actual accomplishment is inferior to normal work. He often believes that he has discovered new methods or new principles and has developed new theories of great importance. When critically considered, his methods, principles and theories are found to be borrowed from well-considered ideas of sane men, already well known, or else they are mere eidolons, without substance and of no practical value. He may talk or write incessantly, but what he says or writes is confused, wandering and useless.

Soon, hallucinations of the various senses occur, and delusions of persecution are added. The patient is nervous and irritable, and sleeps but little, unless, as is common, he takes morphin, alcohol, chloral or any hypnotic he can get. Motor excitement and motor ataxia soon become so marked that in walking he wanders all over the sidewalk. If he takes up a glass of water to drink he may drop or throw the glass across the table or upon the floor at the far side of the room. Emaciation is rapid and marked in these cases. If the cocain and other drugs be stopped the patient recovers after weeks or months.

It is said to be easier to stop the use of cocain than morphin or alcohol. But while addicted to the first, the individual is a bad surgical risk. In order to be cured he must be put under restraint for a long time.

A truthful man has told me that soon after cocain became available, he took it as a stimulant and found it most agreeable. He used it much as the average drinker takes alcohol, as a pleasant means of escape from care and the daily annoyances of life, and used to sit and read pleasant books and enjoy himself. He was a man of middle age, in good health and with a physique unimpaired by dissipation. His maximum dose was 40 grains of cocain. He decided that the drug might be dangerous, stopped at once, and has never taken another dose for more than 25 years.

The nervous and physical degeneration exhibited by the cocain habitué in a short time are much more marked than is to be observed in morphin cases, except those very far gone in chronic morphin poisoning; and yet the former can, when under restraint, be more readily brought back to a comparatively normal condition if taken in time.

The main difficulty about curing the cocain habit is that this drug is rarely used alone. Its effects, though delightful, are evanescent, and the after-depression follows quickly, and is of a most damnable description. A man whom I knew many years ago, and who was one of the first cocain habitués, told me that the dose had to be repeated every hour in order to keep comfortable. Sleep without some hypnotic was impossible. He used whiskey and morphin and, being a sensible man, later had himself locked up for a year and a half. He still survives after nearly 30 years, is a distinguished and useful man, and never went back to his slavery.

I am not one of those who prefer local anesthesia for surgical cases. My objections are that with local anesthesia many operations are very painful, even with the most skillful use of the anesthetic, and entail unnecessary suffering. The fact that the patient suffers is apt to cause the operator to hurry and may well impair his technic. At least, his attention cannot be given so completely to the operation, and this may cause some serious error of omission or commission. The wound healing is also sometimes less perfect in my experience than when a general anesthetic is used, due probably to technical errors in sterilization of the solution injected.

There is in my opinion an unwarranted fear of general anesthesia in certain groups of cases. I refer particularly to operations for exophthalmic goiter. If skillfully given, general anesthesia by gas and ether does not materially increase the operative risk in these cases.

Where *sequestration* of the part is possible, as in the extremities, local anesthesia offers advantages in certain cases, notably in diabetes, arteriosclerosis, nephritis and where the heart muscle is degenerated. In these cases a general anesthetic may increase the operative risk, and with care even amputation of the thigh may be done with relatively little pain. In diabetic cases of gangrene of the foot and leg I have amputated in the middle third of the thigh with sequestration anesthesia of novocain and adrenalin, with only the slightest pain in cutting the sciatic nerve and none at all in sawing the femur.

## SYPHILIS

Speaking broadly, syphilis, even in its earlier and more active stages, is not a contra-indication to surgical operations. These patients, more especially if put on active treatment before and after operation, do about as well as others. The surgeon runs some risk of infecting himself, and yet, if gloves be worn, such risk, as shown by experience, is slight though real.

There are, however, many cases where the surgeon does not know that his patient is syphilitic. The wound may heal in a sluggish way. There is no active infection, and yet the healing is not ideal. The wound edges normally united in a week or less do not agglutinate. A drainage orifice does not close as it should. There is little or no discharge, and yet, somehow, the wound does not heal and close as it should. Enquiry, or the Wassermann test, may reveal a history of former infection. Neosalvarsan and mercury by inunction and iodid of potassium internally, in moderate doses, will work a magical cure. Since we now have a Wassermann test made almost as a rule, many errors are avoided. In many of these cases a spirit of kindly humanity will cause the surgeon to allege to friends that a suitable tonic was all that was needed to cause the wound to heal.

There are, however, many cases of active and late syphilis where the question of a surgical operation and the decision of this question are a very serious matter. In cases of severe syphilitic cachexia owing to want of treatment or in cases severely poisoned by mercury, operations are strongly contra-indicated.

I have seen cases of early malignant syphilis where in spite of the most active and careful treatment the lesions were severe and recurrent. If not improved by neosalvarsan, these patients should be sent to the "Hot Springs of Arkansas" and after a sojourn of six weeks or two months they will usually return well, all active manifestations gone and in good general health. They are then good surgical risks, and any operation of expediency may be done with nearly the same prognosis as in a normal individual. The operator must, however, bear in mind that his own risk of infection may be the same, and that a slight abrasion or a needle prick may make him also a syphilitic.

Cases of late syphilis (tabetics) bear operations quite well. Ordinary fractures usually unite, but one caution may not be out of place. Resection of a Charcot's knee joint is followed by non-union so far as my experience goes. Another observation worth recording is that, in tabetics, perforative appendicitis may not present the characteristic signs and symptoms. Pain, rigidity and tenderness may be slight, and yet there may be an extensive purulent exudate in the abdomen.

The relation of syphilis to aneurysm is well known, probably more than fifty per cent. of true aneurysms occurring in syphilitic subjects. Indeed, since syphilis may attack any tissue or organ in the body, its relations to surgery are very extensive. Most important it is that the surgeon should be able to recognize syphilitic lesions when he sees them, and that every student of medicine should receive thorough clinical training in the diagnosis of syphilitic lesions. Since the several blood tests for syphilis have, as stated, come to be a routine in any doubtful case, it is astonishing to find how large a percentage of the population is syphilitic.

## TETANUS

Of the complications following surgical operations there is none more terrible than tetanus. Fortunately it is very rare. And yet it may occur even though every possible aseptic precaution has been observed. When it develops in this way, the attack is as a rule acute and rapidly fatal in spite of treatment. Accidental wounds are followed by tetanus in a small proportion of cases in this vicinity. The disease is common in the tropics.

Contused or lacerated wounds with embedded foreign bodies, punctured wounds, wounds of the extremities—notably of the hands and feet—are those most likely to be infected. The sources of infection are, garden soil and street dirt, manure, other feces, toy pistol wadding and the like, impure cow pock vaccine, and imperfectly sterilized catgut in surgical operations. The treatment of the disease receives attention elsewhere. I shall mention here briefly the prophylatic measures in common use.

All wounds in which tetanus infection may be suspected should be most carefully disinfected by the thorough application of tincture of iodin, Chlumpsky's solution,

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|---|---|
| Carbolic acid | 30 |
| Camphor | 60 |
| Alcohol | 10 |

M.

or pure carbolic acid (wash with alcohol). The wound may need to be laid open for the purpose. Careful search and removal of foreign bodies is indicated. The patient then receives an injection of at least 500 units of antitetanic serum, at once. When the symptoms of lockjaw, etc., have developed the serum is of little use, and other measures (see Volume IV) must be added.

## DIABETES MELLITUS

The presence of sugar in the urine is a contra-indication to all surgical operations except those which are absolutely necessary.

If in addition the urine contains acetone and diacetic acid the risk is greatly increased. If also Beta oxybutyric acid is present the patient is in a dangerous condition and is likely to go into coma at any time. Persons in this condition who receive a general anesthetic and undergo a serious surgical procedure are very apt to pass into diabetic coma and die in a few days. If, as in cases of diabetic gangrene, it becomes necessary to operate, the patient should be put upon diabetic diet, and if acidosis is present should receive large doses of sodium bicarbonate.

An attempt should be made to determine the quantity necessary to render the blood alkaline, this being a fair measure of the patient's resistance, according to Blum. In mild cases this quantity will be about 20 gm. daily; in more severe cases 20-30 gm., in bad cases 50 gm. In cases of coma no amount of sodium bicarbonate taken internally will make the blood alkaline. Wiener considers that when the daily excretion of ammonia exceeds 1 gm. serious surgical procedures are contra-indicated.

A local measure of benefit when moist diabetic gangrene is present is the application of dry heat in the form of a blast of hot air. This is accomplished by a special electrical apparatus. This application should be made for a half or three-quarters of an hour daily and should be applied to living as well as dead parts, since an active hyperemia is produced, thereby improving nutrition. To the living parts the temperature of the air may be 80° to 100° C. To the dead tissues 200° to 300° C. or higher. By this means the dead tissues are rapidly desiccated, bacterial growth and septic absorption are diminished, the pain and evil odor are lessened, and the general condition improved, so that with a proper diet the patient may be changed from a hopeless to comparatively good surgical risk, and an amputation be done with a successful result.

In a large proportion of these cases a marked degree of arteriosclerosis is present. This may be treated with the vasodilators. The best of these is iodid of potassium, which may be given in 5/10 grain doses well diluted in water, t. i. d.

The surgical complications of diabetes depend largely upon a diminished resistance of the tissues to pyogenic infections. The most common are boils, carbuncles, and gangrene of the toes and foot. In addition, acute progressive necrotic infection of the toes and sole of the foot and chronic perforating ulcer of the sole of the foot are not uncommon.

The gangrenous processes are associated with arteriosclerotic changes in the arteries supplying the part, with complete or partial obliteration of their calibers, sometimes with thrombosis.

In treating these processes surgically by incision of boils, excision of carbuncles, and amputation of gangrenous members, we are sometimes able, by diet and other measures, to improve the patient's general condition and bring him to the operating room a better surgical risk. Moreover, with improved resistance, a less radical operation may suffice; for example, removal of one or more toes instead of amputation through the thigh. One caution is here in order, namely, if the infection is spreading rapidly or is acute, as in moist gangrene of the foot with septic absorption, which resists the measures already described, or in carbuncle of the back, the risk of a radical operation is less than that of delay.

**Diet.**—In cases where the delay is permissible we prepare the patient as stated, by diet and other agents. This diet treatment has been studied and formulated with great care. To be effective, it must be carried out with skill and watchfulness. The details are so important that I here quote in some detail from an article by Thomas B. Futcher in Osler's "Modern Medicine" (Vol. I, Chapter XXIX):

"We have seen that the symptoms of diabetes are directly or indirectly dependent upon the hyperglycemia, the grade of which is pretty accurately indicated by the amount of glucose excreted. Our object, therefore, should be to eliminate the hyperglycemia if possible. This will be most quickly effected by cutting out of the dietary those constituents that are most readily converted by the digestive processes into grape-sugar—namely, the carbohydrates.

"When a diabetic patient comes under observation, it should be the physician's first duty to ascertain the patient's capacity to warehouse carbohydrates, or, in other words, to determine his tolerance for carbohydrates. This is done by placing the individual for at least five days on a diet absolutely free from starches and sugar; that is, on a proteid-fat diet. In so doing his weight must be taken into consideration and the diet so arranged that it will provide approximately forty calories for each kilo body-weight. This can, as a rule, be fairly readily done—and in a hospital work should always be done—as the proteid and fat percentage of the various foods is given in some of the standard works on dietetics. Knowing that 1 gram each of proteid and carbohydrates yields 4.1, and 1 gram of fat, 9.3 heat units, the caloric equivalent of the diet can be readily calculated. As the carbohydrates, which ordinarily provide the largest number of calories in our diet are cut off, it will be seen that the proteids and fats must be largely increased to make up for this deficit. Before arranging the non-carbohydrate diet, the individual likes and dislikes of the patient should be ascertained, so as to secure one that will be most palatable and one that will likely be entirely eaten each day during the test. The following may be used as a 'standard' diet for tolerance test, subject, to be sure, to variations according to the patient's age, weight, and likes or dislikes for certain forms of meats:

"*Breakfast.*—7.30 A. M. 120 grams (℥ iv) beefsteak or mutton chops without bone; two boiled or poached eggs; 200 c. c. (℥ vi) of tea or coffee.

"*Lunch.*—12.30 P. M. 200 grams (℥ vi) cold roast beef, mutton, or chicken; 60 grams (℥ ii) celery, fresh cucumbers, or tomatoes, with 5 c. c. (ʒ i) vinegar, 10 c. c. (ʒ ii) oil, pepper and salt to taste; 20 c. c. (ʒ v) whiskey (if desired); 400 c. c. (℥ xiii) of water or Apollinaris water; 60 c. c. (℥ ii) coffee.

"*Dinner.*—6 P. M. 200 c. c. (℥ vi) clear bouillon; 200 grams (℥ vi) roast beef; 60 grams (℥ ii) lettuce with 10 c. c. (ʒ ii) vinegar; 20 c. c. (ʒ iv) olive oil, or three tablespoonsful of some well-cooked green vegetable, as spinach; three sardines à l'huile; 20 c. c. (ʒ iv) cognac or whiskey (if desired), with 400 c. c. Apollinaris water.

"*Supper.*—9 P. M. 2 eggs, raw or cooked; 400 c. c. Apollinaris or seltzer water.

"With the four meals at least fifteen grams (about ʒ iv) of butter should be used in making the gravies and with the eggs. No milk or sugar is permitted with the tea or coffee. Saccharin may be used to sweeten them. The time of taking lunch and dinner, of course, may be reversed. This daily diet should provide a person of 60 kilos (132 pounds) with a little over the requisite 2,400 calories for an individual of that weight. One precaution must be emphasized here. If the patient has been eating freely of starches, these must be cut down slowly for two or three days before he is placed on the standard diet. Any sudden and radical change from one diet to another is liable to induce coma. As it has been found that a dog must fast five days before the glycogen of his liver has been all used up, it is well to keep the diabetic on the above diet for at least five days; by so doing it practically eliminates the possibility that any sugar excretion at the end of that time is derived from the stored-up glycogen of the liver.

"While on this diet, the total amount of urine should be collected for each twenty-four hours, mixed, measured, and the sugar determinations made from a specimen of the twenty-four-hour amount. The reduction in the sugar excretion is often very striking in the first twenty-four hours. If the patient becomes aglycosuric within the first five days the case may then be considered a mild form of the disease, and it is then desirable to ascertain how much starch can then be added to his diet without sugar appearing in the urine; in other words, to determine his tolerance for carbohydrates. This is probably best done by allowing the patient a weighed quantity of plain white bread, which contains approximately about 55 per cent. of starch. For the first day 25 grams of bread may be allowed. If sugar fails to appear in the urine another 25 grams (a little less than ℥ i) may be added to the next day and so on until glycosuria does develop. The formula for the tolerance is as follows: Tolerance = Standard diet + x grams starch, x representing the number of grams of starch the patient can take without sugar appearing in the urine.

"If the patient continues to excrete sugar after being on the standard diet for five days, it indicates that he is suffering from a severe form of the disease. It further means that the tolerance for carbohydrates is entirely destroyed, and that the sugar eliminated in the urine is manufactured from his tissue-albumins. In the cases in which glycosuria persists after the patient has been on the non-carbohydrate diet for five days, Naunyn recommends that a 'Hunger Tag,' or hunger day, be instituted, during which time no food whatever is taken for twenty-four hours. In a certain percentage of these cases the patients will become aglycosuric as a result of the starvation-day. Naunyn's reason for establishing a hunger-day is to remove the hyperglycemia even though it be for only twenty-four hours. By so doing he claims that the tolerance for starches is increased, and that it is then possible to give small quantities of starch without glycosuria occurring, which, without the hunger-day, would not be warehoused. The increased tolerance is believed to be due to the tissues securing a temporary rest from sugar formation. The writer's experience with the hunger-day is that it is useless to advise it if the percentage of sugar is 0.5 or over, as when it is that high the sugar rarely entirely disappears. In the treatment of diabetics it is most advisable to put them on such a standard diet at least every three months in order that their tolerance for carbohydrates may be increased.

"The foods the diabetic should be warned against taking, excepting with the permission of the physician, are as follows: Bread of all sorts, wheaten, rye, and brown; all farinaceous preparations such as rice, sago, tapioca, hominy, semolina, arrow-root, and vermicelli.

"Thick soups are to be avoided. Among meats, liver is about the only form to be prohibited, owing to the glycogen it contains. For the same reason, oysters are sometimes prohibited.

"All starchy vegetables: Potatoes, turnips, parsnips, squashes, vegetable marrow, beets, corn, peas, and artichokes.

"Beverages: Beer, the sweet wines and sweet aerated drinks. These are excluded owing to the sugar, and not to the alcohol, they contain.

"Fruits: Grapes, dates, figs, currants, raisins, dried prunes and plums, and other dried fruits rich in sugar, should be forbidden. Certain fruits such as peaches, apricots, stewed green gooseberries may be permitted in mild cases. Some authorities on this disease are inclined to be rather more lenient in regard to fruits. It is well to remember that levulose (fruit-sugar) has been shown to be tolerated better by the diabetic patient than any other form of sugar.

"Sugar for sweetening purposes must be omitted. Without the physician's permission, milk must not be taken.

"The following foods the diabetic may take unconditionally: Soups: Bouillon, ox-tail, and turtle; broths, soups with marrow and eggs permitted. Fresh meats: All the muscular part of the ox, calf, sheep, pig, deer, wild and domestic birds—roast or boiled—warm or cold, in their own gravy or in a mayonnaise sauce.

"Internal parts of the animals: Tongue, heart, brain, sweetbreads, kidneys, marrow-bones, served with non-farinaceous sauces.

"Preserved meats: Dried or smoked meat, smoked or salt tongue, corned beef, American canned meats.

"Fresh fish: All kinds of fresh fish, boiled or broiled, prepared without bread crusts or cracker-meal and served with any kind of non-farinaceous sauce, preferably melted butter.

"Preserved fish: Dried fish, salt or smoked fish such as codfish, haddock, herring, mackerel, flounders, salmon, sprats, eels, etc.; tinned fish, such as sardines in oil, anchovies, etc.; caviar.

"Eggs: Raw or cooked in any way, but without any mixture of flour.

"Fresh vegetables: Green lettuce, cress, spinach, cucumbers, onions, asparagus, cauliflower, red and white cabbage, French beans. The vegetables, as far as they are suited to this method of preparation, are best cooked with meat or a solution of Liebig's Extract and salt, with plenty of butter. The addition of flour is not permissible.

"Preserved vegetables: Tinned asparagus, French beans, pickled cucumbers, mixed pickles, sauerkraut, and olives.

"Spices: Salt, white and black pepper, Cayenne pepper, curry, cinnamon, cloves, nutmeg, English mustard, and capers.

"Cheese: Neufchâtel, Edam, Stracchino, old Camembert, Gorgonzola, and other fat and so-called cream cheeses.

"Beverages: All kinds of natural and carbonated waters, either clear or with lemon juice, or with rum, whiskey, cognac, and cherry brandy. Light Moselle or Rhine wines, claret, dry sherry, or Burgundy, in amounts prescribed by the physician. Coffee, black or with cream, without sugar but sweetened with saccharin if desired. Tea, clear or with cream or rum.

"From this list it will be seen that the number of articles not containing starch the diabetic may choose from is quite extensive, and permits him to vary his diet from time to time. In making up the standard diet certain articles in the above list may be substituted for some of those in the diet outlined.

"Bread is the article of diet the cutting off of which the diabetic tolerates least well. Sooner or later a craving for it is inevitable. Various substitutes have from time to time been put on the market. The oldest of these and the one in most extensive use is *gluten bread* or biscuits made from gluten flour, first introduced by Bouchardat, in 1841. It is prepared by washing away the starch from wheat flour. The text-books on cooking give recipes for making bread and biscuits from this flour. Many firms claim to make pure gluten flour. Others are more conscientious, and state the percentage of starch their various preparations contain. It is easy to demonstrate that these gluten flours almost without exception contain starch, by adding a few drops of Lugol's solution. A blue, or even black, reaction is obtained, according to the amount of starch present.

"Another substitute is bread or biscuit made from aleuronat flour, advocated by Ebstein and prepared by Dr. Hundhausen of Hamm, Westphalia, Germany. It is a vegetable albumin prepared by a special process from wheat. It contains from 80 to 90 per cent. of albumin in dry substance and only 7 per cent. of carbohydrates. In making bread from it, a considerable percentage of starch had to be added.

"Flours prepared from soya bean, almonds, cocoanuts, and Iceland moss have had their advocates as substitutes for wheat flour. The writer's experience has been limited to the use of gluten and aleuronat bread, and it has taught him that patients eventually tire of them and they still crave white wheat bread. Owing to the expense and the unreliability of most gluten flours, the writer has given up their use. It is much better to allow a diabetic to have daily a definite weighed quantity of white bread, the starch percentage of which we know to be about 55 per cent. It is well to have the bread thoroughly toasted. Well-toasted graham bread may be used as a substitute with advantage.

"Starch, in the form of potato, is thought to be more easily assimilated than wheat starch, and the comparatively recent work of Mossé seems to bear this out. The observations at the Johns Hopkins Hospital tend to confirm this view. Mossé allowed his cases 1 to 1.5 kilos (2 to 3 pounds) of potatoes daily. He says that there is a marked amelioration of all the distressing symptoms under the potato treatment. It is best to bake the potatoes. Naunyn does not speak very enthusiastically of this special cure in his last edition. He thinks that, when benefits result, it is mainly due to the fact that the diet in the case heretofore has not been properly arranged so far as the allowance of carbohydrates is concerned. Von Noorden recently has advocated very strongly a specially prepared oatmeal, and has claimed remarkable results in eliminating glycosuria.

"In mild cases of diabetes (those who have become aglycosuric on the standard diet), the best course to pursue is to add to this standard diet weighed quantities of well-toasted white bread, the amount to vary with the tolerance of the individual. Occasionally, a roast potato may be substituted for the bread. In these cases milk is especially useful, as it contains only between 4 and 5 per cent. of lactose, which is very well assimilated by diabetics. A pint or a pint and a half, accordingly, may be permitted daily. The monotony of the standard diet may be from time to time relieved by making substitutes from the list of unconditionally allowable foods given above.

"In the severe cases (those who fail to become aglycosuric on the standard diet) it, at first thought, would appear that the addition of carbohydrates would be contra-indicated, as they would tend to increase the glycosuria, considering that the tolerance is *nil.* Experience, however, shows that these do better, and are more likely to hold their weight, if given very moderate quantities of starchy food. The danger of coma is increased by any long continuation of an exclusive proteid-fat diet.

"In both forms, a return to the strict diet, in order to increase the tolerance, should be made at least every three months for a period of ten days. It is desirable at shorter intervals in the severe forms.

"No attempt should be made to restrict the water taken by the diabetic. No good will follow by doing so, as the thirst and polyuria are dependent on the hyperglycemia. Harm, on the other hand, is likely to ensue, as the increased thirst causes increased mental and physical distress. Apollinaris and seltzer water may be allowed, and the thirst may be quenched by drinking lemonade sweetened with saccharin instead of sugar. A drink made by dissolving a dram of cream of tartar in a pint of boiling water and flavoring with lemon peel and saccharin, and then cooling, may be given freely for the same purpose.

"Alcohol, in the form of whiskey, cognac, or rum, is to be recommended, as it aids fat digestion, and tends to make up for the loss in heat units resulting from the cutting off of carbohydrates. One gram of alcohol by its combustion yields 7.0 calories.

"Sawyer, of Cleveland, claims to have obtained marked benefit in diabetes by systematic gastric lavage."

These cases of pyogenic infection or of necrotic processes in diabetics try the soul of the surgeon; let alone, they die; operated upon, many die also, and yet by skillful management many can be saved and live perhaps in comparative comfort for many years.

To state a paradox, the older they are the better the prognosis. Young persons who have diabetes and surgical complications die almost invariably. Persons of middle life or older, diabetics, have, as a rule, a small or moderate amount of sugar in the urine. They may live for many years and even have serious surgical complications requiring surgical interference and operative care, yet survive. Such individuals have been known to live for many years.

A man who has been a diabetic patient of mine since 1885, and whose brothers, four in number, all had diabetes, and whose father died of this disease at the age of 82 years, is now alive at the age of 80 years, in fairly good health. He has no serious discomforts of any sort. During these years he had suffered two serious fractures, one an intracapsular fracture of the hip joint, one a fracture of the shaft of the humerus. Both fractures healed quickly and without complications.

The question of where to amputate in cases of diabetic gangrene of the foot is one not always easy to answer. If the process is a spreading moist gangrene without line of demarcation and is associated with cellulitis and suppuration of pyogenic origin, amputation should be done through the lower third of the thigh. The same rule applies to spreading cases of septic necrotic cellulitis of the deep structures of the foot not associated with putrid decomposition. If one or more toes alone are involved and there is little or no tendency to spread into the sole or dorsum of the foot, and if the process is dry, amputation may be done at any level where free bleeding occurs in cutting into the limb. This is a fairly safe rule, but reamputation will be found necessary in some cases. An

Esmarch bandage or a large soft rubber tube an inch or more in diameter may be loosely applied over the femoral artery and quickly tightened if necessary. Unless free bleeding occurs a higher level must be chosen.

Another method for determining the level for amputation is to apply an Esmarch bandage to the limb from below upward, tight enough to render the limb bloodless. A second bandage or constrictor is then wound about the limb at its junction with the trunk, compressing the main artery. The first bandage is removed and a few minutes later the second. As the circulation returns, the skin becomes suffused with a deep red blush, which extends from above downward, but stops where the limb is not properly nourished. Amputation should be done well above this level.

Ether is the general anesthetic of choice, though gas and oxygen may be used. It is less likely to be followed by coma. Sequestration anesthesia, novocain and adrenalin, may also be used to great advantage in these cases.

I have amputated the thigh by this method, even in a large stout man, with almost no pain and no shock. The technic is as follows: The patient may properly receive a hypodermic injection of morphin one-half hour before the operation—in a large adult 1/3 of a grain. The limb to be amputated is held vertically for several minutes (but in case of gangrene not stroked) in order to free it from blood, as far as possible. An Esmarch bandage or large soft rubber tube is then applied as a tourniquet at least 6 inches above the proposed point of amputation. It must be applied, quickly, tightly and accurately and must occlude all the vessels in the first turn, thus closing instantly both arterial and venous circulation. A second ligature is similarly applied 6 or more inches below the first one. A section of the limb 6 or more inches in length is thus rendered bloodless and removed from vascular communication with the remainder of the limb. The internal saphenous vein is then sought for and freed. It is opened or divided. With a large glass syringe 50-100-150 c. c. of a 1 per cent. solution of novocain and adrenalin is injected into the vein under pressure, slowly and with some force. The tip of the syringe in the vein must, of course, be surrounded by ligature to accomplish this. The section of the limb takes on a peculiar blanched appearance. After waiting a few minutes, an amputation is done in any way the surgeon prefers.

This procedure is quite different from ordinary local anesthesia and more efficient. Amputation of the thigh may be done with scarcely any pain. I have amputated the thigh in several cases of diabetic gangrene in this way, without any complaint of pain except a single exclamation of "Ouch" when the sciatic nerve was cut, and without any notable signs or symptoms of shock, and the results were in each instance good.

It might be well to record my experience with gangrene of the toes and foot in cases of presenile gangrene and diabetic gangrene of the lower extremities. Imprimis amputation of the lower third of the thigh is followed by good wound healing and by no recurrence. Amputations at a lower level, though theoretically good, are in many cases not followed by cure, good wound healing or satisfactory results. In the less favorable cases, gangrene of the stump occurs and reamputation is necessary; in the more favorable ones the flaps either slough or heal very slowly. In some cases the patient returns with a poorly nourished stump, which is ulcerated and painful; he is unable to wear an artificial limb, and intolerable pain may drive him to seek a higher amputation.

## OBESITY

Persons who are abnormally fat are not good surgical risks. Their tissues do not resist infection as well as those of normally nourished individuals. In order to do a given operation, the cut, as a rule, must be longer and deeper. The soft, friable tissues are more easily bruised and torn by retractors and other instruments, sutures cut through readily, etc., and wound healing is often less perfect.

Fat necrosis in the subcutaneous tissues is not a rare accident. These difficulties obtain when operating on all inordinately fat people. But much more serious dangers may exist than these. Among the obese of middle life or advanced age, a number of serious organic weaknesses are prone to develop, anemia, bronchitis, mechanical interference with action of the heart, fat infiltration and weakness of the heart muscles, arteriosclerosis, often of the coronary arteries. These changes in their advanced stages produce cardiac asthma, anginal attacks, cerebral hemorrhage. Among other conditions often observed in these cases are hernia, glycosuria, albuminuria, edema and general muscular weakness.

Therefore, only necessary operations are to be done on the very stout. If the patient is plethoric, i. e. full-blooded, with the normal number of red cells and hemoglobin, the prognosis is better than in the anemic type of obesity.

There is one common group of cases, however, where it is better and safer to operate than not. I refer to the large irreducible herniæ of fat women, where the viscera cannot be permanently retained within the abdomen by belts, binders, corsets, and trusses. In deciding for or against operation in these cases the surgeon must study the general and local conditions with care. In neglected cases the tumor may be so large that replacement may be impossible. In these, if the contents of the sac consist largely of intestine, it is wiser to forbear. If, on the other hand, large masses of omentum are recognized, they may be resected, thus making more room for the bowel. Such resections of large masses of omentum are not devoid of risk and must be made with great care. (See chapters on Hernia.)

When wisely selected these cases do well. Unoperated, the danger of strangulation is great, and the mortality following operations for strangulation is very high.

## RICKETS

Inasmuch as the disease is rarely seen in its active stages after the age of three years, the surgeon is interested in treating the resulting deformities rather than the disease itself.

The causes of death during the active stages of the disease are, most commonly, bronchitis, bronchopneumonia, convulsions and laryngismus stridulus. The disease is very amenable to treatment by diet, i. e., by cutting down carbohydrates and increasing the fats. If cream is not obtainable, cod liver oil may be given. During the treatment the child must not be allowed on its feet until marked improvement occurs, usually for several months. Phosphorus is believed to be useful if well borne, and bathing and general massage help the general health.

## SCURVY

Scurvy occurs when, under unfavorable hygienic conditions, chiefly cold and wet, persons are obliged to live on a dietary wanting in fresh vegetables, or their equivalent, and fresh meat. The alkalinity of the blood is diminished. Whether the disease is caused by this alone, or whether an added infection through the mouth is necessary, is not definitely determined.

As is generally known, one of the most notable characters of the disease is a marked tendency to hemorrhages into tissues and organs and from mucous surfaces.

When death occurs in scurvy, it may occur from bleeding—either external from an ulcer, or internal from the mouth or nose—from heart failure, gangrene of the lung, or a putrid bronchitis associated with a bloody effusion into the pleural sac.

It is to be borne in mind that the subcutaneous and subperiosteal hemorrhages may occur without trauma. This fact may be of medico-legal importance, more especially when we recall that the crews of merchant ships, even to-day, sometimes develop scurvy.

This alone would render a scorbutic individual a bad surgical risk; but to this must be added a general depression of all the vital forces and marked anemia, so that, if it is possible to avoid it, no surgical operation should be attempted until the individual has been improved by a suitable diet and warm dry surroundings. Even under favorable conditions it will be weeks and months before the patient regains his normal health and strength.

Most important in the treatment of scurvy is a diet containing abundance of fresh vegetable food. In addition, among the articles believed to be most useful are fresh lime and lemon juice. Among preserved vegetables sauerkraut is excellent. Infusion of malt is of value. Fresh meat and meat juice and fresh milk in liberal doses are all anti-scorbutic.

Drugs are of less value. Iron may be given for the anemia and a bitter tonic, such as quinin, for the appetite. Diarrhea may require treatment.

Astringent and antiseptic mouth washes should be given at frequent intervals: Potassium permanganate solution, chlorate of potassium, Dobell's mouth wash, etc. Ulcers, if they exist, demand antiseptic and stimulating treatment, such as balsam of Peru, etc., with protection and support. Intravenous injections of horse serum may be given, if available, for hemorrhages.

## ACUTE POLYARTICULAR RHEUMATISM

Although a form of streptococcus has been demonstrated in the joint exudates of acute articular rheumatism, yet, as a matter of experience, such joints rarely require surgical interference. Complete restoration of function is the rule upon recovery.

If the joint inflammation is very severe and resists the ordinary means of treatment, a needle may be introduced, and if the exudate is found to be purulent, containing pyogenic cocci, the joint should be opened, washed out with a mild antiseptic—e. g., carbolic acid 1-60 or a weak solution of formaldehyd solution—drained for a few days and immobilized until the joint cavity remains dry.

## GOUT

The relations of gout to surgery are of two kinds:

1. If a gouty tophus breaks down and suppurates, it should be incised and curetted, or excised, thus sparing the patient the formation of a chronic sinus. If a tophus becomes unsightly or from its size and situation interferes with motion or causes pressure symptoms, or is itself pressed upon by the shoe, it may be removed.

2. Persons with chronic gout are often obese, they often develop chronic interstitial nephritis, with arteriosclerosis, they may develop a dilated heart muscle or coronary disease, and they sometimes have glycosuria. They are, therefore, to be regarded in many instances as extra-hazardous surgical risks. Accordingly, patients who have gout should be carefully examined with the above facts in mind before they are subjected to an operation of expediency.

## POISONING BY BICHLORID OF MERCURY

Acute poisoning by mercurial bichlorid has within the past year acquired a fleeting interest for surgeons on account of certain accidental fatal poisonings and, later, attempts at suicide, owing to the publicity afforded these accidents by the press. Bichlorid of mercury tablets are easily purchased, and they are to be found in almost every household, for the treatment of wounds, for bed bugs, or for less obvious reasons.

Some years ago, Edebohls proposed and carried out a procedure in cases of chronic interstitial nephritis, based upon the assumption that the kidney underwent degeneration and loss of function on account of undue tension of its fibrous capsule. He cut down upon the kidney, split and stripped the capsule from the organ, and alleged that such cases were improved by the operation. We are not here concerned with this contention whether justified by results or not.

In acute poisoning by mercuric bichlorid the patient immediately suffers from abdominal pain, nausea, vomiting and diarrhea. The passages from the bowel are often bloody. The history of these patients is, however, peculiar. After two or three days the acute symptoms of gastro-intestinal irritation subside to some extent and they become quite comfortable. They may look well, but they pass no urine. The kidneys have ceased to functionate. The catheter withdraws merely a dram or two of turbid or bloody fluid from the bladder. Patients may live for a number of days, and, until they become comatose from uremic poisoning, suffer but little. They are rational and look so well that it is hard to realize that they are doomed to speedy death.

On January 2, 1914, I saw one of these cases—a man, aged 60. On account of business troubles, threatening bankruptcy, he became desperate. He took into his mouth, chewed up, and swallowed 5 of the ordinary 7½ grain bichlorid of mercury tablets. Some acute symptoms followed; acute abdominal pain, nausea, vomiting and general distress. I was called to see him 3 days after he had swallowed the poison. He had in the meantime changed his mind. The presence of his wife and children, and of numerous sympathetic friends, and the attention he received in the hospital changed his point of view. He was just as anxious to live as he had been to die. He appeared quite normal. He was a large, plethoric, healthy-looking man, a temperate, sane, intelligent Hebrew. His face was flushed, his eyes bright, and he had a rapid high-tension pulse. It was hard to realize that this man so normal in appearance was to die in a short time. I was induced against my judgment to operate.

I exposed his kidneys and split and stripped their fibrous capsules. Neither kidney was enlarged, nor did the parenchyma appear to be under any tension. The left kidney was dark red in color and the cortex bled freely, the capsule was adherent. The right kidney was of normal size and softer than normal. The capsule stripped easily. The whole kidney was pale in color. Scattered over the surface of the cortex were numerous areas, large and small, of a yellowish white color. These appeared to be areas of necrosis. The wounds were closed. The patient passed no more urine and died comatose the following day. The operation was quite futile, and I shall never repeat it. I believe operation is contra-indicated in these cases. The microscopic examination of these kidneys showed total necrosis of the entire parenchyma.

## PHOSPHORUS POISONING

Acute poisoning by phosphorus has no surgical interest. Chronic poisoning by this element possesses only an historical interest in America, and is a purely occupational accident.

In former years while white phosphorus was used extensively in the manufacture of matches, such poisoning was common among those who were daily exposed to the fumes of this element. The lesions produced were inflammation of the gums followed by progressive necrosis of the jaw, usually the lower jaw. One tooth was first involved; toothache of a severe character was followed by the extraction of the tooth and the escape of fetid pus from the tooth socket, unless upon the first sign of irritation the individual was removed from danger; then followed progressive and rapid necrosis of the jaw. In some cases the process involved **total necrosis** of the lower jaw, and these unfortunates became hideously disfigured and on account of the horrible fetor were disgusting objects. The condition is rare in this vicinity. I have never seen a case of this kind.

## TUBERCULOSIS

Although almost every structure in the body the seat of tuberculosis has been the object of surgical attack and although a large percentage of surgical operations are for the cure of this disease, there is one aspect of the subject which always demands serious consideration on the part of the surgeon, namely, the question of a surgical operation in the presence of tuberculosis of the lungs.

The condition may demand operation upon the pleura or the lung itself, as in tuberculous empyema and pyopneumothorax. Operations have also been done on the chest wall to put the diseased lung at rest and to obliterate dead spaces, and upon the lung itself. All these conditions receive due consideration in other parts of this work. We are here concerned with modifications in treatment when we are obliged to do any serious operation upon a subject of lung tuberculosis.

These patients are poorer surgical risks, the more acute and extensive the process. If the operation can be delayed, it may be well to precede it by a sojourn in a suitable locality, a strictly out-of-door life, good food and the best of hygienic surroundings. The local processes may thus be improved and the resistance of the patients increased.

A very important point is the selection of the anesthetic. A local anesthetic should be used when possible. Novocain and adrenalin is the best combination. If a general anesthetic must be given, nitrous oxid gas and oxygen is the safest. It must be given by one skilled in its use, since it is at best troublesome for both surgeon and anesthetist; but it is safer than ether or chloroform, and does not leave behind irritating effects upon the respiratory tract, noted after the two latter. Cyanosis and absence of muscular relaxation are the trying features. It cannot be too forcibly impressed upon the practitioner of medicine and surgery that nitrous oxid and oxygen anesthesia, although useful, can only be undertaken with propriety by a man of large experience and training. Here a few remarks may perhaps be made in regard to anesthesia in general.

The editor speaks from an experience of 30 years, having given and seen given all the local and general anesthetics in use at the present time. When in doubt give *ether;* it is less dangerous than chloroform, and its administration requires less skill and judgment than that of any other anesthetic, local or general. **It may be given by a fool** or a totally inexperienced person with less danger than any other anesthetic. Local anesthesia may well be used when the operation takes but a short time for its performance or when general anesthesia would be very dangerous.

Patients operated upon under local anesthesia, where the operation is prolonged, suffer very much when the operation involves a rather deep dissection and when the anesthetic is injected into the skin and superficial parts only. See, however, the discussion of sequestration anesthesia, under Diabetic Gangrene, page 174; also Chapter on Anesthesia, Vol. I.

# PART II

James H. Kenyon

## DISEASES OF THE DIGESTIVE SYSTEM

**Diseases of the Mouth.**—All the various forms of stomatitis increase the danger of inhalation pneumonia if a general anesthetic is given, and if the operation is in the region of the mouth or pharynx the danger of a wound infection is increased. Thrush absolutely contra-indicates operation for harelip or cleft palate, as it prevents union of the flaps.

The local condition should be cured by local and constitutional treatment, if possible, before operating. If time is not available for this, employ a general anesthetic with special attention to thorough disinfection of the local condition, both at the time of operation and subsequently.

**Diseases of the Pharynx.**

(a) ACUTE AND CHRONIC PHARYNGITIS.

(b) ULCERATION OF THE PHARYNX.—The same precautions as detailed under diseases of the mouth should be applied here.

(c) ACUTE INFECTIOUS PHLEGMON.

(d) RETROPHARYNGEAL ABSCESS.—This condition requires only local or nitrous oxid anesthesia, never sufficiently deep to abolish the coughing reflex, the chief aim being to prevent aspiration of the infectious material into the larynx.

In children no anesthetic is necessary. As soon as the opening is made in the abscess cavity, the patient should be quickly turned face downward to facilitate the escape of the pus and to prevent its entrance into the larynx. In many cases the Rose position with the head lowered is useful.

(e) ANGINA LUDOVICI.—As these cases often develop intense dyspnea, preparations for intubation or tracheotomy should always be made, not only previous to the operation, but the tracheotomy set should always be at hand for some days during the postoperative treatment.

**Diseases of the Tonsils.**—Any obstruction to respiration from enlarged tonsils may be overcome by the use of a nasal tube to the posterior pharynx, the ether vapor being blown through this tube. Or the regular mask or inhaler may be employed if a free airway is provided by passing a fenestrated rubber tube through one or both nostrils, or a somewhat larger tube through the mouth to the level of the epiglottis. A flat metal tube with a curve to fit the roof of the mouth, the inner end extending to just below the base of the tongue, the outer end provided with a flange which rests against the lips, has been constructed for the purpose.

All the above-mentioned diseases contra-indicate operation on any other part of the body, except that of an emergency, as the patient's reparative powers are lowered and the danger of complications increased.

**Diseases of the Esophagus.**—Diseases of the esophagus result in such an impairment of nutrition that the patient is not a good subject for operative procedure. The local condition should be dealt with first and some means instituted to improve the general condition. If the patient is suffering from malnutrition directly attributable to the inability to obtain sufficient nourishment, a preliminary gastrostomy with subsequent feeding through the tube will do much to improve the general condition if time permits.

Any retained secretions or material in the dilated esophagus or its diverticula should be carefully washed out before giving any general anesthetic, in order that this material may not escape into the pharynx and add to the risks of an inhalation pneumonia. For this reason intratracheal anesthesia should be chosen.

**Diseases of the Stomach.**—Each of these diseases will demand individual treatment both before and after any operation that is undertaken.

In all cases except those of a suspected perforation of the stomach or duodenum, or hemorrhage, the stomach should be thoroughly washed before administering the anesthetic. One should shorten as much as possible the time of operation and the amount of ether used.

The postoperative position of a semi-sitting posture favors gastric drainage and lessens vomiting. Absolute failure of gastric digestion or assimilation, or persistent vomiting, may necessitate feeding through a jejunostomy.

**Diseases of the Intestine.**—Diseases of the intestine associated with diarrhea, from their general weakening effect on the patient, make it necessary to shorten, as much as possible, any operation which is required. Light ether anesthesia and as little manipulation of the tissue as possible are indicated.

**Enteroptosis.**—While this condition does not in any way contra-indicate operation upon any part of the body for other disease, attempted operative relief of the relaxed structures themselves is seldom attended with great success.

**Diseases of the Liver.**—Jaundice from any cause, particularly with fever, renders the patient less able to stand the shock of an operation and more liable to bleed. The coagulation time is retarded from 8 to 10 minutes. For this reason, when it can be done, some preliminary treatment to increase the clotting power of the blood should be employed before operating.

In all diseases of the liver the duration of the operation should be as short as possible, and particular care taken to control all bleeding points and surfaces, either with ligature, suture or firm packing. Local anesthesia, if possible, or nitrous oxid and oxygen or a very light ether anesthesia is most desirable.

**Diseases of the Pancreas.**—Acute hemorrhagic pancreatitis does not present a favorable condition for any anesthetic, but an operation is always indicated.

The rapid, feeble heart should be steadied with the proper medication or a hypodermoclysis. The stomach, which is very apt to dilate quickly, should be washed out before starting the anesthetic. It is often advisable to leave the stomach tube in place throughout the operation.

Light ether or gas oxygen anesthesia should be chosen, if possible. In some cases local injections of novocain may be sufficient.

**Diseases of the Peritoneum.**—Acute general peritonitis demands the shortest possible operation and the least possible manipulation. The anesthetic may be local, gas oxygen or light ether.

## DISEASES OF THE RESPIRATORY SYSTEM

**Coryza and Chronic Catarrh.**—The conditions should have, if possible, some preliminary treatment before a general anesthetic is given. If this cannot be done the excessive secretion may be controlled by morphin and atropin. One should use a local anesthetic if possible, or ether and oil by rectum may be used. Theoretically, any of the anesthetics commonly used would be better than ether in that they produce less inflammatory reaction of the mucous membrane and less secretion, but, practically, ether may be safely used in many cases.

**Diseases of the Larynx.**—Diseases of the larynx render the administration of a general anesthetic inadvisable, in that they are apt to be complicated by acute edema of the larynx and obstruction, or are followed by a postoperative pneumonia. Intratracheal insufflation, ether and oil by rectum, or perhaps tracheotomy would be indicated.

**Diseases of the Bronchi.**—Diseases of the bronchi render anesthesia by any inhalation method undesirable. Either gas-oxygen, ethyl chlorid or chloroform should be chosen if the need of a general anesthetic is imperative. Otherwise a local anesthetic is better.

**Diseases of the Lung.**

A. PNEUMONIA.—Pneumonia contra-indicates all operations, except something of a very urgent nature, in which case nothing but local anesthesia should be used.

B. EMPHYSEMA.—Local anesthesia or the inhalation of ethyl chlorid is taken very well by these patients. The latter should be chosen in preference to ether or gas.

C. GANGRENE OF THE LUNG.

D. ABSCESS OF THE LUNG.—In these cases local anesthetics or ethyl chlorid may be used. Chloroform is theoretically better in some respects, but it has many drawbacks and added dangers. Ordinary ether anesthesia may be used. To prevent too much pulmonary embarrassment when the pleural cavity is opened, intratracheal insufflation should be employed.

**Diseases of the Pleura.**—The presence of any considerable amount of fluid in the pleural cavity embarrasses respiration, particularly if the patient lies on the sound side. As an anesthetic, ethyl chlorid inhalation, nitrous oxid, or a light ether may be employed. Local anesthesia with novocain will be sufficient in many cases, even for resection of a rib. If a large amount of fluid is present and the patient's general condition is poor, a large dressing should be quickly applied; or, better, a rubber tube which snugly fits the opening in the chest wall and extends below the level of sterile fluid in a bottle placed on the floor may be used. The object is to prevent a sudden change of intrathoracic pressure from too rapid an escape of the pleural contents, and also, in the latter case, to prevent a pneumothorax. For a detailed description of this method see chapter on "Aspiration and Aspirating Devices in Operative Surgery."

When operating upon any other structure, in cases with much dyspnea from a considerable amount of fluid in the pleural cavity, great relief may be obtained by a preliminary aspiration of the fluid. After this has been done, if the dyspnea is less or has disappeared, a general anesthetic could be given, but in those cases in which a local anesthetic is possible it should be chosen.

Pneumothorax, hydropneumothorax, and pyopneumothorax are best operated upon with local anesthesia or with ethyl chlorid inhalation or nitrous oxid-oxygen. The use of the above-mentioned long tube which makes an air-tight fit with the opening in the chest wall and terminates below the level of sterile fluid in a bottle furnishes a water trap check valve which permits the escape of air and fluid, but prevents the entrance of air into the pleural cavity. The preliminary treatment in these conditions should be directed toward relieving the embarrassed respiration.

**Affections of the Mediastinum.**—Affections of the mediastinum require intratracheal anesthesia or a cabinet for differential pressure.

## DISEASES OF THE CIRCULATORY SYSTEM

**Plastic Pericarditis.**—Plastic pericarditis generally contra-indicates operation only in so far as the disease to which it is secondary contra-indicates or modifies the surgical procedure, as, for example, rheumatism, gout, tuberculosis, septic processes, chronic nephritis, etc.

**Pericarditis with Effusion.**—This is a much more serious condition and contra-indicates operation, except that required for its own treatment. The anesthetic should be local, light ether, gas-oxygen, or ethyl chlorid.

**Diseases of the Heart.**

ACUTE ENDOCARDITIS.—Acute endocarditis contra-indicates operation.

CHRONIC ENDOCARDITIS.

CHRONIC VALVULAR DISEASE.—Cases of the last two mentioned diseases generally stand operation with a general anesthetic very well, provided there is good compensation. Light ether anesthesia with particular regard to the varying degrees of cyanosis, pulse rate, and blood pressure is very satisfactory.

HYPERTROPHY AND DILATATION with poor compensation render any operation very dangerous. Cardiac stimulants and, in some cases, withdrawal of blood may steady the cardiac action so that an emergency operation may be performed. Local anesthesia, if possible, otherwise light ether should be used.

**Wounds of the Heart.**—Intratracheal insufflation of air and ether is very desirable, as the pleural cavity on one or both sides may be opened and cause embarrassed respiration.

**Neuroses of the Heart.**—These do not contra-indicate operation, but require a little more care on the part of the anesthetist. General anesthesia is satisfactory.

**Congenital Affections of the Heart.**—These affections do not absolutely contra-indicate operation. A light ether anesthesia combined with oxygen should be used. Special attention must be paid to the blood pressure and to the patient's color.

**Diseases of the Arteries.**—DEGENERATION, ARTERIOSCLEROSIS, ANEURISM. —Cases with the above-mentioned diseases demand special care in making the operation as short as possible with gentle handling of the tissues. Many advise against any operation if the blood pressure is high. In these cases ether or chloroform can be used, although it is better to use a local anesthetic if possible. But the high blood pressure in itself does not contra-indicate operation.

## DISEASES OF THE BLOOD AND DUCTLESS GLANDS

**Anemia.**—Although an operation is not contra-indicated in this disease, the risk from shock or possible infection is doubtless increased, and even a moderate hemorrhage rendered more serious. Healing is usually slow and convalescence prolonged.

If time permits, the general condition of the patient should be improved by the use of diet, food, drugs, general hygienic treatment, or transfusion. Often, however, the anemia is secondary to some surgical condition which demands immediate operative treatment. Before and after the operation every precaution should be taken to lessen its severity, making it as short as possible, with special attention to control of hemorrhage. Gas-oxygen with more or less rebreathing with the closed ether apparatus, or light ether anesthesia is to be preferred. All the precautions employed in cases of shock should be used if indicated, such as external heat, fluids in the vein, under the skin, or in the rectum, position with the head lowered, bandaging of the extremities, etc.

**Leukemia.**—The resistive power of the patient is lowered and the healing of the wound prolonged. What has been said with regard to the severe anemias applies to this condition.

**Hodgkin's Disease.**—This does not contra-indicate operation.

**Purpura and Hemophilia.**—These diseases lower the resistive power of the patient and render any operation dangerous because of the profuse bleeding which follows. Every attempt must be made to make the blood coagulate more quickly.

**Status Lymphaticus.**—Status lymphaticus would always contra-indicate operation if this condition could be recognized with certainty, although those cases in which an enlarged thymus alone is apparently responsible for the symptoms respond very well to an operation for its partial removal.

**Diseases of the Thymus.**—In diseases of the thymus, on account of the tracheal obstruction to breathing, an intratracheal anesthesia may be required, although ether by the drop method is very satisfactory. The operative procedure should be made as short and simple as possible.

**Diseases of the Spleen and Suprarenal Bodies.**—These do not contra-indicate operation.

**Diseases of the Thyroid.**—Goiter and tumors of the thyroid do not unfavorably influence an operation. Wherever an operation is indicated, gentleness in handling the tissues, with special care to have a clean, dry operative field, should be observed. This is especially true if the thyroid itself is being operated upon.

If there is any obstruction to breathing from pressure on the trachea, intratracheal anesthesia should be employed.

EXOPHTHALMIC GOITER.—Patients suffering from this condition should have a preliminary rest in bed, and, in certain severe cases, ligation of two or more arteries before any operation is undertaken. If a general anesthetic is to be used, it is well to accustom the patient to the inhalation of it for a short time for several days. This tends to relieve him of the mental strain accompanying the knowledge that an operation is about to be performed. Local anesthesia should be used whenever possible. Light ether, or gas-oxygen, are the general anesthetics most easily taken. Too much emphasis cannot be placed upon extreme gentleness in handling the tissues and careful control of bleeding. Enough gland tissue and as much of the posterior capsule as possible should be left undisturbed in order to insure the presence of sufficient parathyroid tissue after the operation. Operations elsewhere are not generally considered unless absolutely necessary, but when indicated the precautions mentioned above should be carried out as far as possible.

## DISEASES OF THE KIDNEY

**Anuria.**—If not due to a surgical condition demanding immediate operation, anuria should be relieved before operations elsewhere are considered.

**Uremia.**—Operations should not be undertaken in patients suffering from uremia.

**Acute Nephritis.**—This condition does not absolutely contra-indicate an operation, but renders the outcome more serious and should, if possible, first receive its appropriate treatment. If the urgency of the condition demands surgical interference, local or gas-oxygen anesthesia should be used.

**Chronic Nephritis.**—This condition, even with a high blood pressure, does not contra-indicate an operation, but does demand special precautions with regard to the anesthetic used, the duration of operation, and the postoperative treatment.

Local, gas oxygen or ether anesthesia may be used. The operation should be short and as simple as possible. In the postoperative treatment one should make a special point of filling the system with plenty of fluids and aiding the skin elimination as much as possible by employing hot packs, hot air baths, etc. In short, the regular treatment for the nephritis should be continued.

Any condition requiring the removal of one kidney should not be undertaken until the functionating power of the other kidney has been ascertained.

## DISEASES OF THE BLADDER

Diseases of the bladder do not contra-indicate operations elsewhere. Bladder conditions in which there are retention of urine and impairment of kidney functions demand an appropriate treatment before other surgical procedures are instituted. Acute gonorrheal urethritis is a contra-indication to operations for hernia near the genitals.

## DISEASES OF THE CENTRAL NERVOUS SYSTEM

These diseases, both central and peripheral, do not contra-indicate operations except in cases of edema, cerebral hemorrhage, tumors and cysts, and abscess of the brain. In these cases operation other than that indicated for the actual condition is contra-indicated except in extreme urgency. Then a local anesthetic is to be chosen if possible, though a general anesthetic may be used.

In certain of these cases emergency operations may be performed without any anesthetic.

## TROPICAL DISEASES

The tropical diseases contra-indicate operation only in so far as they weaken the patient and lower his vitality and render him less able to withstand any surgical procedure. Furthermore, there is a local contra-indication in those cases which have a lesion in the skin or subcutaneous tissue, rendering infection more probable and delaying or preventing the healing of the wound.

If the operation is not absolutely demanded both the local and general condition should first have its appropriate treatment.

## SKIN LESIONS

Contra-indications to operations and conditions modifying operative procedures are found in the following skin lesions:

A. Lesions of the skin which might cause wound infection.

B. Lesions of the skin which might cause wound infection and also general infection.

C. Lesions of the skin which might cause delayed healing of the wound.

D. Lesions of the skin which might cause a recurrence of the condition in the wound, or in some other part of the body, or in both places.

E. Lesions of the skin which can be better treated in some non-operative manner.

**A. Lesions of the Skin Which Might Cause Wound Infection.**—Under this heading might be grouped such diseases as acne, carbuncle, dermatitis, eczema, erysipelas, furunculosis, parasitic diseases, scabies, impetigo contagiosa, dermatitis venenata, pemphigus, vaccinia, burns, and destructive traumata of the skin.

In certain cases in these conditions the patient's general vitality may have been so lowered that only a very urgent operation would be advised. If the operative field or the adjoining region is involved the danger of subsequent wound infection is greatly increased and, unless operative intervention is absolutely necessary, it is better to treat the skin lesion first.

In cases of eczema caused by an irritating discharge from a wound or sinus which escapes and spreads over the skin the most efficient method of treatment is the application of continuous suction by means of an appropriate double tube introduced into the sinus or wound a short distance to remove all the discharge before it reaches the surface. After this removal of the irritating factor is obtained, the ordinary applications are sufficient. See Chapter on "Aspiration."

**B. Lesions of the Skin Which Might Cause Both Local and General Infection.**—The conditions mentioned under A in their more severe forms might cause a general as well as a local infection.

**C. Skin Lesions Which Cause Delayed Healing of Wounds and Render Any Operation, Other than That of Emergency or Simple Incision and Drainage, Undesirable.**—Examples of this are such conditions as elephantiasis, leprosy, myxedema, and scleroderma.

**D. Lesions of the Skin Which, After Their Operative Removal, Tend to Recur Locally or by Metastasis.**—Such are keloid, melanotic sarcomata, and pigmented mole. In the last two serious conditions the removal of a considerable area outside the diseased region, with the minimum amount of handling and traumatism to the pathological tissue, will give the best result and afford the least danger of metastasis.

**E. Lesions of the Skin Which Can Be Treated in Some Non-operative Way.**—Examples of this are syphilitic conditions, lupus, and some cases of superficial epithelioma.

# CHAPTER VI

## THE PROPHYLACTIC AND THERAPEUTIC ADMINISTRATION OF VACCINES AND SERA

Joseph C. Roper

The administration of vaccines and sera of various kinds in an effort to develop an immunity against a particular organism or to supplement the natural immunity of the body has come to be a well-recognized therapeutic procedure. To avoid confusion if possible, and to have a definite view of the indications for and limitations of this method of treatment, a short discussion of the essential features of immunity is presented.

### IMMUNITY

Immunity in its broadest sense is the power of living organisms to resist successfully any harmful influence. The type of immunity which we shall consider is usually divided into that due to inherited characteristics, "natural" immunity to certain diseases of bacterial origin, and that developed through infection or treatment, "acquired" immunity. This type of immunity is absolutely essential for the perpetuation of organic life. Without it the bacteria would quickly overcome all animal life. The cessation of life and the consequent cessation of immunity production are followed by complete bacterial invasion and destruction. This is a necessary part of the scheme of animal existence, releasing as it does the combined body nitrogen for the use of plant life, thus permitting its subsequent elaboration by the plants into a form available for later re-utilization by animal life.

**Natural Immunity.**—Natural immunity, that is, the property of immunity to ordinary saprophytic bacteria, is inherent in man. The bacteria against which natural immunity is complete are non-pathogenic. The bacteria against which there is no natural immunity or against which there is only a relative natural immunity are or may be pathogenic. In other words, the question of pathogenicity is dependent on immunity rather than on any inherent properties of the bacteria.

Natural immunity varies with the species, the lower animals being immune, for example, to the gonococcus and spirochæta pallida, while man is immune to many animal diseases. Relatively it varies, also, with age, with body conditions which influence the activities of the leukocytes, as exposure to cold and wet, with fatigue, with the state of nutrition, as when the food is improper or of poor quality, and with chronic diseases, such as nephritis, diabetes, cirrhosis, etc. It is diminished, also, by alcohol and by general anesthetics, particularly by prolonged anesthesia. On the other hand, it may be augmented by favorable conditions and surroundings.

It has been clearly shown that the blood of many persons in normal health contains measurable amounts of diphtheria antitoxin. Several units to the c. c. have been demonstrated in the blood of children apparently immune to diphtheria. This form of immunity would perhaps more properly come under the head of acquired immunity, as it probably results from mild infections with attenuated organisms.

**Acquired Immunity.**—Acquired immunity, as the term is generally used, expresses the immunity resulting from an attack of a particular disease or that developed by special treatment, and differs from the augmentation of natural immunity, which may be brought about by improved hygiene, etc.

The ability of an individual to develop immunity varies with the individual and with the exciting organism. The duration of the immunity also varies, many diseases conferring a lifelong immunity against a second attack, as, for example, small-pox, while others, such as pneumonia, develop but a transient immunity. (Recent work on pneumonia suggests the possibility that the recurrent attacks may be due to different strains of the pneumococcus, it having been shown that immunity against one strain does not protect against some of the others.)

In the development of immunity, the virulence of the invading organism is an important factor. This virulence is known to vary greatly under different conditions. Many attempts have been made to produce avirulent cultures of pathogenic organisms which might be safely used in the living state to produce immunity.

Acquired immunity exists in 2 forms: active immunity and passive immunity. *Active immunity* may result (1) from a natural attack of a disease, (2) from an artificially induced attack, (3) from the use of living cultures of diminished virulence, and (4) from the injection of killed organisms. The second method is used to some extent in animals. The best examples of the third method are vaccination against small-pox and inoculation against rabies. The small-pox vaccine probably consists of an organism modified by passage through calves. The material for the vaccine against rabies is obtained from the cords of rabbits killed by the virus, which is then modified by drying the cords for varying lengths of time. The fourth method is the one in which we are interested in this chapter, and the principles on which the production of immunity by this means depends will be considered later.

*Passive immunity* is the immunity conferred by injecting an animal with the serum of another in which active immunity has been induced, and protects only against the organism against which the original animal has been immunized.

**Time Required for Production of Immunity.**—The difference in the time involved in the production of the 2 types of immunity is marked. Active immunity develops slowly, requiring at least a week under favorable circumstances, while passive immunity is conferred almost at once by the injection of the serum. Unfortunately most of the attempts to produce potent sera which would confer a passive immunity have been unsuccessful.

**Duration of Immunity.**—Passive immunity is much more transient than active immunity. It begins to diminish almost at once, because of the elimination of the antibodies, and usually endures but 3 to 6 weeks, while active immunity may persist for from 1 to several years.

**Theories of Immunity.**—Various theories have been advanced to explain immunity. Among them may be mentioned the exhaustion theory of Pasteur, who argued that the immunity was due to the lack of suitable food for the bacteria, and the theory of Metchnikoff, who considered that the immunity was due entirely to the phagocytic properties of the leukocytes. The leukocytes, according to him, had fixing and digesting properties for bacteria, the former corresponding in a measure to Wright and Douglas' opsonins, as at times they might be liberated by the phagocytes. He considered also that the leukocytes had the property of absorbing toxin.

Experiments which showed that the blood of persons recovered from infections or of animals immunized against certain organisms had a protective power gave rise to the humeral theory.

Ehrlich's Side-chain Theory.—Ehrlich's side-chain theory, which graphically permits of an explanation of many of the phenomena, was advanced in 1897 and is still most highly regarded.

In 1896 Weigert proposed the following hypothesis to explain hyperplasia resulting from irritation or injury: The maintenance of normal structure and function of tissues depends on the equilibrium produced by a series of mutual restraints exercised by neighboring cells on each other. The functions of the cell itself depend on similar restraints exercised by its component units on each other. Injury or irritation of one of these cells or component units changes the relation of all the other cells or units to each other and unrestrained development or growth takes place. This growth, Weigert points out, always goes on to excess, more new material being produced than is necessary to replace that lost.

This hypothetical reasoning will explain the occurrence of free antibodies and will enable us to comprehend the equally hypothetical side-chain theory of Ehrlich. Ehrlich points out that a cell has 2 functions, one which has to do with a physiological process, such as gland secretion or nerve conduction, and the other with nutrition. That portion of the cell which discharges the physiological function must be nourished. The property of providing nourishment must be regarded as due to a series of activities separate from those that have to do with the physiological activity. The former is the more important function in relation to immunity. It enables the cell to appropriate food from the circulating fluids and to elaborate it into molecules of protoplasm to replace waste. This property is probably at bottom a chemical process, the food molecule becoming attached to some portions of the cell or groups of atoms for which it has a chemical affinity. These groups he calls side chains, haptines or receptors (Fig. 1). While their principal function is to convert the particles of food into a condition suitable for assimilation by the main portion of the cell, they also have a variety of other functions. These enable them to combine with substances which are not food. One of these substances is the toxin molecule. The toxin molecule may be represented as containing 2 groups, a haptophore or combining group and a toxophore group (Fig. 2). The haptophore group permits the toxin molecule to attach itself to the haptine or receptor of a body cell and thus enables the toxophore or poison group to exert its enzyme-like action on the cell (Fig. 3). Depending on the number of toxin molecules anchored by a cell, the cell may be injured or destroyed. If the insult to the cell has not been enough to destroy it, there takes place a great change in cell tension and there is an immediate regeneration of fresh receptors to replace those lost. If this phenomenon is reproduced several times by doses of toxin insufficient to destroy the cell, the cell eventually develops the faculty of manufacturing more receptors than it can accommodate and these are thrust off into the circulation, thus forming toxin receptors or antitoxin (Fig. 4). It will be readily seen that, if these free receptors combine with the toxin molecule, the latter cannot attach itself to the cell and its toxophore group is rendered inert.

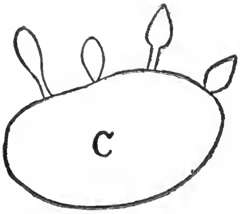


Fig. 1.—Cell with Receptors or Haptines.


Fig. 2.—Toxin Molecule with Haptophore (Combining) Group H and Toxophore (Enzyme-like) Group E.

Many experimental facts have been brought forward in support of this theory, and its simplicity permits of the presentation of the principles of immunity in a concrete form.

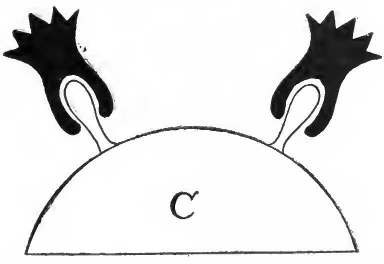


Fig. 3.—Cell with Toxin Molecules Attached by Combination of Haptophore Group and Receptor.

Receptors or antibodies, according to Ehrlich, are not all of the same composition or structure, and individual receptors may exercise entirely different functions. Each cell is supplied with a multitude of these receptors, which, when thrust off, constitute antibodies. Ehrlich has divided the receptors into 3 orders. The first order, the simplest of these antibodies, is represented by the antitoxin molecule, which has only a single group, a haptophore or combining group (Fig. 5). The second or more complicated order is represented by the agglutinins, which contain an agglutinaphore group in addition to the combining or haptophore group (Fig. 6). The third or most complicated order contains 2 combining groups and may be typified by the amboceptor (Fig. 7). This group requires for the completion of its activity the presence of complement.

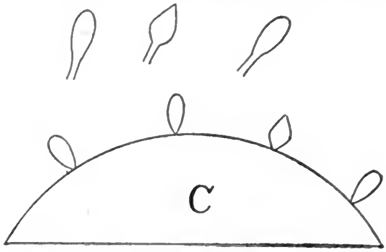


Fig. 4.—Receptors Cast Off Constituting Free Receptors or Antitoxin.

According to Ehrlich, amboceptor is formed for the anchoring of molecules too large for the simple receptors which anchor the toxin molecule. The amboceptor possesses 2 haptophore or combining groups, one to combine with the molecule of food material and the other to combine with the digestive enzyme or complement which breaks down the large molecule and prepares it for utilization. In the same way the amboceptor combines, on the one hand, with antigen and, on the other hand, with complement, a principle made use of in the Wassermann reaction. Complement, therefore, must have 2 groups, a combining or haptophore group and a zymophore or digestive group, and must belong to the second order of antibodies. Its resemblance to the toxin molecule will be evident. This resemblance has been further established by the production of anticomplement. Complement is present normally in the blood and is easily destroyed by heat, acids, etc. Only in combination with complement is the amboceptor able to dissolve bacteria, cells, etc. Sera containing receptors of the third order are bacteriolytic or bactericidal only when combined with complement.

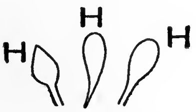


Fig. 5.—First Order of Antibodies free Receptors or Antitoxin Having Only a Single Group, the Haptophore or Combining Group.

Immunity to Toxins.—In the development of the resistance of the body there are 2 factors involved, the immunity to toxins and that to bacteria. It is possible by the injection of suitable small quantities of bacterial toxins at suitable intervals to render an otherwise susceptible animal immune. Immunization against a toxin confers also some degree of immunity against the pathogenic action of the organism that produced the toxin. An animal immunized against the toxin of one bacterium, however, is not protected against the toxin of another.

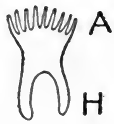


Fig. 6.—Second Order of Antibodies Having a Combining Group H and an Agglutinaphore Group A.

The toxins are of 2 varieties: the *extracellular* or soluble toxins produced and liberated during the growth of an organism and the *intracellular* or insoluble toxins which are liberated only on the death and disintegration of the organism. The former may be separated from the organisms by filtration. All pathogenic bacteria do not form them. Two organisms which form them freely and which have been extensively studied are B. diphtheriæ and B. tetani. The intracellular toxins or endotoxins constitute a property inherent in the bodies of the bacteria and not liberated during growth. The subject is not entirely clear, some investigators claiming to have isolated endotoxins and to have produced antitoxins against them with killed organisms and others denying the possibility of producing such antitoxin. Organisms such as the pneumococcus, which are not known to produce an extracellular or soluble toxin, are supposed to exercise their harmful influence when endotoxin is liberated by the death and solution of the bacteria.

FIG. 7. — THIRD ORDER OF ANTIBODIES HAVING TWO COMBINING GROUPS (AMBOCEPTOR).

It is now generally accepted that toxin and antitoxin form compounds which are devoid of toxic action on animal cells. Various proofs that this union is chemical have been brought forward; the most striking of which, by Martin and Cherry, showed that toxin would pass through a filter impregnated with gelatin, while antitoxin, apparently having a larger molecular structure, would not. They also demonstrated that, when a freshly made mixture of toxin and antitoxin was placed on a filter, the first portion of the filtrate was toxic but that this toxicity diminished in later portions and was absent a few minutes after the mixture had been made. The inference was that the toxin and antitoxin had combined to make a molecule too large to pass through the filter. When freshly made mixtures of toxin and antitoxin are exposed to a temperature of 70° C., the toxicity is restored, the antibody having been destroyed and the toxin resisting this temperature. When this mixture has been allowed to stand for some time, however, the toxicity is not restored by a temperature of 70° C. It is apparent that the molecule formed by the union of toxin and antitoxin, being less thermostable than free toxin, has been destroyed. Ehrlich showed that toxin and antitoxin combined in definite proportions.

Toxins against which antitoxins may be produced possess 2 groups: a haptophore or combining group and a toxophore group. The latter may be destroyed without injuring the former. This has been observed in old preparation of toxins. The resulting molecule is called a toxoid. It is still capable of combining and of exciting antitoxin formation, but is not toxic.

BACTERIAL IMMUNITY.—The main factors in bacterial immunity are bacteriolysis and phagocytosis, operating either independently or in combination. Phagocytosis constitutes the main defense and is so effectual that organisms very rarely find a foothold in the circulation. It is highly probable that in most infections bacteria gain entrance to the circulation but in the great majority of instances they are very quickly destroyed. Normally the blood contains substances which render the bacteria susceptible of ingestion and destruction by the phagocytes. These bodies, called opsonins by Wright, are supposed by him to exist in the circulating blood. Other observers have claimed that they are developed during manipulation of the blood and are the result of clotting or of phagolysis. In support of this, it has been pointed out that in those portions of the body where the circulation is slowest and leucocyte destruction—and therefore, opsonins—most abundant, as the spleen and bone marrow, phagocytosis is most marked, and that it does not occur experimentally to any degree when bacteria are mixed with blood in situ, as in a normal ventricle cut off from the circulation. The opsonins resemble complement in being thermolabile, although some substances which act as opsonins are thermostabile. Similar bodies were discovered by Neufeld in 1904 in the blood of pneumonia patients and called by him bacteriotropins. They play an important part in recovery in that disease and are regarded by some as identical with opsonins. Their action, however, is specific, as normal opsonin is wholly without effect on virulent pneumococci while bacteriotropins permit or cause their ready ingestion by the phagocytes.

The phenomena of destruction by phagocytosis differ materially from the phenomena of bacteriolysis or extracellular solution, the latter necessitating as it does both amboceptor or immune body and complement. The results, also, are different, as in destruction by phagocytosis it is probable that the endotoxins are destroyed or neutralized, while in direct bacteriolysis they are liberated.

**Summary.**—To recapitulate, for the development of immunity there must result from the injection of antigen the formation of antibodies. These antibodies may be of several kinds: antitoxins, agglutinins, opsonins or bacteriotropins, bacteriolysins, etc. The antibodies, whether bacteriolytic or cytolytic, are specific in nature. It is conceivable that we may, through the indiscriminate use of vaccines (antigens), by lowering the antibody-producing power of the cells, interfere with the normal development of protective antibodies.

## VACCINES

**Preparation of Vaccine.**—Vaccines are usually prepared from cultures grown on suitable solid media. Some, however, such as the tubercle bacillus, are grown on liquid media. With the intention of keeping the organisms as little changed as possible, various ways of attenuating their virulence and so permitting the use of live organisms have been tried. Organisms in the living state are very rarely used, however, in the vaccination of human beings. They are killed either by heat, exposure or chemicals. Each method has its adherents, almost all admitting, however, that the ideal vaccine would be composed of living organisms attenuated just to the point where they would not harm the host yet were active enough to excite continuous antibody formation.

As this end has not been attained and the organisms must usually be killed, the method most generally adopted is exposure to as low a temperature as will do this (60° C. for 1 hour).

The routine method at the New York Hospital is as follows: The material supplied, if suitable, is used for streaking plates without any previous manipulation. By this method the purity of the culture is assured. If unsuited for direct use, a tube of broth is inoculated with one or several loopfuls of material, thorough distribution of the organisms is attained by shaking and plates of suitable media are streaked. In this way information is obtained as to the variety and relative number of bacteria involved.

To decide which bacteria are directly responsible complement deviation tests of those isolated are sometimes necessary. In some cases it is possible to determine from their pathogenicity which are the causative organisms, as, for example, in the isolation of a typhoid organism from a gall-bladder sinus. However, the organism must be of definite pathogenicity to justify such a procedure.

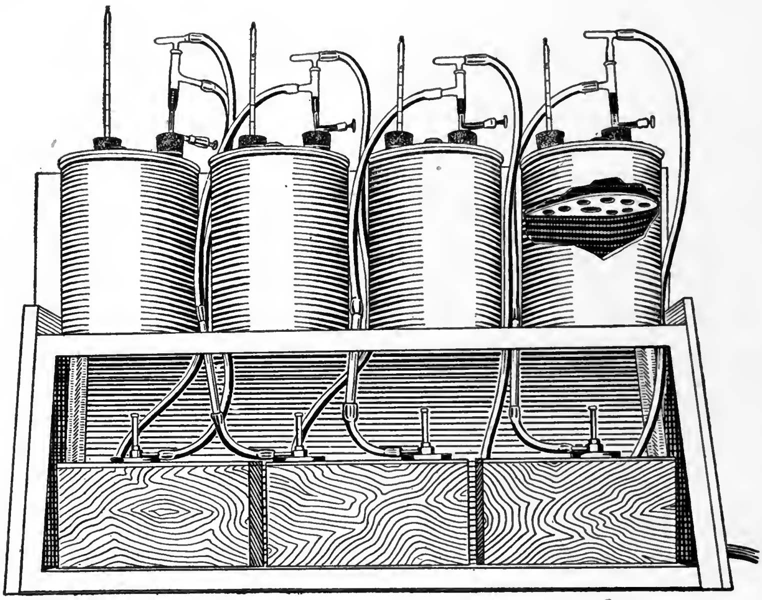

Fig. 8.—Apparatus for "Fractional" Sterilization of Vaccines.

After the cultures have been grown for 24 hours, they are washed into a sterile test-tube with 5 to 10 c. c. of sterile salt solution. The clumps are broken up as far as possible by vigorous and prolonged shaking, the tube is centrifugated a moment to remove the larger particles, and the number of organisms per c. c. determined by the method devised by Wright and Douglas or by counting directly in a counting chamber. The methods for the estimation of the number of bacteria are only relatively accurate. The bacterial suspension is now diluted to the proper strength for injection and is divided among 4 test tubes. The organisms are killed by heating at 4 different temperatures—65°, 70°, 75°, and 80° C.—½ hour. The apparatus used (Fig. 8) consists of a series of constant level water-baths equipped with automatic gas controls and thermometers. In each is a perforated diaphragm for supporting test-tubes containing vaccine. The baths have covers, thus insuring a fairly uniform temperature for all parts of the tube. In this way the objection made to the open bath, that organisms spilled on the sides of test tubes may not be killed, is overcome.

After heating, cultures are made to insure sterility, the different suspensions are combined, and the vaccine is put up in sterile hypodermic vials closed with rubber caps. Through these caps, after immersion in alcohol or application of a drop of carbolic, a hypodermic needle may be thrust and the vaccine withdrawn as needed. The strength of the vaccines varies from 100 to 1,000 millions to the c. c., depending on the organisms involved.

FIG. 9.—CAPILLARY PIPET.

**Standardization of Vaccines.**—Of the various methods proposed for the standardization of vaccines, the method devised by Wright is probably most widely used. By it the ratio of organisms in a given suspension to red blood cells is determined in a stained smear. The bacterial suspension is made as directed under preparation of vaccine. A capillary pipet (Fig. 9) is marked about ½ in. from the end. Blood from a fresh puncture is drawn up to this point, a small bubble of air is drawn in, and then the bacterial suspension is drawn up to mark. The equal quantities of blood and suspension obtained in this way are blown out on a glass slide, mixed thoroughly by drawing in and out of the pipet several times, and a smear is made from a drop of this mixture. The slide is stained with a polychrome blood stain and the relative number of red cells and bacteria counted in a number of fields. At least 500 red cells should be counted. A ruled ocular diaphragm aids greatly in the counting. If this is not available, the slide may be divided into squares. Taking 5,000,000 as the average number of red cells per c. mm., the number of bacteria per c. c. may be estimated. There are very many sources of error in the method.

The organisms may be counted directly in a Helber-Zeiss counting chamber, using a red or white cell pipet for diluting. This method is more accurate than Wright's but takes longer.

A special centrifuge tube has been devised by Hopkins, in which the suspension, filtered through cotton, is centrifugalized for a definite time at a constant speed. This gives a uniform sediment, which is made up to a 1 per cent. suspension. The value of this suspension for the different organisms has been estimated. The method is accurate for organisms of a constant size.

It will be seen that only a relative accuracy is achieved in standardizing vaccines. This is sufficient, however, for practical purposes, as—because of the variation in the organisms themselves—the dose, after the first one, must be determined by the effect.

**Dosage of Vaccines.**—The first dose of vaccine must be decided arbitrarily;

the subsequent doses are dependent on the reactions resulting from the first. Clinical data are usually relied upon for determining the size and time of all doses but the first. **The opsonic method for controlling the dose, etc., has fallen into disuse because of inconstant results.** The initial doses recommended by Wright for the various organisms are as follows:

Gonococcus, 5,000,000 to 50,000,000.
Colon bacillus, 5,000,000 to 50,000,000.
Pneumococcus, 10,000,000 to 50,000,000.
Typhoid bacillus, 5,000,000 to 50,000,000.
Streptococcus, 10,000,000 to 25,000,000.
Staphylococcus, 50,000,000 to 1,000,000,000.

These figures serve as a rough guide for the initial dose only. If following the initial dose there is a marked local or constitutional reaction, no subsequent dose should be given until after this has subsided. Local redness, tenderness, or induration to any considerable extent, with constitutional disturbance and increase in special symptoms, are indicative of overdosage.

**Interval Between Doses.**—The usual custom is to allow an interval of 5 to 10 days to intervene between doses, so as to avoid the so-called negative phase. With the object of developing the immune bodies as rapidly as possible, it has been the custom for several years at the New York Hospital to start the treatment with daily doses for the first 5 days, unless contra-indicated by reactions, and then to give injections at 5-day intervals. There is experimental evidence to prove that agglutinins may be raised more rapidly by this method, and there is a possibility that other antibodies are similarly influenced. The results by this method have been satisfactory.

**Prophylactic Vaccination.**—The injection of vaccines of staphylococci or streptococci before operation in the hope of avoiding infection by developing immunity against these organisms must be regarded as an unsound procedure. In the present state of our knowledge, we can be none too sure that no harm will result.

Following the administration of a dose of vaccine, animals are prone to become ill and while in this condition certainly are less resistant to infection. It hardly seems wise to subject a patient to possible injury and so reduce his resistance.

**Sensitized Vaccines.**—Sensitized vaccines have been prepared for a number of diseases. Living cultures are submitted to the action of specific sera, the organisms are separated from the sera and used as a vaccine. This vaccine will contain the organisms plus the antibodies which have become attached to them while in contact with the serum. This method has been used by Besredka for immunization against typhoid, in which he claims excellent results and no drawbacks. The method is also used by the Pasteur Institute of Paris for the preparation of antirabic vaccine. The dangers of using living cultures have limited the employment of sensitized vaccines. The advantages do not seem to offset these dangers. All organisms cannot be sensitized, so that at best the application will be limited.

**Stock Vaccines.**—In every case autogenous vaccines, where available, are to be preferred. Where a vaccine seems indicated, however, and an autogenous one cannot be prepared, a stock vaccine is permissible if the connection between the disease and a particular organism is undoubted. Because of the number of strains and the variation in the different strains of the same organism, even when the causative agent is known, an autogenous vaccine is vastly to be preferred. The number of strains of gonococci with qualitative differences, isolated by Torrey, illustrates this point. Where an autogenous cannot be procured, a polyvalent vaccine made from a number of strains of the same organism should be used. Many factors, including uncertain source, age and strength, argue against the stock vaccine.

In no case should a stock vaccine be used without definite information as to the causative agent involved. The infections in which most benefit has been derived from the use of stock vaccines are those in which the staphylococci are concerned.

Stock vaccines must, of course, be used for antityphoid inoculation.

**Mixed Vaccines.**—This term is used to identify vaccines consisting of 2 or more different bacteria. They must be differentiated from polyvalent vaccines, which contain several different strains of the same bacterium. There can scarcely be any scientific method for the application of a mixed vaccine. While we may be able to determine by the plate method of culture the variety and relative numbers of organisms in the particular material supplied, this is far from being a safe guide to the actual numbers and relative importance of the organisms involved in the process. In mixed infections the complement deviation test may prove to be a practical help.

## APPLICATION OF VACCINE AND SERUM THERAPY TO VARIOUS DISEASES

**Acne.**—Staphylococci of all varieties are found in this condition sometimes associated with the "acne" bacillus, an organism of the diphtheroid type. Vaccines of the former are readily prepared, but the latter grows with difficulty. Where improvement is not obtained with the staphylococcus vaccines, the "acne" vaccine may be tried. The local and general treatment should be continued while the vaccines are being used, but even under those conditions the results are not always satisfactory.

**Chronic Furunculosis.**—The most brilliant achievements of vaccine therapy have been attained in chronic furunculosis. Any variety of the staphylococcus may be present. Autogenous vaccines are easily prepared. If an autogenous vaccine is not available, however, a stock vaccine prepared from several strains of staphylococci may be used, but if prompt improvement does not follow it should be abandoned. The first dose should be large, about 500,000,000; subsequent doses may have to be larger or smaller, depending on the reaction. Daily doses are given for 5 days unless the reactions are severe, subsequent doses should be given at 5-day intervals.

**Carbuncle.**—The staphylococcus aureus seems uniformly to be the organism involved in this condition. Autogenous vaccine should be used, however, wherever practicable and the dosage should be large. Attention to the general health and diet of the patient is very important in conjunction with proper surgical measures.

**Anthrax.**—Although the manifestations of this disease suggest the presence of a toxin, there is no experimental proof of its existence. Attenuated living vaccines are used in developing immunity in animals. For the condition known as malignant pustule in man, serum has been used with success. It may be obtained in the open market. It should be given also in pulmonary anthrax. If the serum is not available, killed vaccines may be tried.

**Arthritis.**—The type of arthritis following definite localized infections should be amenable to treatment with organisms isolated from the site of the original infection if their relation can be established by complement deviation tests. Unfortunately this relation cannot always be traced, and frequently in cases of long standing no definite focus of infection can be found. Recently several organisms have been isolated by Rosenow from the glands in the neighborhood of the affected joints in chronic arthritis, and vaccines made from these organisms are being used. Vaccines made from organisms whose relation to the disease has been established by complement deviation tests alone have been used with some degree of improvement. The results, while encouraging, have not been brilliant, however.

In these conditions all possible accessible sources of infection must be kept in mind, as the accessory sinuses, antrum of Highmore, teeth, tonsils, ears, urethra, uterus, prostate, bladder, etc. The source of the infection, however, if it is an infection, may be in an organ not readily accessible, such as the gall-bladder or appendix.

**Bacillus Aerogenes Capsulatus Infection.**—In conjunction with efficient surgical treatment, the use of vaccines in this comparatively rare and relatively fatal infection may be of assistance. The initial dose should be small.

**Cholera (Vibrion Choleræ).**—Sera have been prepared which have a protective value in animals but no curative value. The serum of recovered patients is very strongly bacteriolytic. Haffkine, using attenuated living organisms, has used preventive vaccination in India with considerable success.

**Infections with Colon Bacillus.**—Organisms of the colon group have been isolated from a variety of conditions. They are prone to locate in the gall-bladder and pelvis of the kidney. The variations in the members of this group and the marked differences in the biological characteristics of the different varieties make the value of stock vaccines of the type usually used (the bacillus coli communis) highly problematical. The members of the group extend from the coli communis, through the paracoli and enteritides, to the paratyphoid group. Autogenous vaccines are the only ones whose use is justified. Even with autogenous vaccines the results in cases of pyelitis, etc., are frequently disappointing, possibly because the places where the organism thrives are not accessible to the immune bodies. The usual initial dose is about 50,000,000.

**Diphtheria.**—The production of diphtheria antitoxin furnishes a practical example of the development of an active immunity. This organism furnishes a soluble toxin and this toxin is available for immunization.

As marketed, diphtheria antitoxin contains from 300 to 2,000 units to the c. c. The usual sites for injection are the loose subcutaneous tissues of the abdominal wall and between the shoulder blades. In urgent cases the injection should be made intravenously. Park has shown that where, after subcutaneous injection, the blood will show 2 units per c. c. after 6 hours, it will show 20 units per c. c. after same period if a similar injection has been given intravenously.

The same authority strongly recommends one large dose instead of several small ones and has supported his recommendation by showing experimentally that, of 2 animals injected subcutaneously, one with 1 dose of 15,000 units and the other with 4 doses of 5,000 units each at 8-hour intervals, the blood of the former after a short time contained over 3 times as many antitoxin units to the c. c. It was not until after 3 days that the strength of the latter in units of antitoxin to the c. c. of blood equaled that of the former.

The doses recommended for children are as follows: when seen on first day, 5,000 to 10,000 units subcutaneously; on second day, 10,000 to 15,000 units subcutaneously; on third day, 10,000 to 15,000 units intravenously. Even when seen early, if the membrane is extensive, involving the pharynx or larynx, intravenous injections are advised. In very severe or late cases doses of 20,000 to 100,000 units may be given intravenously. There is some evidence to suggest that large doses may separate the toxins from their combinations with the cells.

If there is no distinct improvement in the general and local condition after twelve hours, it is customary to repeat the dose or to give a larger dose. Park claims that if the initial dose is of sufficient size this will be unnecessary.

All children exposed should be immunized, the immunizing dose varying between 300 and 1,000 units, depending on the age and size of the child. The protection persists only for from 4 to 6 weeks.

Active immunization has been used with some success for the treatment of "carriers" of diphtheria bacilli. An autogenous vaccine should be prepared.

**Dysentery.**—The bacteria which are regarded as causative factors in dysentery have been divided into 2 classes, those not fermenting mannite and producing a soluble toxin—the Shiga type—and those fermenting mannite and not producing a soluble toxin—the Flexner-Harris type. Organisms belonging to the latter type are the ones most prevalent in the United States.

No satisfactory results have been obtained in active immunization against both types.

In Japan passive immunization with antidysenteric serum prepared against the Shiga type has reduced the mortality from 22 to 26 per cent. to 9 to 12 per cent. As this organism produces a free toxin, the serum is antitoxic in nature. Sera prepared against the variety of organism prevalent in the United

States, however, must depend on bacteriolytic properties, as these organisms do not produce soluble toxins. Therefore, the serum will be antibacterial and not antitoxic. No definite beneficial results have been obtained from these sera. More recently a polyvalent serum has been used with some success, possibly due to antitoxins produced against the Shiga bacillus.

Shiga's serum is given in 10 c. c. doses repeated in 6 to 10 hours if necessary. The same doses are given on the second and third days in severe cases, but not over 20 c. c. are given in one day. The sera against the Flexner-Harris type have been given in larger doses, up to 100 c. c.

**Erysipelas.**—Erysipelas appears to be a self-limited disease in which vaccines, leukocyte extracts, sera and proprietary preparations are apparently without any influence. In a number of cases (95) observed by Erdman at Bellevue Hospital treated by vaccines prepared from stock cultures, by trade stock vaccines, and by other proprietary bacterial remedies, the duration of the disease was not lessened; the mortality remained at the same level; there was no immunity against recurrence, spreading or complications and no change in the subjective symptoms as compared with the control cases.

**Graves' Disease (Exophthalmic Goiter).**—The hopes that were raised with the introduction of antithyroid serum have not been fully realized. The serum appears to have no influence in many cases. Its specificity has been questioned, it having been argued that the precipitate obtained when the antigen is prepared as directed by Beebe contains salts of protein and nucleic acid instead of nucleoproteid, and that the antibodies produced are due to the protein introduced. If tried and found to have no effect on a given case, the use of the serum should not be persevered in.

**Glanders.**—The disease is recognized under 2 conditions, one known as *glanders,* in which it involves chiefly the mucous membranes, and the other known as *farcy,* in which the principal lesions are located in the skin. The causative organism is known as the bacterium mallei. The diagnosis is made by agglutination tests and by inoculating male guinea pigs subcutaneously or intraperitoneally with purulent material or blood. In positive cases enlargement of the testicles follows.

Mallein, prepared along the lines of Koch's old tuberculin, is used for diagnostic purposes in animals. It has no curative value. Attempts at active and passive immunization have resulted only in failures.

**Gonococcus Infections.**—COMPLEMENT-FIXATION TEST (SCHWARTZ AND McNEIL).—A polyvalent antigen is prepared from various strains of gonococci grown on salt-free veal agar, neutral to phenolphthalein. Twenty-four-hour-old cultures are washed off the agar slants with distilled water, and the resulting suspension is heated for 2 hours on the water-bath at 56° C. It is then centrifugated and passed through a Berkefeld filter. When desired for use, this antigen is made up to 0.9 per cent. salt solution by mixing 9 parts of antigen with 1 part of 9 per cent. salt solution. The antigen is preserved in small quantities in sealed tubes heated to 56° C. for ½ hour on 3 successive days. Prepared in this way, it will keep almost indefinitely. It is standardized, if possible, with a known positive serum from a clinical case. If this is not possible, immune rabbit serum may be used, provided the minimum amount of serum which will completely fix complement is used. The anti-sheep hemolytic system is used. Immune rabbit serum may be obtained in the market. The technic and controls are much the same as in the Wassermann reaction, but the reagents are used in 1/10 the quantity.

Schwartz and McNeil regard the complement-fixation test for gonococcus infection as clinically absolutely specific for the gonococcus. The one positive result obtained aside from cases with gonococcus infection was with a highly immune animal antimeningococcus serum. Sera from patients suffering from meningococcic cerebrospinal meningitis have been uniformly negative.

A positive reaction is not to be expected earlier than the fourth week, and then only when such complications as prostatitis, gonococcus arthritis, etc., have supervened. A positive reaction is not obtained when the disease remains confined to the anterior urethra. A weakly positive reaction may appear in the third week when the posterior urethra has become involved. In uncomplicated cases a reaction is obtained only after 8 weeks. A complicated case gives a ++ or +++ reaction in 4 weeks. The fact that the early weeks of the infection do not give a positive reaction may be of value in differentiating a fresh infection from the recurrence of an old one apparently cured.

In females a positive reaction will not be obtained unless the cervix is involved. This is usually the case in women but is an unusual condition in children, hence the latter rarely give a positive complement-fixation test.

A negative reaction should be obtained, as a rule, 7 or 8 weeks after cure. In other words, if a positive reaction is obtained 7 or 8 weeks after a clinical cure the patient should be regarded as harboring gonococci.

The test is of great value when a bacteriological examination fails. This is especially true in the female. If the complement-fixation test is negative and the bacteriological test positive, the latter should be accepted only when the proof is absolute, i. e., the isolation of the gonococcus culturally.

VACCINE AND SERUM TREATMENT OF GONORRHEA.—For treatment of gonorrhea, both vaccines and sera have been employed. A polyvalent stock vaccine is usually used in an initial dose of 50,000,000 in the chronic cases with gonorrheal involvement of joints and other structures. Many observers claim some help from the vaccines. There is general agreement that they are of little or no benefit in the acute processes. Cases treated with antigonococcus vaccine give a strongly positive complement-fixation test, showing that antibodies specific for the gonococcus are readily produced in the human system.

Improvement has been reported in cases of localized infection, such as vulvovaginitis of children and epididymitis. In the former condition, however, relapses occur just as in the unvaccinated cases. A shortening of the course is the most definite result, but this can be demonstrated only when a large series is considered and even then it is open to doubt. The organisms, as in the infec

15

tions of the pelvis of the kidney, are in a position not readily influenced, if reached at all, by immune bodies.

In epididymitis and chronic infections of other adjacent parts, such as the seminal vesicles and prostate, cultures form the urethra after massage of the prostate and vesicles may reveal secondary infecting organisms against which a vaccine may be used. It is well, however, to control their pathogenicity by a complement-deviation test. This vaccine should always be an autogenous one.

Antigonococcus serum has been prepared, along the lines suggested by Torrey, by vaccinating rams with various strains of gonococci. The serum, like the vaccine, gives no definite results in acute cases, but some observers claim benefit in the chronic cases and in complications due to the gonococcus. The usual dose is 2 to 6 c. c., but larger doses up to 12 to 15 c. c. have been used. The serum has not been standardized, and its action may be due to contained antigen, as the animals, probably deficient in their ability to form antibodies, may lack the power to combine the injected antigen. No antitoxic power has been demonstrated. Serum sickness is prone to follow its use and more than 5 to 7 days should never elapse between injections. The serum may be purchased in the open market.

**Hodgkin's Disease.**—Diphtheroid organisms (called corynebacterium hodgkini) have been isolated from the glands in this condition and vaccines made from them have been used and improvement reported in some cases. The history of the so-called diphtheroid organisms shows that at one time or another they have been regarded as the causative factor in almost all diseases of obscure origin. For this reason many refuse to accept their association with Hodgkin's disease as anything more than an incident. In judging the value of treatment one must not lose sight of the many unexplained periods of improvement which may occur in the course of an untreated case of this disease.

**Localized Infections.**—In angina, otitis media, adenitis, osteomyelitis, etc., the causative organism should be isolated and an autogenous vaccine prepared.

In conditions such as these, in which the causative organism is not constant, every effort should be made to identify the bacteria involved. In otitis media usually several varieties are associated. The results of vaccine treatment in this condition are not very encouraging, but vaccines may be of help in conjunction with efficient local treatment.

**Infections with Bacillus of Influenza.**—In chronic processes following an acute influenza vaccines of the influenza bacillus should be of value if the relation of the organism to the process can be established. Other microorganisms may play a part. Their identity should always be determined before using a stock vaccine.

**Meningitis.**—In all cases lumbar puncture should be performed to determine the character of the infection. For lumbar puncture the space between the third and fourth lumbar vertebræ is the site usually chosen. This is on a level with the highest point of the iliac crests. The patient should be lying on his side with thighs and neck strongly flexed. Occasionally the sitting position is chosen. In some cases a slight degree of general anesthesia is necessary, but usually a moderate degree of local anesthesia by freezing or cocain is sufficient. The spinal canal is reached at a depth of 1 to 1½ in. (in children ¾ in.).

The gross characteristics of the fluid are a help toward diagnosis. With well-marked symptoms of meningitis, a clear fluid under pressure suggests a tuberculous process. When an epidemic prevails, a turbid fluid, in the absence of any focus pointing to a different cause, suggests the diplococcus intracellularis, and Flexner-Jobling serum should be injected at once. Smears and cultures should be made from the fluid, but often a positive bacteriological diagnosis cannot be established without some delay. The earlier the serum is administered, the better are the results. In the presence of a focus of infection, such as a fracture of the skull or an otitis media, smears and cultures should be carefully examined for the infecting organism, usually a streptococcus, pneumococcus or staphylococcus.

In treatment by serum the usual procedure is to draw off as much spinal fluid as will run easily and to inject slowly from 30 to 60 c. c. of antimeningococcus serum. In severe cases a second injection may be made in about 12 hours, but usually 24 hours elapse between treatments. Subsequent injections depend on the symptoms, the appearance of the fluid, and the presence of organisms. It is customary to continue treatment for a day or two after organisms have disappeared, even if the temperature has become normal. A recurrence of the organisms in the fluid naturally calls for more treatment. The serum is bacteriolytic, bacteriotropic, and anti-endotoxic in action.

Vaccination with diplococcus intracellularis for curative purposes has been ineffectual, but prophylactic vaccination has met with some success.

In cases of meningitis due to streptococci antistreptococcic serum has seemed to have a curative influence in some cases. The procedure is the same as that outlined above for the meningococcus.

No satisfactory sera exist at present for treatment of staphylococcic or pneumococcic infections of the meninges.

**Pyorrhea Alveolaris.**—Cultures may be made from the root canal if the nerve is dead, from the tip of the root reached alongside the tooth or if an abscess at the root has been demonstrated by X-ray by incising the gum and boring through the bone of the alveolar process. The use of a suitable autogenous vaccine in connection with local treatment seems to be of benefit in obstinate cases. It is in this field that complement deviation work should prove especially helpful.

The streptococcus viridans has been isolated from a number of cases. Pyorrhea alveolaris may furnish a portal of entry for this organism into the general circulation, at times with disastrous results.

Considerable work has been done in establishing the relation of this condition, and the organisms isolated from it, to cases of arthritis of obscure origin.

**Bacillus Pestis (Bubonic Plague).**—The organism may be isolated from the buboes or from the blood. Vaccines have been used for protection and treatment and sera have been prepared and used. The reported results show wide variations. The prophylactic use of the vaccine seems to have reduced the morbidity.

**Infections with Pneumococci.**—The pneumococci may be divided into several groups differing entirely in their immune reactions. Immune serum prepared against one group will not protect against or agglutinate the members of another. Antipneumococcus sera and vaccines have been tried extensively in pneumonia, but their routine use cannot be advised, as their value has not been clearly established.

Localized infections due to the pneumococcus may be benefited by an autogenous vaccine. That it should be an autogenous vaccine there is no question. The initial dose may vary between 20,000,000 and 100,000,000.

Many of the so-called postoperative pneumonias are really not true pneumonias but inflammatory processes due to emboli. Their course differs from that of a true pneumonia, and the organisms involved may not be pneumococci. The use of an antipneumococcus vaccine in this condition therefore is not rational.

**Puerperal Infection.**—The organisms isolated from this condition include the streptococcus, pneumococcus, colon bacillus, gonococcus, and bacillus aërogenes capsulatus.

In every case a blood culture should be made, as in this way if successful we may be sure that we are finding and dealing with the causative organism. Failing in this, a culture from the uterus may demonstrate an organism with pathogenic properties, but this latter method is always open to doubt. In a prolonged local infection, however, the use of a vaccine from this source might be justified. The indiscriminate use of stock streptococcus vaccines, however, cannot be commended.

Cases have been reported which have been benefited by antistreptococcus serum. The mechanism of the action of such a serum must be bacteriotropic and, as in the case of the pneumococcus, the serum probably must be prepared against the special strain involved. The indiscriminate use of antistreptococcus serum, therefore, is irrational.

**Rabies.**—By vaccination against rabies, immunity is established after infection, that is, during the incubation period of the disease. The diagnosis of hydrophobia in a suspected animal is made from Negri bodies in the brain tissue or by inoculating an emulsion of the brain cord or medulla into the subdural space of a rabbit through a trephine opening. The organism causing the disease has not been identified. The virus as administered in all probability contains the living organisms in an attenuated form.

According to the method originally devised by Pasteur, cords of rabbits dead of the disease were used in preparing the virus. These cords were dried over caustic potash for varying lengths of time. For the first injection Pasteur used a cord dried for 15 days. Cords kept as long as this are now regarded as practically innocuous. Various modifications of the original procedure have been made.

The scheme of treatment advised by the U. S. Hygienic Laboratory at Washington, known as the intensive method, is the one followed by the Department of Health of New York City.

The treatment may be administered by the physicians of the department or it may be administered by the patient's private physician, to whom the department will mail each day the dose appropriate for that day. To physicians outside of the city who are desirous of treating their cases personally the dose for each day is mailed on the preceding day or earlier if necessary because of the distance. The preparation is always administered subcutaneously into the abdominal wall.

The routine treatment covers 21 days. On the first day a mixture of cords dried 8, 7, and 6 days is given; on the second day a mixture of 4- and 3-day cords; on the third day a mixture of 5- and 4-day cords; on each succeeding day a dose is given derived from a cord dried from 5 to 2 days. Only in rare cases are 1-day cords used on eighth and twenty-first days.

Very rarely an attack of paralysis has developed during the administration of the virus. These have usually been mild, but some severe cases have been reported. Many modifications in the preparation of the virus have been devised to avoid the possibility of paralysis, but their use cannot be advised at present, as their value, like that of antirabic serum, has not been definitely established.

**Acute Rheumatic Fever.**—Although definite progress seems to have been made regarding the causative organism or organisms in this condition, it is not one at present amenable to either vaccine or serum treatment.

**Scarlet Fever.**—As the relation of the streptococcus to this disease is not clear, there is hardly any justification for the use of streptococcus vaccines. The same may be said of antistreptococcus serum, although good results have been claimed for the latter by some.

**Tetanus.**—As is well known, infection with the bacterium tetani may occur after gunshot wounds or any lacerating or penetrating wound which has been contaminated with garden, street or barnyard soil. As the results of the preventive use of tetanus antitoxin are so much more satisfactory than its use as a curative agent, it is the duty of every physician to administer a prophylactic dose in all such cases.

Tetanus antitoxin is prepared in the same way as diphtheria antitoxin. The dose for prophylactic purposes is from 1,500 to 3,000 units given subcutaneously as soon as possible after the injury. Depending on the richness of the nerve supply at the site of injury the period of incubation varies from 2 to 14 days, the usual period being 10 days. Once symptoms of tetanus have developed, the disease must be treated vigorously by intravenous and intraspinous injections, as advised by Park and Nicoll. The antitoxin has also been injected intracerebrally into the lateral ventricles through a small needle introduced through a trephine opening.

While theoretically only the free toxin will be neutralized by the antitoxin, there is some evidence that even that which has entered into combination with the nerve cells may be affected. This has been explained on the theory of "mass" action causing dissociation. There is clinical justification for its use after active symptoms have developed in the fact that the mortality in untreated cases is from 80 to 90 per cent., while in treated cases it is about 20 per cent. lower. Recent results from early intraspinous treatment promise to reduce this percentage much lower.

In this condition, as in diphtheria, Park claims that 24 hours after a single large dose there is a large amount of free antitoxin in the circulating blood. While this obtains, subsequent doses are unnecessary.

The possibility of tetanus developing in any given condition must be judged from the nature of the injury. The bacteriological diagnosis after symptoms have developed may be impossible.

Park and Nicoll make the following recommendations:

"In every case strongly suspected of being tetanus, from three to five thousand units of tetanus antitoxin should be given at the first possible moment intraspinally, slowly, by gravity, and always, if possible, under an anesthetic. In order to insure its thorough dissemination throughout the spinal meninges the antitoxin should be diluted, if necessary, to a volume of from 3 to 10 c. c. or more, according to the patient's age. When fluid is drawn off previously to the giving of the antitoxin, an amount of the latter somewhat less than that of the fluid withdrawn should be given. A number of cases of 'dry tap' have been observed in the disease by those so expert in spinal puncture as to leave no room for doubt that the canal was properly entered. In such cases only a small amount of tetanus antitoxin should be injected (from 3 to 5 c. c.).

"It must be remembered that in the human type of the disease there is frequently a focus constantly pouring out more and more toxin, for which reason it is probably advisable to repeat the intraspinal injection in twenty-four hours. While unquestionably the blood will soon become antitoxic through the intraspinal use of antitoxin, in order to insure the quickest possible neutralization of all toxins in the tissue fluids, it would seem advisable to give, at the same time as the first intraspinal dose, a dose of 10,000 to 15,000 units intravenously. A similar dose given subcutaneously three or four days later will insure a highly antitoxic condition during the next five days. We do not believe there is any advantage in giving larger amounts of antitoxin than those indicated."

**Typhoid Fever.**—Antityphoid vaccination as a preventive measure is established on a firm basis. It was first used extensively in India with but indifferent success. The results in South Africa during the Boer War were more satisfactory. In the United States army the published results have been most striking and have fully established the value of the procedure.

The vaccines used are from cultures on slant agar, 24 hours' growth, the organisms being killed at 60° C. This is one of the few conditions in which the use of stock vaccines is permissible. In adults the first immunizing dose is

500,000,000, given subcutaneously. For the site of the injection the upper arm or loose tissue of the abdomen, back, or subclavicular region may be chosen. This first dose is usually followed by 2 other doses of 1,000,000,000 each, given at intervals of 5 to 7 days. Depending on the weight, age, and condition of the patient, it may be necessary to vary these doses somewhat. In children Russell advises that the dose should bear the proportion to the average adult dose that the child's weight bears to the average adult's weight (150 lbs.).

The reaction to the vaccine varies. Sometimes there is none. Usually, however, there are headache and malaise; occasionally temperature of 103°, chills, vomiting and diarrhea. The local reaction may be marked, and the glands in the neighborhood may be enlarged and tender. The reactions usually come on in 6 or 8 hours and may last 2 or 3 days.

**The duration of the immunity conferred is uncertain, but it is believed to vary between 1 and 3 years.**

In the vaccine treatment of typhoid fever much smaller doses are used than those advised above. Reaction must be avoided. Some observers report satisfactory results, but there is no sound scientific basis for the use of vaccine during the course of the disease. Post-typhoid involvements of gall-bladder, bones, joints, etc., are, however, appropriately treated with vaccines in conjunction with suitable surgical procedures.

## TUBERCULIN THERAPY

**Varieties of Tuberculin.**—Under the term tuberculin is included a great number of preparations differing from each other in their physical condition or manner of manufacture but all derived from cultures of the tubercle bacillus. Some of these are made from the media in which the organisms have been grown, while others are made from the organisms themselves. No tuberculin is derived from serum.

Hamman and Wolman have conveniently divided the various tuberculins into groups.

GROUP 1.—Group 1 comprises the tuberculins which contain the bodies of the tubercle bacilli, dead or alive, subjected to only physical changes. This group contains B. E. Behring's Vaccines, Tebeau, and Tuberculo-Sero-Vaccine.

B. E. is the *bacillen-emulsion* of Koch (1901). For its preparation the organisms are grown at body temperature for 6 or 8 weeks in flat-bottomed flasks in a thin layer of slightly alkaline bouillon medium plus 5 per cent. of glycerin. The bacilli are filtered off, dried, and pulverized by grinding. When examination has proven that all the organisms have been destroyed, 1 part of the powder is diluted with 100 parts of distilled water and 100 parts of glycerin. Thus, 1 c. c. contains 0.005 gm. of tubercle bacilli unchanged, as they have not been washed or submitted to heat.

GROUP 2.—Group 2 comprises those tuberculins which are made by extracting the tubercle bacilli without any attempt whatever at the isolation of the ultimate principles. In this group are T. R., Beraneck's tuberculin, von Ruck's tuberculin, the aliphatic tuberculins derived from fatty substances, Krehl and Mathes' tuberculin, Vasilescu's oxytuberculin, Sciallero's, Maréchal's, Jacob's, Benario's, Contani's, Turmann's, and Rosenbach's tuberculins, tuberculoplasmin, frozen bacilli, prosperol, tuberculin liquid, and Ishigami's tuberculin.

T. R., *tuberculin residue* or *new tuberculin* (Koch, 1897), is derived from young virulent cultures 4 to 6 weeks old grown as for B. E. The bacilli are filtered off and dried in a vacuum, and 1 gm. of the dried bacilli is ground in a mortar until there are no intact bacilli. One hundred c. c. of distilled water are now added, and the mixture is centrifugated. The clear fluid is decanted and is known as T. O. (*tuberculin oberes*). The sediment is again dried, powdered, and again taken up with a small quantity of water. It is again centrifugated and the fluid preserved. This process is repeated until the sediment consists only of large particles. The fluids, with the exception of the first, are united and 20 per cent. of glycerin is added for preservation—the volume not to exceed 100 c. c. Each cubic centimeter should contain 0.002 gm. of solids, representing 0.01 gm. of dried tubercle bacilli.

Beraneck's tuberculin consists of equal parts of the filtrate of a culture of tubercle bacilli and a 1 per cent. orthophosphoric extract of the residue.

Von Ruck's tuberculin is prepared from a culture concentrated in vacuo to 1/10 volume. After several precipitations and filtrations, the preparation represents a 1 per cent. aqueous solution.

GROUP 3.—Group 3 comprises preparations derived from culture fluids. In it are O. T., B. F., Jochmann's tuberculin, iron-tuberculin, tuberculin purum or endotin, Jesseu's, and Leber and Steinharter's. Some of these belong, also, in Group 2.

O. T. is the *original tuberculin, alt tuberculin* or *old tuberculin* (Koch, 1891). It was Koch's first tuberculin and was prepared by concentrating 6 or 8-weeks-old cultures to one-tenth of their original volume by a current of steam. The concentration of glycerin having been 5 per cent. in the original culture medium, is 50 per cent. after evaporation. The bacteria are removed by filtration through a Chamberland filter. The result is the familiar brown fluid ready for use.

B. F., or *bouillon filtrate,* was first prepared by Denys in 1905. The culture is grown as for O. T. Without having been heated or concentrated in any way, the mixture of bacteria and culture medium is passed through a bacteria-proof porcelain filter. This filtrate is used without further preparation.

Jochmann's tuberculins are made from organisms grown on a protein-free medium. They are no more efficient than O. T., but are claimed to be less toxic.

GROUP 4.—Group 4 includes modifications which aim at the isolation of a pure principle, as tuberculol, tuberculocidin, Haentjen's filtrase, and tuberculonastin.

Tuberculol was made by Landmann in the hope of conserving all the important factors. The fragmented bacilli are extracted with glycerin-normal salt solution at increasing temperatures from 40° to 100° C. These extracts are combined and concentrated. The original culture medium is concentrated, combined with the concentrated extracts, and sterilized by passing through porcelain.

GROUP 5.—Group 5 consists of tuberculins in which emphasis has been placed upon the type of bacillus to be employed: as Spengler's tuberculins from bovine and human strains; the tuberculins made from avian or other acid-fast bacilli; Calmette's Cl and autogenous tuberculins.

The tuberculins most used are those of Koch—O. T., T. R., and B. E.—Denys' B. F., and Beraneck's tuberculin. Clinically there seems to be no reason for a preference. These various tuberculins are used as vaccines in attempts to develop immunity. None of them have been shown to have any direct bactericidal effects. The development of the immunity must be judged by clinical symptoms.

**Experimental Observations.**—The original observations on which Koch founded his tuberculin therapy were as follows: Following inoculation of a healthy guinea pig with turbercle bacilli there is no reaction until 10 to 14 days later, when a small nodule appears at the site of inoculation. This nodule breaks down and ulcerates, and the ulcer persists until the death of the animal. If, however, the pig inoculated is tuberculous (has been successfully infected with tubercle bacilli 4 to 6 weeks previously) a necrotic area develops at the site of inoculation 1 or 2 days after the injection. This area sloughs off, leaving a shallow ulceration which heals rapidly without involvement of the neighboring glands.

He also showed that killed tubercle bacilli could be injected under the skin of a healthy pig in considerable quantity with the production of local suppuration as the only result. Tuberculous pigs, on the contrary, were killed in 6 to 48 hours by similar injections. By using smaller doses, however, he was able not only to avoid death but to obtain improvement in the tuberculous animals. He regarded the killed organisms as unsuitable for use in human beings and devised his extract known as O. T., arguing that the virtue lay not in the organisms themselves but in their products.

**The Reaction.**—In using tuberculin therapeutically it is generally agreed that strong reactions are to be avoided, lest, being uncontrollable, they may be so severe as to do harm. The agreement is not universal, however, and it is possible to divide the users of tuberculin into 2 schools, one of which seeks to avoid all reactions and another which gives tuberculin more freely, paying but slight heed to slight reactions. Trudeau and Sahli represent the former group and Petruschsky represents the latter. Sahli claims that patients treated cautiously attain a tolerance as soon as or sooner than those who have shown reactions. Petruschsky claims that time is wasted by this method and enough local reaction for healing is not excited. Hamman and Wolman favor the slower method, but do not confine themselves absolutely to it. They are inclined to group the patients into classes of slow, intolerant or sensitive and rapid, tolerant or insensitive. Attention is centered on the patient and not on the dose, careful watch being kept for local, focal, and general signs of a reaction. These signs include pain, tenderness, or swelling at the site of injection, cough, expectoration, dyspnea, hemoptysis, etc., as focal symptoms in pulmonary cases, and fever, rapid pulse, loss of weight, headache, etc., as indicating constitutional disturbance. Fever, loss of weight, and symptoms of general depression are regarded as most important guides for dosage. The dose following one giving rise to a vague feeling of not being well has so often been followed by a reaction, that stress is laid on the general feelings of the patient. "The smallest fraction of a degree rise in temperature above the usual maximum is looked at askance," and close watch is kept for additional signs. Slight changes in temperature alone may sometimes be disregarded, but any associated signs call for a repetition only or even a diminution of the dose unless a definite, intercurrent, independent non-tuberculous cause can be discovered.

Denys refuses to consider any temperature which does not appear within 48 hours as due to tuberculin. Hamman and Wolman have been so impressed by the occurrence of a local reaction preceding the dose which liberates the general reaction that they are inclined to discredit an elevation of temperature coming suddenly in the midst of an otherwise smooth course, i. e. without a preceding local reaction. This local reaction must be watched for with care as it occurs alone more often than any other sign. It may consist of tenderness and redness only, or there may be infiltration and gland involvement. The dose should not be increased if there is any local reaction. Indeed, even the repetition of the dose which called forth the local reaction may cause an undesired systemic reaction. The safer proceeding is to give a smaller dose. Strict watch must be kept for other symptoms, as fever, increase of pulse-rate, loss of weight, dyspnea, headache, chilliness, loss of appetite, sleeplessness, gastro-intestinal disturbance, etc.

**Dosage.**—To avoid reactions, the initial dose should be small and the tolerance of the patient rather than any arbitrary scheme must determine the size of subsequent doses. In determining the initial dose, Hamman and Wolman divide the patients into 3 classes: (a) children, (b) patients with slight pyrexia or not in good general condition, (c) patients with no fever and in good general condition.

A and B receive the smaller initial doses and C the larger in the following table. Only very rarely is there a reaction to the initial dose if this scheme is followed.

| Tuberculin | Initial Dose | Maximal Dose |
|---|---|---|
| O. T. | 0.0000001 to 0.000001 c. c. | 1 c. c. |
| T. R. | 0.000001 " 0.0001 " | 2 " |
| B. E. | 0.000001 " 0.0001 " | 2 " |
| B. F. | 0.00000001 " 0.0000001 " | 1 " |
| Beraneck's | of A/32 0.05 " | of H 1 " |

**Preparation of Tuberculins for Use.**—Tuberculins are prepared for therapeutic and diagnostic use by dilution with 0.8 per cent. sodium chlorid solution to which has been added 0.25 per cent. carbolic acid. The solution should be made with pure sodium chlorid and distilled water to avoid the flocculent precipitate which may otherwise form. Eight grams of NaCl and 2.5 c. c. of carbolic acid are mixed with 1,100 c. c. of distilled water. This may be distributed in 10 small flasks, 110 c. c. to each, and sterilized by boiling for 15 minutes on 2 successive days. The extra 10 c. c. allow for evaporation. For holding the diluted tuberculin 7 small bottles or vials such as are used for vaccines are sterilized and numbered from 2 to 8. In each is placed 9 c. c. of salt solution. To No. 2, 1 c. c. of tuberculin is added; to No. 3, 1 c. c. from No. 2; to No. 4, 1 c. c. from 3 and so on through the 8 bottles. The result will be:

| | | | | | | |
|---|---|---|---|---|---|---|
| No. 2— | 9 c. c. salt solution | 1 c. c. | tuberculin | 10 c. c. | of which 1 c. c. | 0.1 |
| 3 | " " " | " | No. 2 | " " | " " | 0.01 |
| 4 | " " " | " | 3 | " " | " " | 0.001 |
| 5 | " " " | " | 4 | " " | " " | 0.0001 |
| 6 | " " " | " | 5 | " " | " " | 0.00001 |
| 7 | " " " | " | 6 | " " | " " | 0.000001 |
| 8 | " " " | " | 7 | " " | " " | 0.0000001 |

For the sake of economy dilutions may be started with 3, using 9.9 c. c. salt solution and 0.1 c. c. tuberculin. The result will be the same as 3 in the table, and the succeeding dilutions may be made as before.

**Method of Treatment.**—Treatment is begun with the initial dose given above. At first the interval between injections is 3 to 4 days. This period gives ample time for the development of reactions. The interval is increased to 1 week when the dose reaches a certain size: for O. T. at about 0.1 c. c.; for T. R. and B. E. at about 0.2 c. c., and for B. F. at about 0.05 c. c. If a reaction does occur in spite of all precautions, tuberculin must be stopped until it has completely disappeared. If reactions continue to appear with diminished dosage, tuberculin treatment may have to be interrupted for several months. If no symptoms of reaction develop, the dose is increased regularly. This increase may be conveniently made with the dilutions described in the table on this page. Beginning with dilution 8 the patient will receive 0.1 c. c. or 0.00000001 gm. (1/100,000 mg.) for the first dose, 0.2 c. c. for the second dose, 0.3 c. c. for the third dose, and so on until the tenth dose has been reached. This dose being equivalent to the first dose of dilution 7 the latter is given instead.

It must be borne in mind that each dilution is 10 times as strong as the one immediately below it. Thus 0.1 c. c. of 7 is equal to 1 c. c. of 8 and 0.2 c. c. of 7 is equal to 2 c. c. of 8; therefore, the second dose of dilution 7 represents an increase 10 times as great as has been the rule when using dilution 8.

When passing from one dilution to the next, it is wise in most cases to repeat the first dose of the new dilution and on the next dose to give but ½ the stronger dose. If, however, the patient has been found to be possessed of considerable tolerance, it may have been possible to increase the dosage by more than 0.1 c. c. each time. If the patient has tolerated an increase of 0.3 or 0.5 c. c. in the weaker dilution, one may go on with the stronger dilution without repeating the first dose.

The limit of dosage is arbitrary, the usual maximum for O. T. or B. F. being 1 c. c. and that for B. E. or T. R. 2 c. c. There is no definite reason why this dose should not be exceeded if indications seem to warrant it. It has been claimed, however, by some observers that a higher limit is harmful, and it must be admitted that the above figures express the average maximum dose. The procedure varies when the maximum dose has been reached. Some continue with the maximum dose at intervals of 8 to 14 days, as long as it seems beneficial. Others interrupt the treatment for periods of 4 to 8 weeks or even more. Again the patient is the most satisfactory guide, the chief tendency being to continue the maximum dose as long as he seems to be benefited by it. In some individuals the maximum dose may be much lower than the figures quoted.

When the patient is being benefited by tuberculin severe reactions are absent, the fever is favorably influenced, cough and sputum diminish, pains are lessened or disappear and digestion improves.

Cutaneous reactions have been used in attempts to determine what is the maximum optimum dose with no reliable results.

SITE OF INJECTION.—The subcutaneous tissue of the back below the angle of the scapula is advised as the site of injection. Fewer local reactions occur in this situation than in the arm. The subcutaneous method is recommended. When the injection is given intramuscularly or intravenously, the impossibility of observing the local effect is a handicap. The oral route is unsatisfactory.

**Results of Tuberculin Treatment.**—The results obtained in adenitis, laryngitis, eye affections, bone and joint involvement—operative and nonoperative—and many other conditions have been encouraging and at times striking. The usual hygienic therapy must be combined with the tuberculin, and all surgical indications must be promptly met. It must always be borne in mind that tuberculin is only an aid, although often a valuable one.

**Diagnostic Use of Tuberculin.**—For subcutaneous use for purposes of diagnosis, dilutions 3 and 4 of the table on page 219 are used. The generally accepted routine is to give 0.0002 c. c. (1/5 mg.) as the first dose. If no reaction has occurred within 48 hours, 0.001 c. c. (1 mg.) is given. If after another 48 hours no reaction has developed, 0.005 c. c. (5 mg.) are given. Failure to react to the last dose reasonably excludes tuberculosis, but if physical signs or local symptoms render the presence of a tuberculous lesion very probable, a dose of 0.01 c. c. (10 mg.) may be given after another 48 hours. Failure to react to this dose gives "added assurance" that the lesions are not tuberculous. It is desirable that the series of injections be given as outlined above in order to avoid the hypersensitiveness to tuberculin, which reaches its maximum in 10 to 14 days. In average children from 8 to 14 years of age, 0.0001 c. c. may be given as the first dose, and 0.001 c. c. as the last dose, with 2 intervening graded doses. For poorly nourished children half these amounts or less may be sufficient.

The principal phenomena of the reaction are possibly some inflammatory reaction at site of injection, a sharp rise in temperature of varying degree, and a fall almost equally abrupt, general malaise, chilliness, etc.

Of the other diagnostic tests for tuberculosis, von Pirquet's reaction is produced by placing a drop of O. T. on the skin of the forearm or arm and scarifying through it, as in vaccinating against small-pox. One or two similar scratches without tuberculin are made in the neighborhood to act as controls. When the reaction is positive, an area of hyperemia or infiltration of varying extent develops at the site of inoculation within 24 to 48 hours.

The test is chiefly useful in the diagnosis of tuberculosis in children under 4 years of age. Up to the age of 8 a positive reaction has some value, but in older children and in adults the possibility that an old healed lesion is responsible for the reaction renders it unreliable.

The Moro test is performed by rubbing into the skin below the clavicle on one side about 0.1 gm. of an ointment consisting of equal parts of O. T. and lanolin. Plain lanolin is rubbed into the opposite side as a control. In a positive reaction an area of redness, with some papular elevations, develops within 24 to 48 hours. The test is less satisfactory than von Pirquet's.

Calmette's conjunctival reaction is elicited by dropping into the eye 2 drops of a solution made by precipitating tuberculin with alcohol and dissolving the precipitate in water. **Usually when positive it gives rise to a mild conjunctivitis, but at times the reaction or secondary infection has been so severe that the test has lost favor.**

## FIXATION OF COMPLEMENT

For the complement-fixation test the following substances are necessary.

Antigen: In testing for syphilis, antigen is prepared from either a syphilitic liver or from a normal heart or liver. In testing for bacterial diseases an extract of the bacteria against which the serum is to be tested is used.

Suspected fluid: Serum from blood drawn from vein or obtained in other way, spinal fluid, etc. Blood serum should be inactivated by exposing it to a temperature of 56° for 30 minutes.

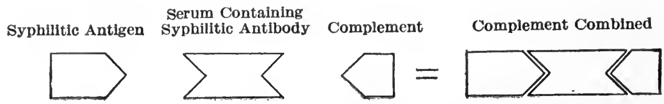


Fig. 10.—Diagram to Illustrate the Binding of Complement Which Takes Place on Mixing Complement with Homologous Antigen and Antibody. (For example, syphilitic antigen and syphilitic serum.) No free complement present.

Complement: Usually fresh guinea pig serum.

Red blood-cells: Human or sheep cells, washed and diluted.

Hemolytic serum: Containing amboceptor against the red blood-cells employed. Usually rabbit serum.

In addition to the suspected serum there must be, where possible, as in syphilis, sera from positive and negative cases to be used as controls.

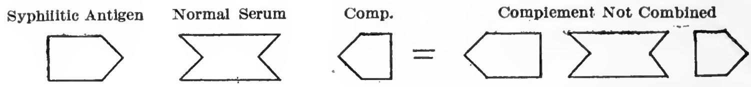


Fig. 11.—Diagram to Illustrate the Lack of Complement Binding when Complement is Mixed with Heterologous Antigen and Antibody. (For example, syphilitic antigen and normal serum.) Free complement present.

The fixation or deviation of complement (Bordet-Gengou phenomenon) is dependent on the ability of a mixture of antigen, antibody (amboceptor) and complement so to combine that when red blood-cells and serum capable of causing hemolysis of those cells, because of its hemolytic amboceptor, are added, the cells will not be dissolved. This is because there is no free complement to combine with the hemolytic amboceptor and so activate it. The

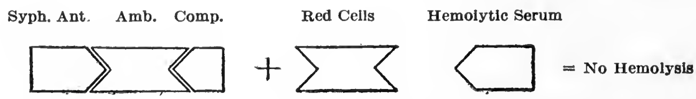


Fig. 12.—Diagram to Illustrate Lack of Hemolysis when Red Cells and Hemolytic Serum are Added to Mixture Illustrated in Figure. No free complement = no hemolysis; i. e., a positive reaction.

complement has been fixed or deviated by the original mixture. This deviation of complement in the original mixture occurs only when the antigen and amboceptor are homologous. This may be illustrated by the Wassermann reaction. If a mixture of syphilitic antigen, serum containing syphilitic antibody (amboceptor), and complement are incubated at 37° for 1 hour, the result will be as represented in Figure 10. If the serum employed contains no syphilitic antibody (is not homologous), the result will be as shown graphically in Figure 11. If now to the mixture depicted in Figure 10 hemolytic amboceptor and susceptible red blood-cells are added, the result may be illustrated by Figure 12. Complement is necessary for the completion of hemolysis but, there being no free complement, the hemolytic amboceptor cannot act, there is no hemolysis, hence a positive Wassermann reaction. If red cells and hemolytic serum are added to the mixture depicted in Figure 11, containing

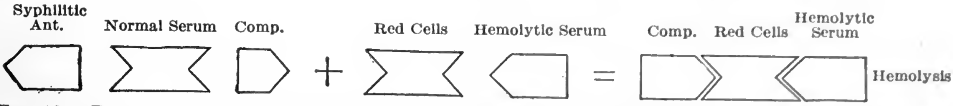


Fig. 13.—Diagram to Illustrate Occurrence of Hemolysis when Red Blood Cells and Hemolytic Serum are Added to Mixture Represented by Figure. Free complement permits hemolysis = a negative reaction.

normal serum, not homologous, they will find free complement, and hemolysis will occur as shown in Figure 13.

In all complement deviation tests, all reagents must undergo a preliminary titration shortly before using to determine their strength, and the test must be carefully controlled. Actual laboratory experience is necessary for the proper performance of the test and for the interpretation of results. Wide application is being made of this reaction, it being used to determine the presence or absence of antibodies against various organisms in obscure conditions.

## SERUM SICKNESS

Occasionally following or even during the course of the injection of serum, symptoms more or less alarming may develop. These include chills, fever, sweating, cyanosis, collapse, asthmatic attacks and skin rashes. While the above symptoms may appear shortly after the injection, serum sickness usually develops 8 to 12 days later.

The chief symptoms which characterize the late appearing reactions are fever and urticarial eruptions, sometimes accompanied by joint pains, rarely by an actual arthritis.

While the above alarming phenomena may occur on the occasion of the first injection of serum they are more prone to develop when following a first injection an interval of 12 to 40 days is allowed to elapse before a subsequent injection. This condition of sensitization has been termed anaphylaxis.

The generally accepted theory of serum sickness is that a foreign proteid, when first introduced parenterally, is broken down very slowly. Following the first injection of the foreign proteid, there develop a large number of free antibodies capable of rapidly breaking down the proteid molecule. On the second injection, these antibodies immediately attack the foreign proteid and break it up so rapidly that toxic substances are liberated in poisonous doses. In the unsensitized individual the process is slower and the toxic substances are present only in small quantities. To avoid as far as possible the dangers of sensitization, injections should be made at 6-day intervals and special care must be exercised where it is necessary to immunize persons subject to asthmatic attacks, as they are prone to have a degree of sensitization. To such patients, if time warrants, the intradermic injection of 0.01 c. c. of serum has been advised. If they are sensitized, a local inflammatory zone should develop within 24 hours.

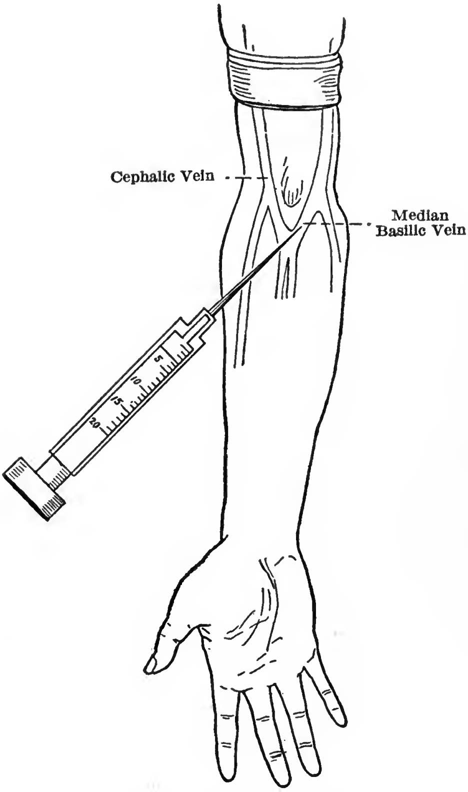


FIG. 14.—VEINS FROM WHICH BLOOD MAY BE MOST ADVANTAGEOUSLY DRAWN AND INTO WHICH VACCINES AND SERA MAY BE INTRODUCED. Where these veins are not accessible as when covered by thick layer of fat, the veins in the back of the hand may be entered, using a very fine needle.

In using sera intravenously particular care must be exercised to note the development of any symptoms suggesting an anaphylactic reaction.

## SERUM THERAPY

Since the development of potent sera against the toxins of diphtheria and tetanus, numerous attempts have been made to produce sera active against other organisms. No definitely active sera, however, have been produced against many of the common pathogenic organisms, as, for example, the pneumococci and streptococci. These organisms belong to the class producing no extracellular toxin and sera active against them must have properties other than antitoxic. It is true that sera with definite protective properties have been produced by immunizing with these organisms, but their curative value is not great, or they may have none, particularly when directed against cases of septicemia. Where, however, the serum may be brought in direct contact with the organisms, as in meningitis, more definite results have been seen. The activity of these sera seems to be due to bacteriolytic, bacteriotropic and antiendotoxic antibodies. A rather serious objection to their use is the absence of any accurate method for their standardization. The method applicable to the standardization of antitoxins cannot be applied to the antibacterial sera. To some extent they are standardized by the estimation of their opsonic power.

The dose varies from 10 to 100 c. c.

Sera are usually administered subcutaneously into the loose tissue of the abdominal wall or of the back between the scapulæ.

At times intravenous administration may be advisable. The technic of this proceeding is the same as that for blood-cultures. The usual site is the median cephalic or basilic vein (Fig. 14). A tourniquet having been applied to the upper arm, the skin is sterilized and the needle plunged into the vein parallel to its course. The tourniquet is removed as soon as the blood entering the syringe shows that the vein has been entered, and the serum is injected slowly. Severe cases of undoubted streptococcus septicemia should have the possible benefit of 1 or 2 doses of a polyvalent antistreptococcus serum. The second dose may be given in from 4 to 8 hours. If no beneficial effect has been apparent in 24 hours, the serum is probably not potent against the infection. If further serum treatment is attempted, a different product should be used. When used intraspinally for streptococcic meningitis, the technic is the same as for meningitis due to the meningococcus, which see.

## TRANSFUSION OF BLOOD

Direct transfusion of blood has been used in the hope of conferring passive immunity.

In chronic infections good results have been reported following the repeated transfusion of small amounts of blood at 3 to 7 day intervals. In this condition, as in pernicious anemia, more benefit seems to be derived from repeated small doses than from single large doses. Indeed, the latter may do harm if very large. The amounts transfused vary from 200 to 400 c. c. at a time. A possible field of usefulness is the transfusion of blood of a normal person who has been vaccinated against the organism infecting the recipient. Such a proceeding could be rationally used in cases of chronic endocarditis with septicemia due to the *Streptococcus viridans,* in which condition vaccines so far have failed.

In all conditions involving transfusion, hemolysis and agglutination tests should be made on the blood of donor and recipient. In cases of extreme urgency, as in hemorrhagic disease of the new born, where an immediate relative is available as donor, this may be omitted, but the effect of the transfusion must be watched with extreme care.

## DEFENSIVE FERMENTS (ABDERHALDEN)

The ability of the cells of the body to develop defenses against foreign ("disharmonious") substances has been made the subject of special investigation by Abderhalden and his co-workers. According to Abderhalden's views these defenses are of the nature of ferments.

"According to our observations there is not the slightest doubt that the animal organism is not left without means of defense against disharmonious substances. If such products make their way into the body, the latter sends out defensive ferments that are directed against special kinds of substrates. Not only do they effect the destruction of the specific character of the parenterally introduced substance by means of an extensive decomposition, but they render possible the utilization of the products of the decomposition in the general metabolism. The reaction we have demonstrated enables us at any time to decide whether a certain substance is in harmony with the body cells or not. We must distinguish not only substances that are in, or out of, harmony with the body, but also those which are in, or out of, harmony with the blood or its plasma, or again with the cells. The intestine, with its ferments and those of its accessory glands, decomposes all disharmonious substances until an indifferent mixture of only the simplest units is left; the cells of the gut walls and of the liver carefully test the absorbed products for all substances that are out of harmony with the body and blood. Moreover, all the cells of the body take care that nothing shall pass from them into the circulation which has not attained a certain grade of decomposition. For further protection, the lymph with all its complicated arrangements is interposed between the cells of the body and the circulation. Here everything is tested afresh and nothing is let loose into the circulation that has not been rendered harmonious with the blood and its plasma. . . . The lymph is to be considered as a sort of buffer between the cells of the body and those of the blood; as a neutral zone in which everything is assimilated as far as possible."

"If these views are correct, it should be possible to trace such substances as are in harmony with the body, but not, with the blood and its plasma, by demonstrating definite ferments. It is quite conceivable that, in certain diseases, the cells only partially effect the decomposition of the nutritive material and the constituents of the body, and that to a certain extent, materials that are harmonious only with the cells are handed on to the lymph. The lymph would do its best to correct this failure by means of its leukocytes and lymphatic glands and would attempt to decompose some of the disharmonious substances before they reached the blood. In many cases, however, disharmonious material will get into the blood and produce all kinds of disturbances. We know of at least two conditions in which disharmonious substances undoubtedly circulate in the blood, namely, Bence-Jones's albuminuria and pregnancy."

The fact that chorionic villi had been demonstrated in the circulation suggested the possibility that there might be present in the circulation during pregnancy substances that were in harmony with the species but not with the plasma. The presence of such disharmonious substances should result in the setting free of special ferments. Experiments showed that such ferments were constantly present and that they bore no relation to the occasional presence of chorionic villi in the circulation. Abderhalden's view is:

"The organism of the mother has at its disposal, up to the appearance of pregnancy, a certain amount of cells of a certain kind which all harmonize in their metabolism with each other. With conception, appears an entirely new kind of tissue with particular duties. Although the impregnated ovum and the developing placenta, with its various cells, are in harmony with the species, the metabolism of these cells appears as something quite new and strange to the complex of cells composing the organism of the mother. The blood probably receives substances—perhaps also secretions—which are out of harmony with the plasma, and remain so; and the time is too short for the blood to accustom itself entirely to these new kinds of substances."

The placenta and fetus, according to this point of view, never settle down completely within the organism of the mother. During the whole period of pregnancy defensive ferments, which are able to reduce placenta albumin, circulate in the blood. These ferments may be demonstrated within 8 days after impregnation. With the expulsion of the placenta the ferments disappear fairly quickly, 14 to 21 days.

Abderhalden is inclined to attribute the power of producing these ferments to all the cellular elements of the blood, leukocytes, erythrocytes, and blood platelets.

So convinced is he from his own experience of the specificity of the test in pregnancy that he lays down the following rule to govern workers:

> "No one should deal with pathological cases by means of the dialysation method or the optical method who has not given evidence of having been able to produce 100 per cent. of correct diagnoses from pregnant and particularly non-pregnant individuals, using placenta as his substrate. Should the technic of the student be found wanting in this branch he has not mastered the method."

**Experimental Observations.**—The first experiments in support of the theory that the organism reacted against foreign substances by the formation of specific ferments were made with dogs and rabbits. White of egg or horse serum was introduced either subcutaneously, intra-abdominally, or intravenously. Abderhalden regarded the following experiment as proving with exceptional clearness that the plasma of an animal specially treated actually reduces proteins. The plasma of prepared animals was mixed with white of egg and the mixture placed in a dialysation tube. Very shortly the presence of peptones could be demonstrated in the outer fluid by means of the biuret reaction. When the plasma of normal animals was placed in the dialysation tube, no substances giving the biuret reaction could be demonstrated in the outer tube, even after several days. When the serum of specially treated animals is mixed with albumen the nitrogenous content of the outer fluid is considerably greater than when the serum of normal animals and albumen are mixed. The latter contains only nitrogen diffused from the plasma.

**Methods.**—In their studies Abderhalden and his co-workers used 2 methods, one a dialysation and the other an optical method.

The technic is so complicated and a strict adherence to the technic so essential to success that only an outline will be given here. For details the original works should be consulted.

The dialysation method depends on the fact that albumen, being a colloid, will not diffuse through animal membranes, while peptones, the first product of the decomposition of albumen, are diffusible.

If albumen is placed in a dialysing tube and the tube placed in water, no albumen will appear in the surrounding fluid. If peptone and hydrochloric acid are added to the albumen in the tube, it will be digested or broken down and the products of its digestion will appear in the surrounding fluid. These products consist of peptones and other simpler compounds. Similarly, if a fluid is to be tested for proteolytic (albumen decomposing) ferments, it is placed in a tube with albumen and the surrounding fluid investigated for products of decomposition.

The fluid to be tested in this case is blood serum. It is obtained during fasting by puncture of a vein in the usual manner, and the blood is allowed to clot; the serum is separated and is then completely freed from form elements by centrifugation. It must also be free from hemoglobin, as its presence shows the destruction of red cells and possible liberation of substances reacting with ninhydrin.

The material to be tested is either an albuminous body or a mixture of these bodies, i. e. an organ. It is called a substrate. On its preparation depends the success of the process. It must be absolutely free from blood and must be submitted to a number of boilings to free it from substances that react with ninhydrin.

A freshly prepared 1 per cent. solution of ninhydrin is used.

The dialysing tubes must have undergone a preliminary testing for their impermeability to albumen and uniform permeability to the decomposites of albumen.

In the optical method peptones are used instead of albumen. The substrates are prepared as before but require less boiling, as substances which react with ninhydrin do not influence rotation. Peptones are formed by hydrolysis with $H_2SO_4$, which is later removed by barium hydroxid.

The peptones are mixed with the serum (absolutely free from hemoglobin and cells) and any ferment action is observed in a polariscope.

The test has been employed in various conditions with considerable diagnostic success. Abderhalden urges the necessity of exhaustive investigations of diseased conditions to support the experimentally established facts. Among those on which work has already been done are cancer, Graves' disease, dementia præcox, and general paralysis. References to the important literature are given in the last edition of Abderhalden's work on the subject.

# CHAPTER VII

## ASPIRATION AND ASPIRATING DEVICES IN OPERATIVE SURGERY

James H. Kenyon

The surgical application of suction, though of very ancient origin, has been vastly improved and widely extended during the last few years. History of savage tribes relates the treatment of wounds from bites of poisonous snakes or insects by suction produced by the direct application of the mouth, or through the medium of a hollow bamboo reed. Cups, wet and dry, and the various forms of aspirating syringes, are familiar to all.

In July, 1903, Karl Connell (5) published the description of an aspirating bottle which he had been using for some time at the New York Hospital. A small amount of alcohol is placed in a strong gallon bottle, shaken, ignited, and after a few moments the stopper is quickly inserted. A clamped rubber tube is fastened to a glass tube which projects through the stopper. To the other end of the rubber tube is attached the aspirating needle. Of course, the amount of suction is limited to the capacity of the bottle.

The chief advance in the surgical application of suction has been due to the employment of an efficient, economical, and steady method of obtaining continuous suction, for hours or days if necessary, at the operative field or at the patient's bedside. Further, to the development of safe and suitable tips or nozzles which quickly remove the fluid material, be it thick or thin, from the wound or sinus, without clogging the tube, sucking the tissues or producing an injurious cupping effect.

## METHODS OF PRODUCING SUCTION

**Pumps.**—The required suction may be produced in various ways, as by the use of mechanical pumps—piston or rotary, operated by power, preferably a small electric motor; a falling column of water, or some form of the jet pump operating on water, steam, or air, with a pressure of 20 pounds or over, may be employed.

MECHANICAL PUMPS.—Mechanical pumps of the to-and-fro or piston type were first made in 1654 and are very efficient. The more modern form consists of several pumps placed close together with a common shaft for their pistons, thus giving a steady suction. Another mechanical type is the circular or rotary pump, made on the turbine principle, a wheel with numerous blades or forms, rapidly turning in a tight casing. All of these are driven by power, preferably an electric motor, either with a direct shaft connection or through the medium of a belt, chain, or gear. Practically all of the numerous vacuum cleaners on the market employ, efficiently, one or the other of these types.

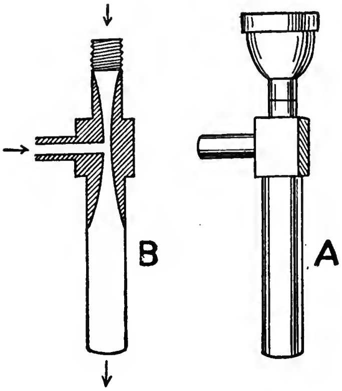

Fig. 1.—A, Filter Pump; B, Filter Pump in Section.

PUMPS OPERATED BY FLUIDS OR VAPOR.—Working on the principle of the barometer, Toricelli, Geissler, Sprengel, and Bunsen devised pumps composed of tubes through which fluid, water, or mercury was allowed to fall. Each particle of falling fluid acted as a piston, forcing the air out ahead of it, and producing a negative pressure behind.

Jet pumps are so constructed that water, air, or steam, with a pressure of 20 pounds or over, rushes at high velocity through a narrow tube across an open space and into another tube, slightly larger than the inlet. These two openings and the space between them are so inclosed that the resulting negative pressure may be utilized.

FILTER PUMP.—The filter pump (Fig. 1), so-called from its employment in the chemical laboratory to hasten the filtering of chemicals, is made in different styles and sizes, of which the medium size, Chapman, is the best. This has two fittings, one, threaded, that may be screwed on to the hydrant or faucet similar to the attachment of a garden hose, the other, a rubber-lined ring that will slip on a faucet. These are made and sold by the large chemical supply houses.

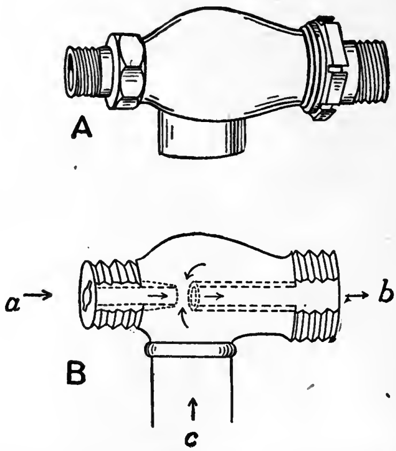

Fig. 2.—A, Steam Ejector; B, Steam Ejector in Section; a, inlet; b, outlet; c, suction.

EJECTOR.—Another jet pump, known as an ejector (Fig. 2), is of similar construction to the injector which is employed to force water into a boiler. Of these the best type is the Hayden Derby or H. D. Model C., No. 1 or No. 2. These operate very well with water or steam having a pressure of 20 pounds or over.

For use in the operating-room the full strength of the suction is desirable, but this may be controlled by regulating the amount or pressure of water or steam flowing through the apparatus. Or it may be controlled by having an opening in the tube very near the nozzle. Air rushes into this opening and prevents any suction at the tip until the operator closes it with his finger. This is better than a valve, but neither is necessary.

The H. D. Ejector Model C. No. 1 has been used continuously at the New York Hospital since 1906 and has been found to be most efficient. It may be permanently connected with the high pressure steam-pipe in the operating-room, one valve on the inlet being all that is necessary. The outlet, or exhaust, may be carried to some convenient flue or chimney or out of the window, the essential point being to have no back pressure. The ejector may be connected with the water pipe, with the outlet running into the sink. For simplicity,

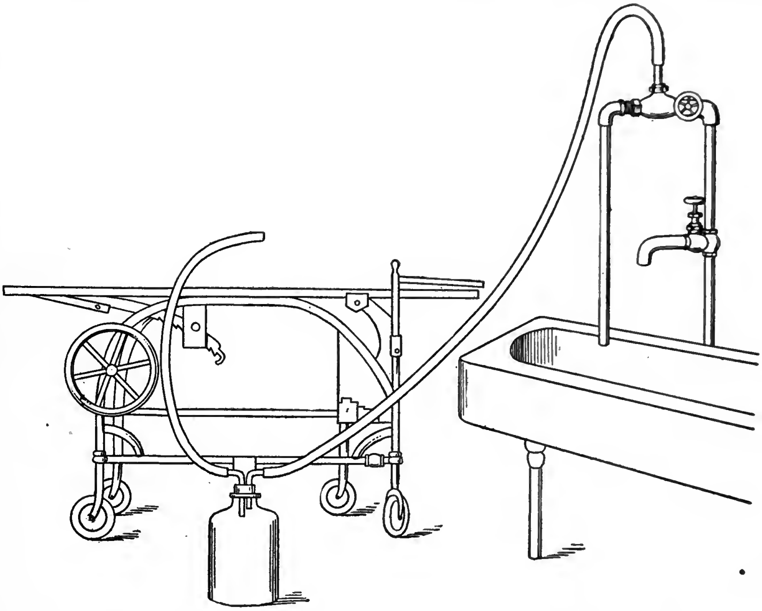

FIG. 3.—METHOD OF CONNECTING THE EJECTOR WITH THE WATER PIPE AND THE SUCTION BOTTLE AND TUBE WITH THE OPERATIVE FIELD.

with no moving parts to get out of order, for heavy continuous service every day, and for efficiency, the preference is to be given to the ejector and the filter pump.

**Methods of Obtaining Suction in Private Houses.**—For operations in hospitals or private houses not equipped with the suction outfit one of the filter pumps can be readily and quickly attached to some near-by faucet over wash basin or bath tub, from which a generous length of stiff tubing—10 to 60 feet or even more—will bring the suction to the place desired.

A small electric motor and pump, or an improvised fitting on a vacuum cleaner, may be employed.

If the water pressure is too low and the room happens to be one or more stories up, the filter pump is connected to the faucet in the usual manner, but on the outlet a rubber tube 30 feet long is fastened, the other end of this tube hanging out of the window or down the staircase to the sink on the floor below. This falling column of water, 30 feet or more, produces the required suction.

**Connections Between Suction Pump and the Wound.**—The suction pipe is connected with a gallon bottle (Fig. 3) under or near the operating-table by a stiff non-collapsible rubber tube or, what is better, a tube composed of rubber and fabric known to the trade as pressure hose. From a connecting tube in the stopper of this bottle a tube 5 or 6 feet in length is led to the operative field. This tube may be smaller than the other but should be fairly stiff and not easily collapsed. This short tube, with the appropriate nozzle, is boiled with the instruments whenever its use is anticipated. The large bottle is emptied and thoroughly cleansed between operations, but not necessarily sterilized, as nothing passes from it toward the wound. The tube from the suction pipe to the bottle is never contaminated unless the bottle upsets, or becomes too full, and its contents are sucked over.

For the special use of the anesthetist to remove secretions from the pharynx another smaller tube is led from the bottle to his end of the table. There is generally enough excess negative pressure in the bottle to permit these 2 tubes to be used at the same time, but if for any reason there is not, one or the other must be temporarily clamped off.

**Care and Cleaning of Apparatus.**—During the operation the nozzle should be occasionally immersed in a basin of cold sterile water to remove from its interior blood and pus that might otherwise dry, clot, and occlude its lumen. At the conclusion of the operation the tube is cleaned by permitting it to suck up soap suds followed by hot water and bichlorid, after which the tube is soaked in bichlorid, boiled, or sterilized in the steam sterilizer.

**When and Where the Method Was Introduced.**—This method was first introduced by the author during the service of the late Dr. Frank Hartley at the New York Hospital in April, 1906. About the same time George Laurens (15) published the description of a mastoid operation, during which suction was obtained by a filter pump, employed to keep the operative field clear of blood and pus. The first cases on which it was used were operations for the removal of the Gasserian ganglion for trifacial neuralgia, the chief object being to give a clear operative field by removing the excess of blood and cerebrospinal fluid, thereby greatly diminishing the amount of sponging necessary and facilitating and shortening the operation. The conditions arising in this operation, namely, a deep opening with a bony wall on one side and the firm dura, partially covered by a broad brain retractor on the other, were such that the simplest type of nozzle was the best.

**Tips or Nozzles.**—Specially constructed tips or nozzles have been devised to meet the requirements of the various operative conditions, dependent upon the region and the lesion.

TIPS MADE OF A SINGLE TUBE.—Figure 4 shows one of this kind, merely a small metal tube about 3 to 5 mm. (⅛ to 1/5 inch) in diameter; 15 to 20 cm. (6 to 8 inches) long; made of soft malleable copper or aluminum, which may readily be bent to suit the depth of the wound. This is held by the assistant so that the tip is near the bottom of the wound, either in the anterior or posterior corner, so as not to obstruct the operative field. From time to time, as occasion requires, the tip is lightly and quickly brushed over the part obscured by blood or cerebrospinal fluid.

The principle of this simple, single, soft metal tube, open on the end, can be applied wherever the soft parts can be protected from the cupping action.

TIPS OR NOZZLES COMPOSED OF A DOUBLE TUBE.—For general use, and particularly in the abdomen, Figure 5 shows the appropriate form of a double tube designed by E. H. Pool (11). This consists of an inner suction tube open on the end or provided with 2 side openings very near the end, the other end of which has a coarse screw thread conical in shape for the rubber tubing. The outer protecting tube is slightly larger than the inner and is provided with many perforations in its lower half and several larger openings near its outer end. This screws into a collar fastened to the smaller tube. This sievelike outer tube forms a well into which the fluid settles to be sucked out by the inner tube. The holes near the outer end, so placed that the operator's hand cannot occlude them, permit an inrush of air which passes down in the space between the 2 tubes to the end of the inner one, and thus prevents the formation of a vacuum or any cupping action on the surrounding tissues. This tube may be inserted anywhere in the abdomen regardless of the omentum or intestines and without danger of damaging them. Figure 4, No. 1, shows the earlier form of this tube which was provided with an irrigating tube so that irrigation and aspiration could be employed simultaneously. When irrigation is desired it is probably better to introduce the ordinary glass irrigating tip, either by the side of the suction tube or at some more distant point, in which case the irrigating fluid has a more extended action.

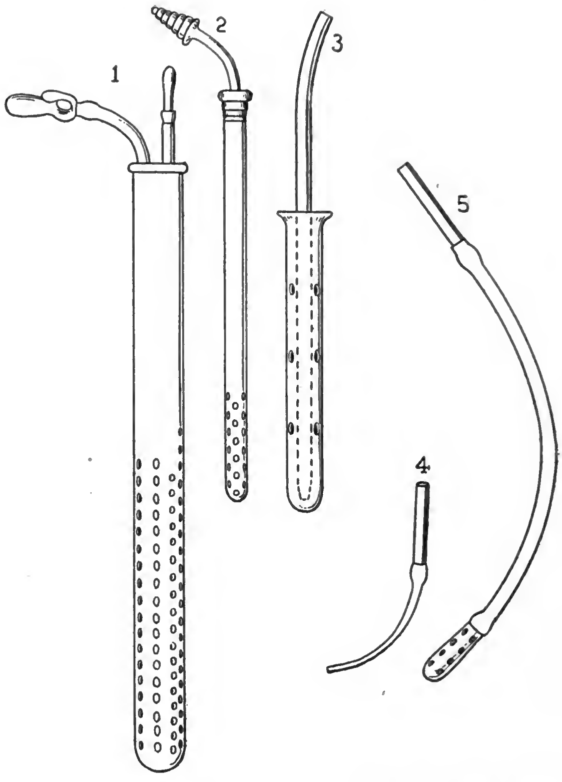


FIG. 4.—SUCTION TUBES. No. 1.—Double tube for abdominal work with extra irrigating tube. No. 2.—Double tube for abdominal work. No. 3.—Double tube for abdominal work. No. 4.—Small single tube of soft metal. No. 5.—Double tube for mouth and pharynx.

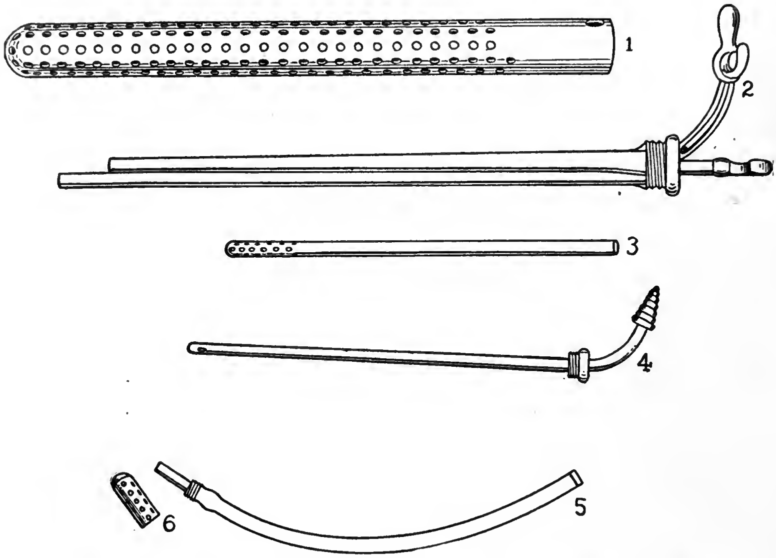


Fig. 5.—Double Suction Tubes. Same as those in Figure 4 taken apart to show construction.

Figure 4, No. 3, shows improvised double tubes of glass. The outer tube is a perforated glass drainage tube and the inner a small glass tube open only on the end.

Figure 6, No. 1, shows a simple method of constructing a double tube suit-

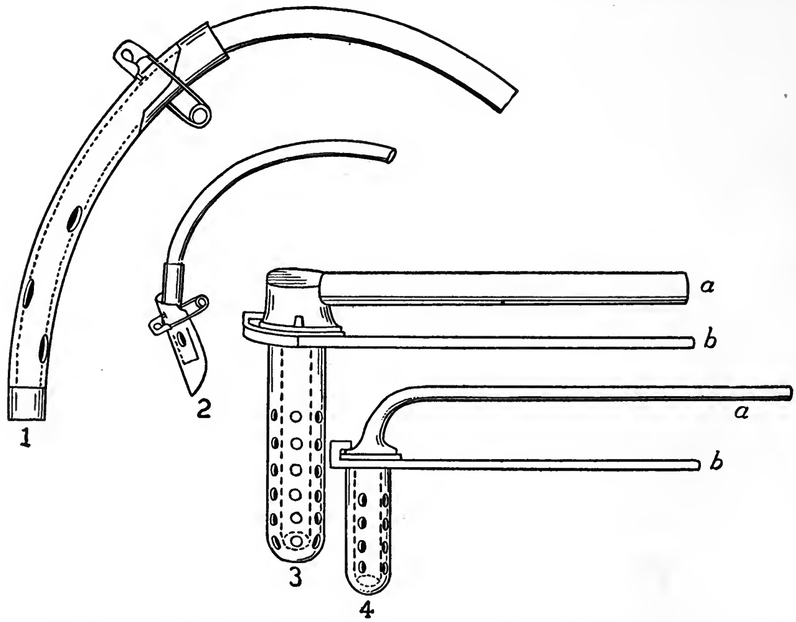


Fig. 6.—Double Tubes for Continuous Suction in Postoperative Treatment. Nos. 1 and 2.—Double rubber tubes. Nos. 3 and 4.—Double metal tubes: a, the inner tube which by turning half way round may be removed from the outer tube; b, thin, flexible metal strip which may be bent to fit the curve of the body.

able for removing pus, blood, or other fluid from the abdomen or any cavity with surrounding soft parts.' The outer tube of rubber, about 15 mm. (3/5 inch) in diameter, and 15 cm. to 20 cm. (6 to 8 inches) long, is fenestrated on every side with numerous small openings. Another rubber tube about 8 mm. (1/3 inch) in diameter and 23 to 25 cm. (9 to 10 inches) long, with only the end opening, is fitted with a snug rubber cuff which has a projecting side. The small tube is inserted in the larger and the cuff fastened to the larger by a safety pin. By firmly holding the cuff the inner tube may be slipped through it inward or outward so that its open end is about 1.5 to 2 cm. (3/5 to 4/5 inch) distant from the end of the outer tube.

TIP FOR MOUTH AND PHARYNX.—Figures 4 and 5, Nos. 5 and 6, show a tip designed by Dr. George M. Creevey for use in the mouth and pharynx to remove mucus, saliva, and blood during anesthesia or operations around the nasopharynx. It consists of a small, short tube, open on the end, near the other end of which is a threaded collar, and beyond this a flange for attaching a rubber tube. A slightly larger metal cap with many perforations slips over this tip and screws on to the collar.

TIP TO BE USED AS A RETRACTOR.—Any of the single tubes that are not too small, as from 1 to 3 cm. (2/5 to 1 1/5 inches) in diameter, may be used as a retractor on soft friable tissue to facilitate its removal. The strength of vacuum is sufficient to hold small masses of tissue or foreign bodies so that the cupping action of these various tips may be utilized. Fedor Krause has devised cupping tips of various sizes and shapes to be used only as retractors, applied directly to the soft friable tumor mass or to a cyst wall. He has used them in this manner in the removal of brain tumors. They may also be used to remove such bodies as renal, vesical, and biliary calculi, and foreign bodies from nose or ear.

## USES AND ADVANTAGES OF CONTINUOUS SUCTION

The advantages of continuous suction during an operation may be enumerated as follows:

(1) Infectious material is removed quickly with little or no soiling of the surrounding tissues, thereby lessening the danger of spreading the infection.

(2) Less trauma, less sponging, therefore less hemorrhage.

(3) Shortens the time of operation.

(4) It gives a clear, clean operative field by removing saliva, mucus, blood, pus, bile, urine, cystic fluid, or irrigating fluid.

(5) It furnishes a retractor on soft friable tissue in which a volsellum or tumor forceps would tear out, or on a deep inaccessible structure where a clamp or forceps would darken and obscure the operative field.

(6) It furnishes a ready means of removing foreign bodies from any of

the tracts communicating with the exterior of the body or from deep wounds or cavities.

(7) It aids the anesthetist in removing mucus, saliva, blood, pus, etc., from the nasopharynx, thus doing away with the irritative throat sponging which oftentimes increases the material one is trying to remove. This rapid removal of such material lessens the danger of inhalation pneumonia.

(8) It decreases the amount of gauze required for sponging and the number of pads and towels that have to be laundered, and at the end of a year will be found to have been an economical feature in hospital management.

(9) It lessens the soiling of the operating-table and the operating-room.

(10) Its application to the sterilizer removes the steam and prevents its escape into the room.

## APPLICATION TO VARIOUS PARTS OF THE BODY

**Head.**—During operations on the scalp there is no particular need for suction, but in intracranial procedures it is most useful. For exploring the brain, either before or after opening the dura, or for tapping the ventricle, the blunt-pointed hollow needle of 1 or 2 mm. (1/25 to 2/25 inch) in diameter, with two side openings near the end, is inserted to the desired depth. Its outer end is connected to the suction bottle with a small rubber tube, which is cut across about 4 to 8 cm. (1 3/5 to 3 1/5 inches) from the needle and a short glass connecting tube inserted to render visible the material aspirated. To control the amount of suction accurately this tubing should have a hole in it, which remains open and sidetracks the suction until the operator closes it with his thumb or finger. If it is desired to save the material aspirated a small sterilized suction bottle of 1 to 2-ounce capacity may be connected with the tube near the needle. The advantage of this method is that any degree of suction may be maintained steadily or intermittently both during the insertion and removal of the needle, without the irregular jerk or slip that so often accompanies the pulling out of the piston of an aspirating syringe. As an adjunct to sponging, to produce a clean operative field, the plain tip of soft malleable metal 3 to 5 mm. in diameter (3/25 to 5/25 inch), bent to the suitable curve, may be used.

This is particularly valuable when a cortical or subcortical lesion is being exposed by the aid of the brain retractors, or where the brain is being retracted and a clear field at the bottom of one of the cranial fossæ is desired.

Examples of these conditions are cortical or subcortical tumors, cysts or abscesses, intracranial neurectomies, as division of the second or third branch of the fifth nerve, or the sensory part of the seventh nerve. It is of very great aid in the removal of the Gasserian ganglion or the division of its sensory root, as it quickly and easily removes, without trauma to the surrounding structures, the cerebrospinal fluid and blood which obscure the operator's view.

**Spinal Cord.**—Aspirating is extremely valuable as an aid to sponging in all operations on the spinal cord. The soft metal tube which can be bent is the appropriate tip. This is placed in the lower corner of the wound toward which the cerebrospinal fluid gravitates. The tip is held parallel to the cord and a slight distance from it, so that there is no danger of injuring the cord.

By this means the field is kept constantly clear with the minimum amount of manipulation and sponging of the delicate cord tissues. If a tumor or cyst is found in the cord or in the surrounding structures, its contents may be emptied. The cyst wall or the tumor can then be drawn up with the cupping tip and its removal hastened. Much less sponging is necessary, the time of operation is shortened, and the ease and accuracy of the dissection favored.

**Mastoid Region.**—A small malleable tip 3 mm. (3/25 inch) in diameter is of service in mastoid operations and also in operations on any of the accessory sinuses. With an assistant manipulating the suction tube, the operator can work more steadily with fewer intermissions than are necessitated by frequent sponging. It has the same advantages in operations on the accessory sinuses as in any deep cavity.

**Mouth and Pharynx.**—The dissection of the tonsil is facilitated by this method of removing blood and mouth secretions. All the operations on the tongue, nasopharynx, and larynx are made easier and the danger of inhalation pneumonia lessened by the rapid removal of blood, mucus, and saliva. Even if the intratracheal method of anesthesia is employed the addition of the suction renders a cleaner and clearer field possible. For cleft-palate and harelip operations a small catheter makes a very useful tip. It may be used intermittently to clear out the pharynx or it may be inserted in one nostril with the eye of the catheter just below the uvula, and the suction attached continuously or at intervals. In the former case care should be taken that the opening in the catheter does not become occluded with tissue or blood.

During esophagoscopy and bronchoscopy a long tube, either metal or rubber, smaller in diameter than the bronchoscope, may be inserted down it to remove secretions. With a suitable tip certain foreign bodies may be cupped, and drawn up through the instrument or drawn against its end and everything removed at once. Foreign bodies in the nares, pharynx, or in the external auditory canal may be thus cupped and removed.

**Thorax.**—Operations on the heart or pericardium, where speed, minimum trauma, and a clear operative field are most important, may be facilitated by the employment of suction. Suction is also of considerable aid in operations on the pleura or lung, either with the cabinet or the intratracheal method, where the work is being done in a deep cavity which renders sponging difficult and slow. It is especially useful in sacculated empyema, interlobular abscess, or abscess in the lung. A subdiaphragmatic abscess that has been approached by going through the pleural cavity may be aspirated absolutely dry—thus lessening the danger of infecting the thorax.

**Abdomen.**—Liver abscess or ecchinococcus cysts are quickly emptied with diminished danger of spreading the process. The daughter cysts are sucked out intact, the cyst wall is drawn up into an appropriate cupping tip, and its subsequent removal made easier.

**Gall-bladder and Ducts.**—The distended gall-bladder may be quickly emptied without any soiling of the surrounding parts, and after it is widely opened for the removal of calculi it may be kept free from bile, thus favoring a thorough inspection of its interior for other calculi and for evidence of its condition which will decide the question of its being left or removed. Incision in the common duct is made in a good visual field, free from blood and bile, and exploration of the ducts is more easily performed. Small calculi in the common duct or, perhaps, some distance up in the hepatic duct, may be cupped and pulled out. Cases of ruptured gall-bladder are quickly relieved of the extravasated fluid.

**Stomach.**—Extravasated stomach contents from ruptured stomach or perforated ulcer are easily removed with less shock and irritation than would follow sponging or washing. Suction forms a very valuable aid to inspection of the interior of the stomach through an incision in its anterior wall, as by this means mucus and gastric contents may be removed, preventing their escape and subsequent soiling of the peritoneum, and also giving a clearer field.

**Intra-abdominal Conditions.**—In intra-abdominal hemorrhage from any cause, as a ruptured ectopic pregnancy, ruptured spleen, liver, or vessels from penetrating wounds, etc., a rapid mopping out of the larger clots with aspiration of the fluid blood greatly hastens the search for and the control of the bleeding structure.

When the contents of any hollow viscus have escaped into the abdomen their removal and the search for the rent are greatly facilitated. **Inflammatory exudates in the peritoneal cavity are easily and quickly removed with less peritoneal trauma than accompanies sponging. Suction has been particularly valuable in removing the pus of an appendix abscess, and furnishes a clearer field for the subsequent removal of the appendix. It has a similar function in the operative treatment of pyosalpinx.**

In general peritonitis and tuberculous peritonitis the exudates are quickly removed and ascitic fluids quickly aspirated without trauma.

Cysts of every description are quickly emptied of all their contents, thus favoring their removal through a much smaller incision than would otherwise be required.

**Genito-urinary Tract.**—Operations on the bladder, particularly the removal of tumors by the transperitoneal method, are performed in a clearer field with more exactness and less soiling of the abdominal contents with urine. With the suction tip the urine and blood are removed as fast as they appear. This facilitates the removal of the growth or the transplantation of the ureter, should these procedures be necessary. In prostatectomy the suction aids in removing urine, blood clots, and the fluid used in irrigating. The patient is kept far drier than by the older methods of treatment. Realizing the age of these patients and the risks of pneumonia from exposure, damp garments, and unnecessary manipulation, any procedure which aims to minimize these risks assumes the utmost importance. In operations on the kidney aspiration is useful in removing collections of pus or urine around the kidney, as, for example, a perinephritic abscess, hydronephrosis, and pyonephrosis. A tuberculous kidney, in which the parenchyma has been replaced by caseous material and the capsule only is left, may be completely emptied through an aspirating needle. Or, better still, a small incision in the capsule may be made through which the suitable suction tip may be passed. This procedure so reduces the size of the structure which is being operated upon that a comparatively small skin incision will suffice for the subsequent steps of the operation, drainage, or nephrectomy.

The use of suction renders operations on cysts or abscesses in any part of the body much easier for the operator, of shorter duration, and therefore easier for the patient. There is also far less soiling of the operating-table and room.

## CONTINUOUS SUCTION AND ITS POSTOPERATIVE APPLICATION

For this purpose the suction may be obtained by employing any of the methods already mentioned, although it is more economical to use water instead of steam.

For use in the wards the suction is obtained from the most convenient water supply, generally in the adjoining wash-room. A small quarter-inch iron pipe is laid from the source of the suction along the baseboard behind 3 or 4 beds, as required, with a stop cock and hose connection opposite each bed. A few feet of stiff rubber tubing lead from this hose connection to the suction bottle under the bed. The tubing from the bottle to the wound may be smaller in diameter but fairly stiff and long enough to permit the patient to turn without disturbing its attachment to the tip in the wound. For this reason it is well to have this extra length resting in the bed. This tubing should be sterilized before using it.

The bottle may be of any convenient size, pint, quart, or gallon, fitted with a tight rubber or cork stopper, through which pass 2 metal or glass tubes, 5 to 8 mm. (1/5 to 1/3 inch) in diameter, with a right angle bend, so that the rubber tubes, dropping down, will not kink. These tubes project a short distance through the stopper into the bottle, 2.5 cm. (1 inch) for one, and 5 cm. (2 inches) for the other. The shorter is connected with the suction, the longer one with the tube from the wound. By this arrangement the wound secretions are prevented from fouling the suction pipe. The bottle should be empty when first used, so that a record may be kept from time to time of the amount obtained.

The application of the suction tube to the region to be drained must be such that no vacuum will be formed in the wound and no cupping action exerted on the surrounding soft parts. This result is obtained by using a double tube. The outer one is fenestrated and of such a diameter and length as to fit the sinus or wound to be drained; the inner one, with only an end opening or two small side openings very near the end, must be smaller in diameter so as to permit free circulation of air between the tubes, and thus prevent a vacuum. The inner tube must not extend into the wound as far as the outer by 1 to 2 cm. (2/5 to 4/5 inch). (Fig. 6, Nos. 1 and 2.)

These two tubes may be held in their proper relative position by transfixing both of them with a large safety pin. This pin, with a split gauze pad under it and a couple of long, narrow adhesive straps over it, serves to anchor the tubes in the wound. The objection to this arrangement is that it may be undesirable to change the outer tube for some time, whereas the inner tube may require frequent removal for cleansing. This would necessitate the removal and reinsertion of the safety pin with probable leakage at the punctures. A further objection is that the pin obstructs, more or less, the lumen of the suction tube and predisposes to its subsequent blockage. To obviate these objections a better method is to slip on the inner tube a snugly fitting rubber cuff about 1 cm. (2/5 inch) wide with a prolongation on one side about 2 cm. (4/5 inch) long. This tongue extends down on the outer side of the larger tube and is fastened to it by the safety pin. This double tube arrangement is sterilized before being inserted in the wound.

Utilizing the same principle, I have devised double metal tubes (Fig. 6, Nos. 3 and 4) of various lengths and diameters which are more easy of application and more readily removed for cleansing.

The varied conditions for which this method of continuous suction is desirable readily suggest themselves. For example, any deep wound with difficult uphill drainage, where the patient is constantly suffering from wound absorption; all cases where the discharge is irritating to the surrounding skin, as fecal fistulæ, pancreatic wounds, etc.; cases in which the discharge is very profuse and the patient is made uncomfortable by being continually wet or is annoyed by frequent dressings.

There are many cases in which the suction is most valuable during the dressing of the wound to remove thoroughly the infectious material from the depth of the wound. If irrigation is being employed, the fluid may be sucked up and carried into the bottle before it runs over and soils the patient's skin and bedding.

## APPLICATIONS TO THE VARIOUS REGIONS OF THE BODY

**Head.**—Infections of the scalp can generally be drained sufficiently by making good generous incisions in the most dependent part, but in a similar condition on the face where the resulting scar would be objectionable, a small incision, if supplied with the double suction tubes, suction being applied continuously or intermittently, will be sufficient.

In infection in the accessory sinuses of the nose, frontal, sphenoidal, and maxillary antrum, otitis media with discharge, suppurating wound following mastoid operation the secretions may be removed without much discomfort to the patient by employing a single rubber or metal tube of suitable size and length to which the suction is applied intermittently. Here again the combination with syringing and irrigation is very effective.

Abscess in the brain has been treated with rather poor results because of the difficulty of securing good drainage. The proper application of the suction will be of great value by keeping the drainage tract open and at the same time completely removing the broken down material from the depth of the abscess without trauma to the brain.

**Mouth and Pharynx.**—All operative procedures around the mouth, pharynx, and larynx, as removal of tumors of the tongue, cheek, tonsil, or larynx, and incisions for quinsy or retropharyngeal abscess are attended with considerable risk of inhalation pneumonia. The employment of suction during the operation and, more or less continuously, during the convalescence has greatly lessened this danger. It has added much to the patient's comfort by relieving him of the painful and frequent swallowing efforts which follow these operations. The injurious mouth and wound secretions are, therefore, not swallowed and do not accumulate in the stomach with the subsequent bad effects from absorption.

The short double tip shown in Figure 4, No. 5, is very serviceable for this purpose. It may be left in the mouth the greater part of the time, or removed and inserted as required. It is particularly useful in removing the fluid used as a mouth wash or gargle, saving the patient the effort of expectorating it.

**Thorax.**—Suction obtained in the above mentioned manner is most valuable for aspirating fluid from the pleural cavity or from the pericardium. Its advantage over the more commonly used methods is that the suction is steady, may be continued for any length of time, and is easily controlled without the jerky character peculiar to the small aspirating syringe. The drainage of the pleural cavity is markedly favored by a moderate degree of negative pressure. Too much suction is bad and may cause bleeding and cupping of the tissues.

By the use of a double tube one can completely remove the pus without cupping the tissues and convert a very disagreeable foul-smelling dressing into a simple clean one, as most of the discharge is collected in the bottle instead of in the gauze over the wound.

This form of drainage, though excellent and many times better than the ordinary short tubes opening into the dressing, has the same objection as the tubes, in that the lung is not relieved of the atmospheric pressure and, as a result, cannot expand as it should.

Dr. George E. Brewer has devised a short rubber tube with a flange which makes an air-tight fit in the chest opening. This tube is firmly held in place by strips of zinc oxid adhesive plaster. The opening in this tube has a slight taper from without inward. Into this tapering tube another similarly shaped tube fits snugly so that there is no leakage. This tube is long enough to extend down to a bottle under the bed. From this bottle another tube leads to the suction apparatus, the suction of which must be very weak.

For this particular purpose Karl Connell has made a very ingenious application of the Sprengel pump, in which a small amount of water (a few drops at a time) drips from a reservoir and flows through a long, narrow tube bent in a circle in its upper portion. The length of the vertical fall below the circle, together with the amount of water flowing through it, governs the amount of suction.

KENYON'S METHOD.—In order to establish thorough drainage of the pleural cavity without disturbing the normal pressure relations on the lung surface and in the air vesicles, I (10) devised a simple method which was first used at the Babies' Hospital in 1910. (Fig. 7.)

The drainage tube consists of fairly stiff rubber, 5 mm. (1/5 inch inside diameter), the wall about 2 mm. (2/25 inch) thick, and about 1 m. (1 yard)

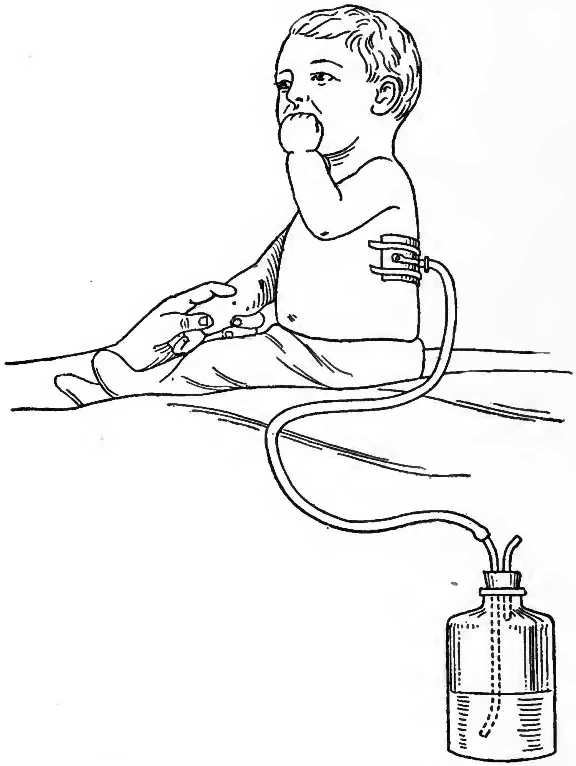

FIG. 7.—METHOD OF CONNECTING LONG TUBE FROM PLEURAL CAVITY TO BOTTLE CONTAINING STERILE WATER. This method may be used in empyema and pneumothorax.

long. Near one end of the tube a small window is cut, and over this end a tightly fitting cuff of a slightly larger tube, about 8 mm. (8/25 inch) inside diameter, is slipped, leaving about 2.5 to 4 cm. (1 to 1 3/5 inches) protruding—just enough to penetrate the chest wall. A piece of tape 10 cm. to 15 cm. (4 to 6 inches) long with a hole, preferably buttonhole stitched, in its center, is threaded over the tube down to the cuff, which prevents it from slipping.

This rubber tube is connected with a glass tube, which passes through a stopper down to the bottom of a bottle of about 500 c. c. capacity. Through the stopper there is another short tube, making a device similar to the "wash bottle" used in the chemical laboratory. A notch in the side of the stopper will serve the purpose of admitting air as well as this second tube.

The bottle, stopper, tube, and tape are sterilized either by boiling or in the steam sterilizer. This sterile bottle is then filled to one-quarter or one-third of its capacity with warm sterile salt solution or sterile water, and the stopper inserted.

The method of inserting this tube into the pleural cavity is as follows: After the operative field has been painted with tincture of iodin, the aspirating needle is inserted to locate the pus. Novocain anesthesia in the skin surrounding the aspirating needle, which is left in position, or a light ether anesthesia may be employed before anything further is done.

A narrow bladed knife is inserted along the side of the needle, between it and the upper margin of the rib below, until it penetrates the pleural cavity. With the knife in this position, a short incision parallel to the rib is made, the knife is then withdrawn and an artery clamp inserted. The needle, which up to this time has acted as a guide, is now withdrawn, and the artery clamp opened to stretch the opening just enough to admit of the tube being crowded in. The tube makes an air-tight fit with this opening and cannot slip further in because of the rubber cuff, and cannot slip out because the buttonholed tape, which is fastened to the chest wall with adhesive plaster, firmly holds the outer edge of the cuff. A small split gauze pad surrounds the tube and completes the dressing.

The other end of this tube, as mentioned before, is connected with the bottle which is placed on the floor or suspended under the bed. The fluid in the bottle moves up and down in the tube with the respiratory movements. The pus from the pleural cavity runs down the tube and mixes with the fluid in the bottle.

If the discharge is very thick and it is desirable to thin it or to irrigate the pleural cavity, the bottle is elevated to the level of the chest or slightly higher and tilted over somewhat. This causes the warm sterile water or salt solution to run from the bottle into the chest, and when the bottle is lowered the fluid, mixed with the pleural exudate, runs back again into it. When the fluid does not move up and down in the tube during respiration or when the small dressing becomes soiled it means usually that the tube is blocked. It is well to have a duplicate set of tubes and bottle sterilized so that a complete change may be quickly made.

The fluid in the bottle is renewed as often as necessary, perhaps every 2 or 3 hours, or possibly only two or three times a day. Before changing the fluid it is well to put a clamp on the tube and also to avoid touching or contaminating the stopper and that portion of the tube which is within the bottle.

When for several days there has been little if any discharge in the bottle, with a normal temperature and pulse, the tube is completely removed and the opening in the chest wall closed with adhesive plaster. In a few cases there may be after this a return of fever, increased pulse rate, and physical signs of fluid in the chest, necessitating a reintroduction of the tube for a time. The above method has been most satisfactory for very young children—from a few months to 2 years old.

For older children, for adults, or for cases with large masses of fibrin or dense adhesions that should be removed or broken up, the ordinary method of rib resection must be employed, but even in these cases the same principle may be used. Here, of course, the opening must be sutured down so as tightly to surround the tube, and a somewhat larger tube used after completing the intrathoracic manipulations.

The advantages of this method are:

(1) A simple operation, easy to perform.

(2) No shock, due to the simple, quick operative procedure, to the slow escape of pus and subsequent gradual change of intrathoracic pressure, and to the absence of pneumothorax.

(3) The single gauze dressing which does not require frequent changing, as there is practically no leakage around the tube. This greatly lessens the danger of serious and often fatal mixed infection of the pleura.

(4) Convalescence is much shorter.

(5) Patients are far more comfortable.

(6) This method is particularly applicable to young children, where with the older methods, as is well known, the mortality is alarmingly high.

(7) Drainage is very efficient, as the discharge is continually thinned and diluted by mixing with the warm sterile salt solution.

This method seems to be ideal for the treatment of pneumothorax, whether pathological or traumatic. The steps of the operation are just as described. The respiratory movements force the air from the pleural cavity down through the tube to escape at its lower end and bubble up through the sterile water. A column of water now ascends in the tube a varying distance, thus preventing any air entering through the tube. The intense dyspnea and cyanosis which accompany these traumatic cases are instantly relieved and the lung is enabled to work under nearly normal conditions until nature or some operative intervention repairs the damage. This method is very satisfactory for use in any operation in the thorax performed with the aid of the intratracheal insufflation or the cabinet, where it is desired to drain for a short time. If both pleural cavities have been opened, they may both be drained in this manner without any danger of the lung collapsing.

**Abdomen.**—Continuous suction may be applied to various conditions in the abdomen, as has been demonstrated in cases of the following conditions: abscess under the diaphragm or in the liver; echinococcus cysts; gall-bladder drainage or sinus leading down to the biliary ducts; wounds following operations on the pancreas; intra-abdominal abscess from any cause; appendicitis; diverticulitis;

or salpingitis. A deep-seated abscess in the pelvis from an appendix, fallopian tube, ruptured bladder, or fractured pelvic bone is particularly amenable to suction. The double tubes with the continuous suction keep the wound clear down to the very bottom, lessen absorption, and favor the healing. The discharge is in this way prevented from coming in contact with the skin—which condition usually gives rise to a troublesome dermatitis. This is particularly important in fecal fistulæ and in sinuses discharging bile, pancreatic secretion, or urine.

Some quite remarkable results have been obtained in the treatment of fecal fistulæ, where the irritating discharge has produced a most acute eczematous condition over a large area of the abdominal skin which did not respond to any treatment and, from its intense irritation, kept the patient in a wretched condition. The application of the short double tubes which penetrated the wound only a few centimeters or really rested in the depression of the wound served to collect all the discharge as soon as it appeared and to convey it to the bottle. The skin condition rapidly cleared up in a few days, the general health improved correspondingly, and, with strapping, the fistula healed.

When one desires to heal an opening in a hollow viscus, as the gall-bladder, urinary bladder, or the intestines, the short double tube which merely penetrates the skin and subcutaneous tissue should be employed. This in no way hinders nature's attempts at repair. The patient's comfort is greatly increased and his rest undisturbed by eliminating the frequent dressings which are generally required in the cases in which the discharge is profuse or offensive.

In suprapubic prostatectomy the bladder is often drained by means of a good-sized rubber tube tightly sutured in the wound by 2 or 3 purse string sutures or 2 or 3 rows of linear sutures. This tube is carried over the side of the bed into a bottle. This method is quite satisfactory and does not require suction, but it is necessary that the sutures be water-tight, and great care must be taken that the tube does not become occluded with blood clots. When, after some days, this tube is removed, there is for some time considerable leakage of urine. This makes the patient most uncomfortable, particularly at night, as the frequent changing of the pads disturbs his rest. All this may be avoided by inserting a small, short, double tube as soon as the original one is removed, strapping the wound around it and applying the suction. This does not necessarily confine the patient to the bed, as, with a sufficient length of tubing, he may be up and around the room—yet absolutely dry. The double tube with the suction may be employed from the first. In this case the larger outer tube, either rubber or metal, should have only the end opening without any side windows. It should extend some distance into the bladder, about half-way down to the region from which the prostate was removed. This tube is sutured in place as described above, and within it is placed the smaller suction tube. This inner one should be large enough, however, to remove the clots.

By means of this suction the bladder never becomes more than half full, with the result that there is no pressure on the suture line, and consequently a more rapid and firmer union.

This is especially important where there has been an extensive suturing of the bladder after the removal of a tumor or from a rupture of the vesical wall or where the ureter has been transplanted. In all these cases a comparatively empty bladder favors a more rapid and stronger healing.

### USE IN PRODUCTION OF HYPEREMIA

Another use for suction obtained in this manner is its application to the various cups and apparatus designed by Bier for the production of hyperemia. These may be exhausted to any degree of vacuum desired and, if provided with a stop cock, several may be employed at the same time.

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# THE PRINCIPLES AND TECHNIC OF OPERATIONS UPON BLOOD VESSELS

# CHAPTER VIII

## THE PRINCIPLES AND TECHNIC OF OPERATIONS UPON BLOOD VESSELS

Frederick T. Van Beuren, Jr.

## GENERAL CONSIDERATIONS

There are two principles common to all vascular surgery which, important as they are in general work, are here preëminent. Cleanliness and gentleness are, you may say, the foundation upon which rests success in operations of this sort; and blood transfusion, transplantation, and anastomosis of vessels are dangerous possibilities in the hands of one not thoroughly trained in the practice of aseptic surgery. Even the clean and capable operator finds plenty of technical difficulties to be overcome, handling the narrow tubes, with their delicate lining and thin, flaccid, or thick contractile walls; and the manipulation of tiny needles and fine sutures, such as are generally employed, requires skill as well as good intentions. So it seems fair to say that no one ought to attempt the more difficult operations upon human blood vessels without previous practice upon animals. And in this respect it is interesting to remember that many of those operations now usefully employed in human surgery were originated by experimenters on animals; while it is entirely possible that many others which are being worked out in the laboratory to-day will, within a short time, become established procedures in the operating-room.

For the sake of simplicity (I) operations upon arteries; (II) operations upon veins; and (III) operations upon capillaries are here considered in separate series. But operations upon blood vessels are, in the main, intended to accomplish one or more of the following ends: to check bleeding or interrupt the circulation; to obliterate the vessels; to alter the blood or circulation for purposes of depression or stimulation; to remove the cause of circulatory disturbances due to varicose veins; to restore or reëstablish the circulation; for drainage of tissues or cavities; to prevent the dissemination of infection. And thus I have, for the sake of a logical arrangement, grouped the various surgical procedures under these sub-headings.

## SURGICAL PROCEDURES

### I

**Arteries.**—The surgical procedures directed against arteries are:

(A) OPERATIONS TO CHECK BLEEDING.—The application of:

1. Postural compression.
2. Bandages and compresses.
3. Digital pressure.
4. Tourniquet.
5. Forcipressure.
6. Torsion.
7. Terminal ligation { a. temporary. b. permanent. }

(B) OPERATIONS TO OBLITERATE THE VESSELS.—(See Chapter on Aneurysms.)

(C) OPERATIONS TO RESTORE OR REËSTABLISH THE CIRCULATION

1. Suture { a. longitudinal wound. b. transverse wound. }
2. Arterial anastomosis, end-to-end.
3. Arteriovenous anastomosis { a. end-to-end. b. end-to-side. c. side-to-side. }
4. Arterial section { a. embolus. b. thrombus. }
5. Transplantation.

### II

**Veins.**—The surgical procedures directed against veins are:

(A) OPERATIONS TO CHECK BLEEDING OR INTERRUPT THE CIRCULATION

1. Posture.
2. Bandage, compresses, and packing.
3. Digital pressure.
4. Torsion, forcipressure, and terminal ligation, ligation *en masse*.
5. Cautery.

(B) OPERATIONS TO ALTER THE BLOOD OR CIRCULATION FOR PURPOSES OF STIMULATION OR DEPRESSION

1. Intravenous injection (blood serum, etc.).
2. Intravenous infusion.
3. Intravenous transfusion { a. artery-to-vein, b. vein-to-vein } direct. { c. intermediate. }

4. Intravenous injection (anesthesia, etc.).
5. Venesection (blood-letting).

(C) OPERATIONS TO REMOVE THE CAUSE OF CIRCULATORY DISTURBANCES DUE TO VARICOSE VEINS

1. Injection.
2. Ligation.
3. Excision.
4. Incision.
5. Suture.

(D) OPERATIONS TO RESTORE OR REËSTABLISH THE CIRCULATION

1. Lateral ligation.
2. Suture.
3. Venous anastomosis
   a. end-to-end.
   b. end-to-side.
   c. side-to-side.
4. Transplantation.

(E) OPERATIONS FOR DRAINAGE OF TISSUES OR CAVITIES

Transplantation.

(F) OPERATIONS TO PREVENT THE DISSEMINATION OF INFECTION

Removal of septic thrombi.

III

**Capillaries.**—The surgical procedures directed against capillaries are:

(A) OPERATIONS TO CHECK BLEEDING

1. Styptics.
2. Packing.
3. Cautery.
4. Ligation *en masse.*

(B) OPERATIONS TO OBLITERATE THE VASCULAR CHANNELS

1. Acupuncture.
2. Galvanopuncture.
3. Injection.
4. Freezing.
5. Excision *en masse.*
6. Desiccation, Kromayer light.
7. Ligation.

IV

**Lymphatics.**—Handley's operation is here introduced for the sake of its relation to blood vascular operations.

## ANATOMICAL POINTS TO BE NOTED

It is, of course, essential for the surgeon operating to have very definitely in mind those muscular and bony prominences which serve to indicate upon the

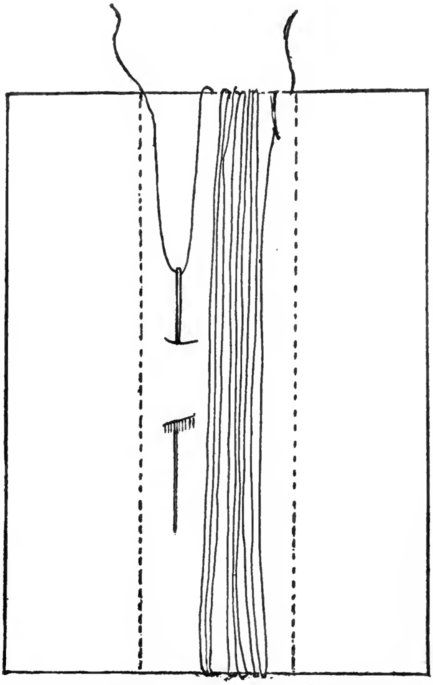


Fig. 1.—Threaded Needle Mounted on Slip of Paper for Convenient Handling. Dotted lines show where paper may be folded.

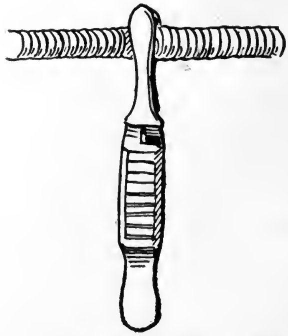


Fig. 2.—Serrefines with Smooth Blades.

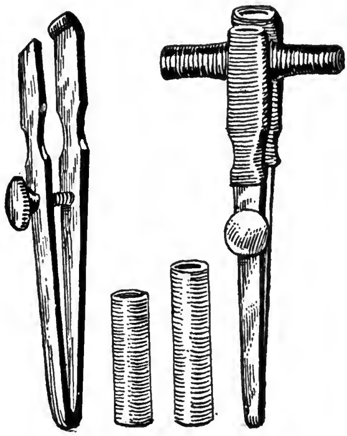


Fig. 3.—Crile's Clamps.

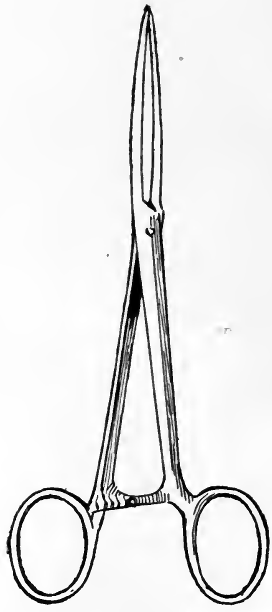


Fig. 4.—Dorrance Clamp.

surface of the skin an imaginary projection of the particular vessel toward which his attentions are directed; and it is almost as necessary that he be thoroughly familiar with the relations borne toward this structure by the veins, nerves, muscles, tendons, and fascial planes which accompany or surround it. The neat and careful exposure of a blood vessel at a predetermined point in its course is quite a different procedure from the often somewhat headlong opening of the peritoneal cavity, in which the exploring hand may palpate, if the incision be long enough, almost every structure from the xiphoid to the cul-de-sac of Douglas. Skin and fascial planes should be cleanly and sufficiently divided for proper retraction without undue tension of the parts. Muscles should be separated, when that is possible, at their intermuscular fascial planes, or split, if it be necessary, in the direction of their fibers. In a word, it is imperative to avoid any unnecessary trauma whose resultant bleeding may obscure the vessel sought, or whose tissue destruction may endanger the success of the operation by inviting to subsequent blood clotting and infection. To accomplish this an accurate knowledge of the site and relations of the vessel to be attacked must be obtained before any operation is attempted. Moreover, there should be a clear understanding of the structure of a vessel wall and the way in which a vessel will behave if bruised, wounded, or divided.

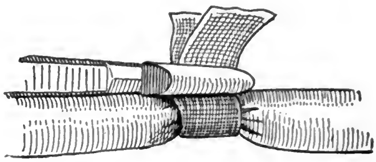


Fig. 5.—Serrefine with Tape or Gauze Strip.

### INSTRUMENTS USED

Besides the ordinary outfit of scalpels, dissecting forceps, scissors, retractors, hemostatic forceps, etc., certain instruments and apparatus of a special nature are required: (A) to control the flow of blood temporarily; (B) to facilitate the approximation and adjustment of the vessel segments, or potentially con-

Fig. 6.—Jeger's Clamps, Straight and Curved.

nect them; (C) to maintain the apposition of the vessel ends or edges until cellular repair has established itself; (D) special instruments for excision of veins.

The first group (A) includes:

(1) Elastic constrictors, linen tapes, or strips, or heavy twisted silk, fastened by forceps or serrefines.

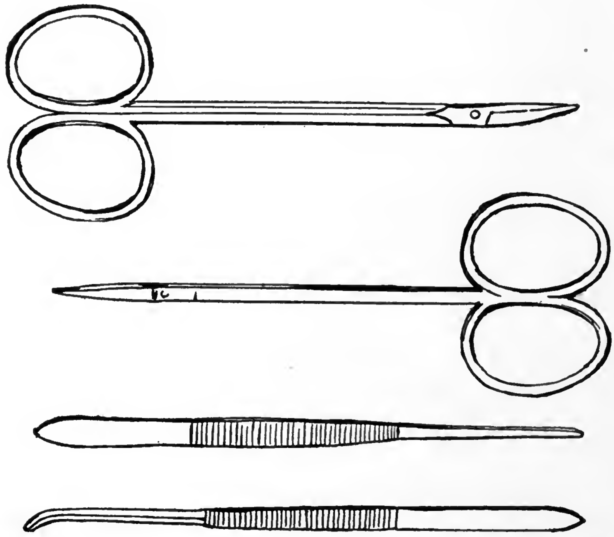


FIG. 7.—FINE SCISSORS AND FORCEPS, STRAIGHT AND CURVED.

(2) Broad-bladed, delicate Billroth forceps; miniature Doyen hysterectomy clamps (Dorrance) (Fig. 4); Herrick's clamps; Crile's clamps (Fig. 3); serrefines with smooth blades (Fig. 2); Jeger's clamps, straight and curved (Fig. 6).

Among the second group (B) are:

(1) Fine thumb forceps (Fig. 7).

(2) Fine scissors (Fig. 7).

(3) Various individual implements such as Payr's magnesium rings; Murphy's forceps; Crile's and Elsberg's cannula; Brewer's tubes; Lindemann's syringes; Curtis and David's container, etc., which will be described each in connection with its appropriate operation.

The third group (C) comprises:

(1) Fine needles, curved and straight (No. 12 to No. 16).

(2) Fine sutures of catgut, Pagenstecker linen or very fine silk (first choice) (Fig. 1). *Carrel* uses special Lyons silk; *Lilienthal* uses No. 000 silk; *Dorrance* uses No. 1 Pagenstecker linen; *Guthrie* uses No. 12 to 16 needle from Kirby, Beard & Co., Ravenhurst Works, Bradford St., Birmingham, and silk from James Pearsall & Co., 71 Little Britain, London, or "Bead silk," whole for large, and untwisted for small vessels.

The last group (D) includes such individual instruments as Mayo's dissector, Mamourian's probe, etc., which will be mentioned more fully later.

### METHODS AND CHOICE OF METHODS

There have been published so many methods of undertaking the various surgical procedures upon the blood vessels, and comparatively so few statistics have been gathered during the short time in which this class of work has been at all extensively practiced, that only those ways of proven value will be fully described, others being mentioned (with reference) for the convenience of the reader.

The choice of a method naturally depends somewhat upon the chooser's individuality, if not peculiarities; but, generally speaking, that method should be the choice which promises to fulfil for the procedure in question the greatest number of the following desiderata: (1) safety, (2) speed, (3) ease, (4) simplicity.

### DANGERS AND DIFFICULTIES: CAUSES OF FAILURE: COMPLICATIONS: RESULTS

The dangers and difficulties, the causes of failure, the complications and results of operations upon the blood vessels can best be detailed in connection with each operation, but it may be said in passing that escape from the first and excellence in the last depend largely upon the avoidance of dirt and roughness.

## I. OPERATIONS UPON ARTERIES

### OPERATIONS TO CHECK BLEEDING

#### Postural Compression

Postural compression is hardly an operating-room procedure, but I have seen its value in at least one case on its way to the table. A man with popliteal aneurysm was wheeled into the City Hospital at Blackwell's Island. As he was being transferred from chair to stretcher the aneurysm ruptured through the overlying skin and he would probably have bled to death then and there had not an unusually intelligent assistant flexed the leg sharply upon the thigh with a folded towel at the bend of the knee. This checked the bleeding sufficiently to allow time to find and apply a tourniquet and get the patient to the operating-room, which was at some distance. In a similar fashion, with a pad between, complete flexion of the hip or elbow joints, and adduction of the shoulder joint will exert obliterative pressure upon the adjacent vessels.

### Bandages and Compresses

A stout rubber bandage, with a gauze compress beneath it, may be used to control arterial circulation or to check arterial bleeding, but it is far inferior to the regular elastic or pneumatic tourniquet and the compress has to be accurately placed over the vessel to make it properly effective.

### Digital Pressure

Digital compression is little used now, except for the temporary closure of a divided vessel until a clamp can be applied, or to control the circulation in an emergency, or for special operations, as in MacEwen's method of aortic compression.

### The Tourniquet

The tourniquet is used, in the operating-room, chiefly to control the circulation; 1, preceded by the application of an Esmarch or Martin bandage, to secure a bloodless field for difficult and careful dissection of complicated structures, such as tendons, etc., at wrist or ankle; 2, to prevent loss of blood in preparing for, or performing, the amputation of an extremity.

There are two satisfactory forms of tourniquet: (a) the solid rod or tube of elastic rubber, about 2 feet long and ½ inch in diameter, and (b) the pneumatic tourniquet [Perthes] with metal reënforcement, a smaller form of which has been much used in connection with blood pressure testing. A description of the instrument will be found in the chapter on Amputations.

Trendelenburg's pin, Varick's modification of it, Thomas's forceps, Wyeth's pins, Jordan-Lloyd's tourniquet, Momberg's tube, etc., are special implements best described in connection with the operations (amputation of hip and shoulder) they were designed for.

The Esmarch method of applying the tourniquet consists in applying tightly, from below upward, in an even spiral, without reversing, an elastic rubber bandage which is carried as high on the limb as necessary. Immediately above it an elastic rod or tube is then wound around the limb sufficiently tight to arrest all arterial circulation below. Thus the limb is emptied of blood and kept so. The tourniquet is then fastened by clamp or tying and the bandage removed from above downward. Instead of the preliminary bandaging the limb may be emptied of blood by elevation for 3 minutes, while massage toward the trunk of the body is practiced.

Matas utters the following warnings anent the use of the tourniquet and the elastic bandage:

> Always apply the elastic tourniquet over the femoral or humeral shaft, or at such points that no vessel can escape a circumferential compression.
>
> Begin by compressing the vascular or adductor side, leaving the outer or extensor

surface of the limb free from pressure, so that venous choking of the limb may be avoided.

Separate each turn of the constrictor by an intervening space to distribute the pressure.

Do not allow the constricted member to be suddenly flexed or extended after the constrictor is in place for fear of tearing subcutaneously the underlying muscles and nerves.

Do not keep the constrictor in place much longer than an hour, or an hour and a half.

It has been objected with good reasons that the ischemia of a limb obtained by forcible elastic compression is likely to be followed by: (1) Excessive capillary oozing; (2) it increases the risk of septic embolism and of cancerous metastases; (3) it greatly favors the absorption of toxic chemical antiseptics; (4) it increases the liability to ischemic necrosis.

For this reason Matas thinks elevation and massage preferable to the elastic compression bandage as a preliminary to the application of the tourniquet.

The pneumatic constrictor is made to encircle the limb at a convenient point proximal to the intended field of operation after preliminary elevation and massage, unless this is contra-indicated. It is then fastened snugly, but not tightly, by its metallic ring, and the pneumatic circlet, which surrounds the limb inside the metal reënforcement, inflated by means of its pump until the pulse, palpated at some point distal to the constrictor, is completely obliterated. This usually requires a pressure of 150 to 200 mm. of mercury.

The only bad results to be feared from the application of the tourniquet are temporary pressure paralysis and injury of diseased vessels at the point of application. This should be kept in mind and the tourniquet must be applied only with sufficient force to obliterate the pulse, which should be under the finger of an assistant during the application. In cases where the arteries are stiff and presumably fragile digital pressure control of the circulation is probably safer. The pneumatic constrictor has this advantage over the elastic tourniquet, that its pressure can be very carefully and easily graduated, but the simplicity of the elastic band has so far brought it into common use. Either one properly applied is safe and of great convenience.

## Forcipressure

Practically the only method now used in operation wounds of checking arterial hemorrhage is forcipressure, with or without subsequent ligation, and this is true of accidental wounds when instruments are at hand. In deep wounds where ligation is dangerous on account of the fragility of the tissues, or impossible because of the narrow space, the forceps may be left on the vessel for from 24 to 48 hours until the formation of a firm clot and the contraction of the crushed inner coats provides for sealing of the vessel. Wherever possible, ligation should follow the application of the hemostatic clamp, unless the vessel is of very small caliber, when many operators crush or twist it (and trust to luck that the retraction and torsion of the inner coat will suffice). Ligation is safer, however, if you are sure that your ligatures are sterile.

It is important that no extraneous tissue be seized in the clamp with the artery, lest nerve fibers be accidentally crushed or included in the ligature and so give rise to subsequent pain or possibly paralysis.

Hemostatic forceps, or artery clamps, as they are usually called, are made in various sizes, weights, and patterns, but the crushing principle is the same in all of those designed for permanent hemostasis. They consist essentially of a pair of jaws whose opposed surfaces are serrated, attached to handles with rings at the end for a thumb and finger. They are provided with a ratchet lock to hold them in adjustment at the desired tension. The jaws may be long or short, broad or narrow, and blunt or narrow-ended, and some have tiny interdigitating teeth at the tip.

The forceps is held by the thumb and index, or thumb and middle finger (usually of the right hand), the wound edges separated and the tissues around the bleeding vessel steadied by the opposite hand, and the end of the divided vessel is caught, as cleanly as possible, in the tip of the jaws of the forceps, which is thereupon closed and locked with sufficient force to hold the vessel securely. The handle of the clamp is held vertical until the ligature has been passed around it and then depressed to raise the tip so that the ligature may be tied beneath it. After the first knot of the ligature has been tied the handles of the forceps are pinched slightly together and separated laterally to unlock the catch, and the jaws are carefully opened and withdrawn from the wound.

The end of the vessel may be cut through and pulled away before the ligature is properly applied if too much force is used in pinching the vessel and pulling upon it. Nerves may be included and injured if the artery is not grasped free from its surrounding tissues.

### Torsion

Some operators draw the vessel a short distance from its sheath, steady it in thumb forceps beyond the hemostat, and twist the end by rotating it three or four times on its own long axis to rupture and cause retraction of the inner coat. This is permissible only with very small arteries.

### Ligation

Terminal ligation is far the best means of permanently arresting arterial bleeding. It may be used in a modified form to control the circulation temporarily, and will be described in connection with suture of arteries. No. 2 catgut is the most commonly used material for tying superficial vessels in soft tissue. In firmer tissue, like those of the scalp, a stronger gut may be required. For ligating large arteries No. 3 or No. 4 chromic catgut is often used and silk and linen occasionally also.

The artery to be ligated is caught by a hemostat as described in the preceding section. The ligature is so handed by the nurse that it may be grasped near the middle by the surgeon's right hand. He passes it round the vessels from right to left, catching the free end in his left hand, ties a single knot, setting it down firmly upon the vessels beyond the tip of the clamp. The assistant then removes the clamp and the surgeon ties a secure knot in such fashion as to form what is generally known as a "square" or "reef" knot, which is less bulky than the "surgeon's" knot, and safer than the "granny." Care must be taken to set the second knot down tightly upon the first and not to "upset" the knot. If too much force is used in tying the first knot the vessel may be cut too deeply and the closure be made less secure. It is not uncommon to see a surgeon in a hurry pull too hard on his ligature while tying a delicate vessel, and tear the end of the vessel off, necessitating a repetition of the procedure.

## OPERATIONS TO RESTORE OR REËSTABLISH THE CIRCULATION

### Lateral Suture

Lateral suture of an artery may be required to repair an accidental wound or rupture, either longitudinal or transverse, or an incision that has been made by the surgeon to remove an embolus. It should not be used in wounds of such size that their closure will occlude the artery, nor in cases of extensive crushing of the artery and perivascular tissues. The presence of infection also contraindicates it. The essential conditions for the operation are: the best possible asepsis, a non-injurious means of temporary hemostasis, gentleness in handling the vessels, accurate approximation of the intimas without unnecessary trauma, means of maintaining this approximation until cellular repair has been established.

The part should be shaved and wrapped in a soap poultice for 24 hours if possible; then scrubbed with a gauze compress with green soap and sterile water; then with alcohol and ether and a gauze compress; then flushed with mercuric chlorid, 1 : 5,000, and, finally, sterile normal saline. The surface landmarks that indicate the line of the vessel to be attacked must be noted and the line marked upon the skin by a light stroke of the scalpel.

**Equipment.**—Beside the usual equipment of scalpels, dissecting scissors and forceps, hemostats and retractors, ligatures and sutures and needles, there are required: several serrefines with rubber-covered or smooth blades (Fig. 2); 1 pair of fine, straight scissors; 1 pair of fine, curved scissors; 1 pair of fine, straight forceps; 1 pair of fine, curved forceps (Fig. 7); several fine hemostats (mosquito clamps); a jar of sterile albolin with eye-dropper; and several fine needles, No. 12 to No. 16, threaded with fine silk (Fig. 1), which should be boiled in albolin.

**Operative Steps.**—The operative steps are as follows: (1) Control the flow of blood through the artery by tourniquet, if possible. (2) Expose the artery by sharp and blunt dissection, using every effort to avoid unnecessary tissue injury and bleeding, and fasten towels to the edge of the skin. (3) If the

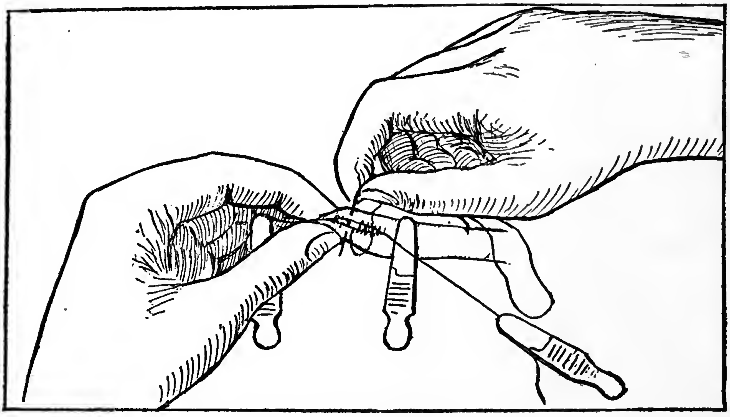


FIG. 8.—SUTURE OF LONGITUDINAL WOUND IN BLOOD VESSEL: GUTHRIE'S POSITION OF HANDS.

artery is bleeding when exposed, an assistant should exert pressure upon it above and below the wound, or, if necessary, with a finger upon the wound until it can be sufficiently isolated from its bed to occlude it temporarily by tape or clamps (Fig. 5) about 1 inch above and below the wound. (4) Remove all blood and blood clots from the wound by sponging with sponges dampened in warm normal saline; and from the vessel lumen, by very gently stripping it toward the wound from both ends, the expressed blood being absorbed by a dry sponge held against the wound. (5) Handle the vessel with the fingers (see Figs. 8 and 9) rather than with the forceps, and as gently as possible. (6) Pick up, in fine forceps, the delicate outer coat of the vessel and trim it away from the margins of the wound for 1 or 2 mm. (1/25 to 1/12 inch) with fine scissors. (7) If the wound edges in the vessel are lacerated or contused, trim them smooth with fine, sharp scissors. (8) Take a few drops of sterile liquid albolene, on the tip of a pair of forceps or in a hypodermic syringe and gently moisten the wound edge with it. If the sutures have not been boiled in albolene, lower them carefully in the jar until they are completely saturated with it. (9) A continuous over-

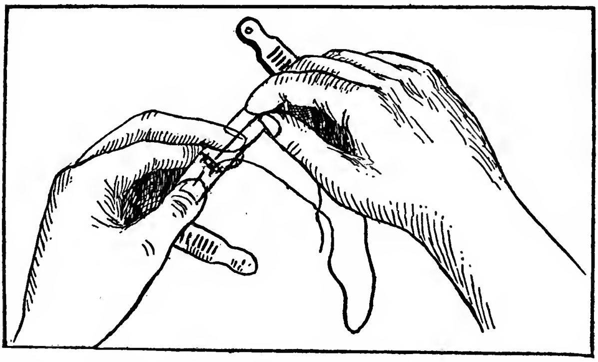


FIG. 9.—SUTURE OF TRANSVERSE WOUND IN BLOOD VESSEL: HOLDING VESSEL ON FINGER.

hand (Fig. 14) or interrupted suture may be done, or a lock stitch (Fig. 11), and should pass through all coats, taking care not to touch the intima with the needle, except at the point of puncture. The edges of the wound should be brought into close apposition without inverting, wrinkling, or puckering, and the suture must not be so tight as to cut through the tissue. The needle should be introduced about ½ to 1 mm. from wound edge and stitches should be placed about ½ to 1 mm. (1/50 to 1/25 inch) apart and the ends tied with a square knot and cut off short.

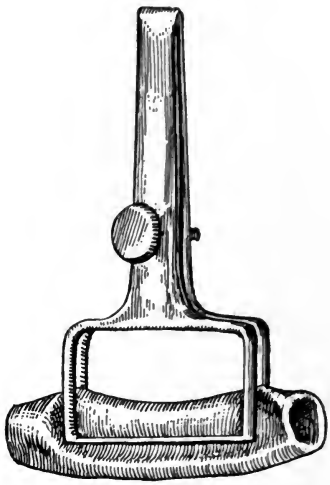


Fig. 10.—Stewart's Clamp for Isolating Portion of Lumen of Vessel.

(10) A continuous mattress suture (Fig. 12) is recommended by Dorrance and interrupted mattress sutures (Briau and Jaboulay) have been used (Fig. 13) by Archibald Smith with satisfactory results. Stewart's clamp may be employed if it is thought unwise to interrupt the circulation (Fig. 10). When the suture is completed, remove the distal clamp or tape and look for leakage at the suture line. If any occurs, press lightly upon the vessel with an absorbent gauze sponge for a minute. Otherwise, loosen the proximal clamp or tape and allow the full blood stream to pass the suture line. If slight leakage occurs, press lightly with a sponge, as before, until it ceases. If it cannot be so controlled, within 3 or 4 minutes, or if a spurting point is seen, replace the tape or clamps to control the bleeding, carefully sponge away the blood and introduce as many extra sutures as necessary to

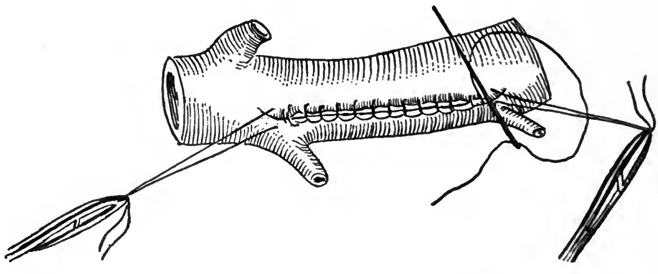


Fig. 11.—Lateral Suture of Longitudinal Wound with Lock Stitch, Using Tension Sutures.

close the defect in the original suture line. Then remove clamps as before. If the suturing has been carefully done there will be very little leakage and this will cease within a few minutes as soon as fibrin blocks the hole around the punctures. Then close the wound of exposure in the usual manner.

The dangers of this operation are not great, if you can be sure of aseptic conditions, gentle handling and proper instruments. But the difficulties are considerable; for it is not easy to get a good exposure of the vessel and collateral branches are apt to complicate the control of the blood current. If they are small, they may be ligated; but, if large, it is better to isolate them sufficiently to close them temporarily with tapes or serrefines. Again, the fine needles are not easy to hold and manipulate and the sutures break very easily, if they are not tied with the utmost care.

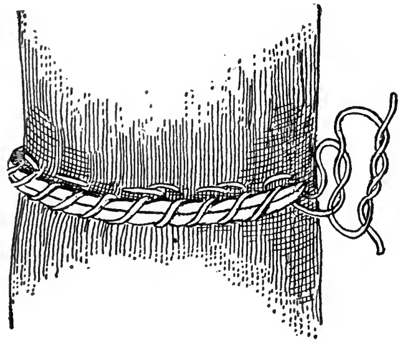


Fig. 12.—Dorrance Suture of Transverse Wound.

The chief cause of failure is occlusion of the artery by thrombus formation. Secondary hemorrhage may occur from tearing out sutures, or following infection, if the sutures are not properly placed or asepsis is imperfect, but it is not likely to happen and only occurred once among the cases reported up to 1912.

The results are generally good in the reported cases as to function, but doubt remains as to permanent patency of lumen.

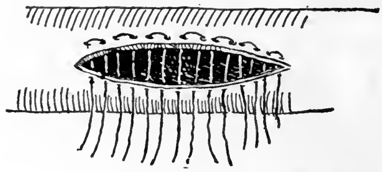


Fig. 13.—Briau-Jaboulay Interrupted Suture.

### Arterial Anastomosis

Circular suture of arteries may be called for where a (1) transverse wound divides more than one-half of the lumen of an artery; (2) where the lateral suture of a gaping defect in the wall would occlude the vessel, or where crushing of the artery necessitates considerable resection of the wound edges; (3) where the artery has been completely divided by knife, bullet, or other injury; (4) after excision of a segment for aneurysm, new growth, or for extensive crushing of an artery.

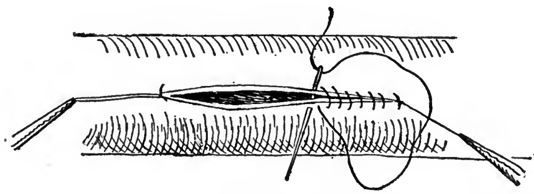


Fig. 14.—Lateral Suture with Continuous Overhand Stitch.

Arterial circular suture is contra-indicated (1) in all smaller arteries whose collateral circulation is normally sufficient to maintain nutrition of limb, etc., after ligation; (2) in all crushed and lacerated wounds when all the perivascular tissues are badly or irreparably injured; (3) in all suppurating, or otherwise infected wounds on account of thrombosis and secondary hemorrhage; (4) in all cases where approximation cannot be obtained without overstretching of vessels and where venous grafting or substitution is impossible. (Matas.)

**Instruments.**—The instruments required are: Usual dissecting set; elastic constrictors; Langenbeck's serrefines (or serreplats); miniature Doyen clamps with elastic covering; selection of Payr's magnesium rings (Fig. 20); fine forceps, straight or curved; fine scissors, straight or curved; finest silk or Alsace thread (No. 500) with Kirby No. 16 straight needle (for small vessels); fine cambric needles, or floss needles, No. 6 to No. 10, with No. 0 or No. 1 oculist's silk (for larger vessels); sterile albolin; black, lint-free field sheet, or a white field sheet, if black sutures are used; skin clips to fasten it to wound edges.

**Methods.**—A considerable number of methods of end-to-end anastomosis of arteries have been reported, but up to the present time only three have been extensively used: (1) The invagination method (Murphy, Payr, etc.); (2) broad marginal apposition (Salomoni, Briau, Jaboulay, Lespinasse and Eisenstaedt); (3) direct marginal approximation (Carrel, Guthrie, etc.). In all of them the chief points of technic are: Complete asepsis, exposure of vessels with least possible injury, temporary interruption of blood current, control of vessel while applying suture, accurate approximation of the walls, perfect hemostasis by pressure after removing clamps, careful toilet of the wound.

INVAGINATION METHOD.—The invagination method is said to be "applicable to all vessels of large caliber, including popliteal and femoral, in which not more than three-quarters of an inch have been removed by injury or excision." If position of limb can be made to relieve tension possibly a greater loss than three-quarters of an inch can be permitted without grafting.

MURPHY'S METHOD.—The steps of Murphy's original invagination method are:

(1) Expose by a generous incision and isolate the artery from its sheath for a distance of at least 1 inch above and 1 inch below injury. If collateral branches interfere, ligate or temporarily clamp them. (2) Apply serrefines or rubber-covered, flexible-bladed clamps at upper and lower ends of isolated portion with just enough pressure to stop bleeding. (3) Excise crushed portion of vessel (up to ¾ inch), or trim edges with sharp scissors, if lacerated or uneven. Pull adventitia over end of stumps and cut off with sharp scissors (Fig. 15), and remove all blood and clots. (4) Incise distal stump longitudinally a short distance with sharp knife (Fig. 16). (5) Place three U-shaped traction sutures, at equidistant points, through

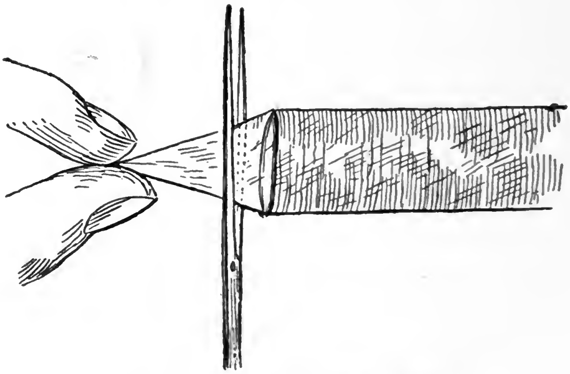


FIG. 15.—CUTTING OFF THE ADVENTITIA.

all coats but intima, of the proximal stump, a short distance (about ¼ inch) from its cut end. (6) Thread the free ends of these sutures in separate needles and pass them from within outward, through all coats of distal stump about ¼ inch from its cut edge at points corresponding to those on proximal stump (Fig. 16). (7) By the aid of these as tractors, and, if necessary, with an assistant manipulating the stumps, the proximal is invaginated into the distal end and the traction sutures tied on the surface of the distal stump. (8) The joint is then reinforced by several interrupted non-penetrating sutures on outer surface of junction of the stumps or by a continuous suture (Fig. 17).

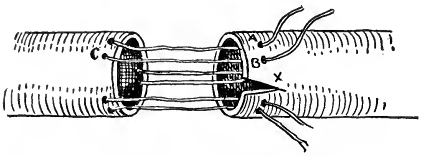


Fig. 16.—Murphy's Earlier Method; Traction Sutures Introduced.

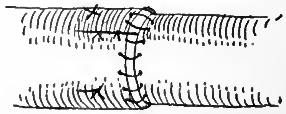


Fig. 17.—Murphy's Earlier Method; Invagination Completed by Circular Suture.

Murphy's more recent technic includes the use of a specially devised instrument, a sort of split, hollow, open-ended cylinder, with separable halves, carried on a handle. The distal stump is cuffed backward over this, the cut end of the proximal stump sutured to the reflection and the cuff then turned forward over the proximal stump and sutured in place (Fig. 18). This was devised for end-to-end arterio-venous anastomosis. Modifications of this method have been proposed by Bouglé, Jensen, O'Day and others.

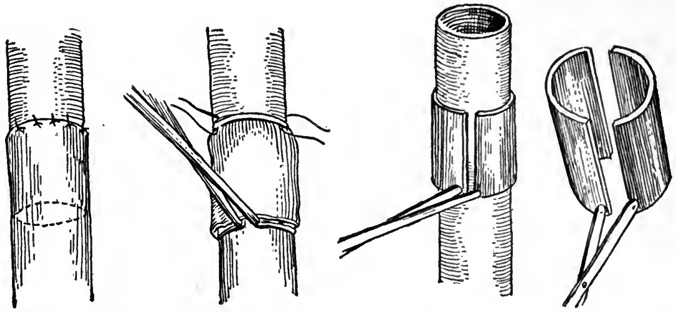


Fig. 18.—Murphy's Recent Method of End-to-end Anastomosis by Invagination.

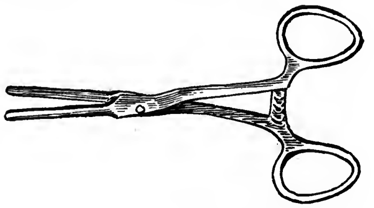


Fig. 19.—Hoepfner-Stich Clamp.

Payr's Method.—Payr's method of invagination utilized a magnesium ring to maintain the lumen size of the invaginated portion (Fig. 20). Hoepfner's modification of Payr's method (1) exposes and isolates the artery sufficiently to apply clamps well beyond the wound or the portion that must be excised; (2) special curved handle clamps, with flat or rubber-covered blades (Fig. 19), are then applied with only sufficient force to shut off the blood current; (3) the adventitia and the bruised

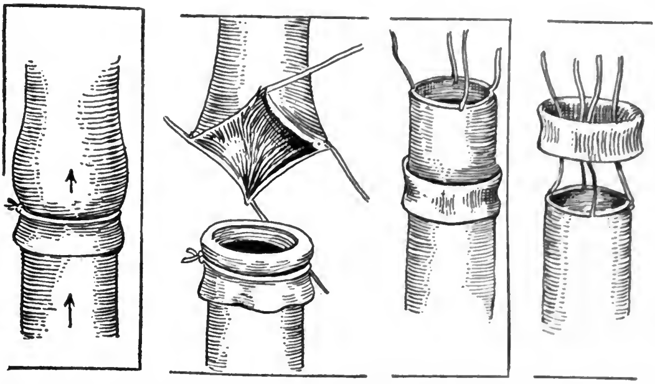


FIG. 20.—PAYR'S END-TO-END ANASTOMOSIS WITH MAGNESIUM RING.

ends of the artery are next trimmed carefully off and the blood washed away with normal saline solution; (4) the distal end of the vessel is then covered with a sponge damp with saline, while three fine silk sutures are introduced at the margin of the proximal stump, 120° apart through all coats and tied; (5) the ends held together are passed through a thin, grooved ring of magnesium (same size as vessel), which is held in a special forceps and slipped, like a collar, over the proximal stump; (6) by traction on the threads, the protruding end of the artery is everted, rolled back over the ring, tied in place by a fine silk circular ligature, fitting snugly into the groove, and the traction sutures removed; (7) three similar traction sutures are now placed in the distal stump to stretch its margin and gently draw its lumen over the everted cuff of the proximal stump where it is tied in place by a fine silk circular ligature. This completes the anastomosis, which brings intima to intima, but slightly narrows the lumen. Jeger has devised an ingenious holder for Payr's rings, which considerably simplifies the technic (Fig. 21). He has also produced a modified ring or cylinder which he recommends for use in uniting deeply placed vessels (Fig. 22).

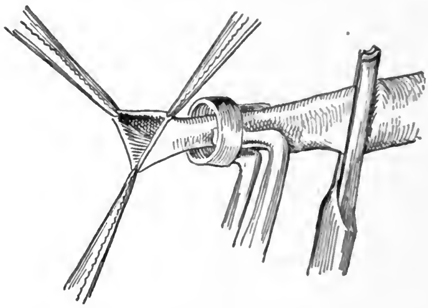


FIG. 21.—JEGER'S HOLDER FOR PAYR'S RING.

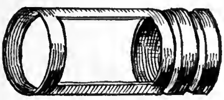


FIG. 22.—JEGER'S MODIFICATION OF PAYR'S MAGNESIUM CYLINDER FOR DEEPLY PLACED VESSELS.

METHOD OF BROAD MARGINAL APPOSITION.—With a similar end in view, of bringing intima to intima, Salomoni (Fig. 23), and also Briau and Jaboulay (Fig. 24), placed their sutures at a little distance from the cut edges of the vessel in such manner as to evert these edges and draw comparatively broad intimal surfaces of both stumps into contact. Salomoni used a simple interrupted suture, while Briau and Jaboulay employed an interrupted mattress suture. Dorrance, using Pagenstecher No. 1 thread, on the finest needle that would hold it, and employing special flexible bladed forceps (Fig. 4), for hemostasis devised a continuous mattress suture (Fig. 25) locked at every third stitch and reinforced by a continuous overhand suture of the everted wound margins (Fig. 26).

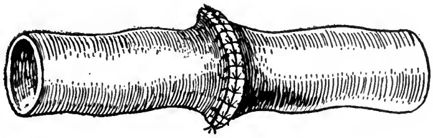


Fig. 23.—Salomoni's Method of End-to-end Suture.

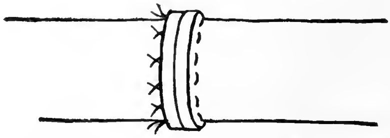


Fig. 24.—Briau-Jaboulay Method of End-to-end Suture.

Lespinasse and Eisenstaedt have reported a method of anastomosis of blood vessels, based on the same principle of broad marginal confrontation of intima. They use chemically pure magnesium rings to facilitate coaptation and comparatively coarse suture material. These rings are "flat, washer-like pieces of metal, with a thickness of one millimeter, and a wall of from one to two millimeters in width. On the wall, eight suture holes are located, equidistantly, which have been countersunk, or beveled to prevent cutting of the sutures when traction is made in tying them. Likewise the circumferential and luminal edges are beveled to prevent injury to the coats of the vessels."

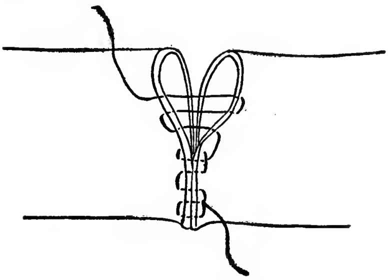


Fig. 25.—Dorrance's Method of End-to-end Suture.

These are applied in such a way that when the final sutures are tied the approximated ends of the vessel are practically clamped between them (Fig. 27). They do not state results, but conclude that this "method is superior because *1st,* the suturing is not fine; it is quite coarse; *2nd,* the sutures and rings are extravascular and do not come in contact with the blood stream. The normal intima alone comes in contact with the blood stream at the completion of the operation."

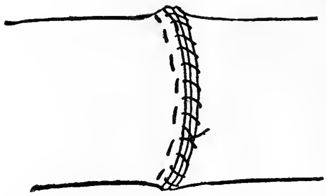


Fig. 26.—Dorrance's Method. Mattress Suture Reinforced by Continuous Overhand Suture.

Method of Direct Marginal Approximation.—The method of direct marginal approximation by continuous through-and-through sutures of the vessels has been very completely developed by Carrel and Guthrie, whose methods are practically the same. Guthrie has recently published a very full account of his technic and results and the following description of Carrel's technic is abbreviated from one of his recent communications.

Carrel's Method.—*General Rules.*—To avoid complications of stenosis, hemorrhages, and thrombosis: (1) A rigid asepsis is absolutely essential; an infection not sufficient to prevent primary union of a wound may yet cause thrombosis. (2) Blood vessels may be freely handled in the fingers, but not with forceps; the latter, if used, must take only the outer sheath in its grasp, and when employed for hemostasis must have smooth jaws with carefully regu-

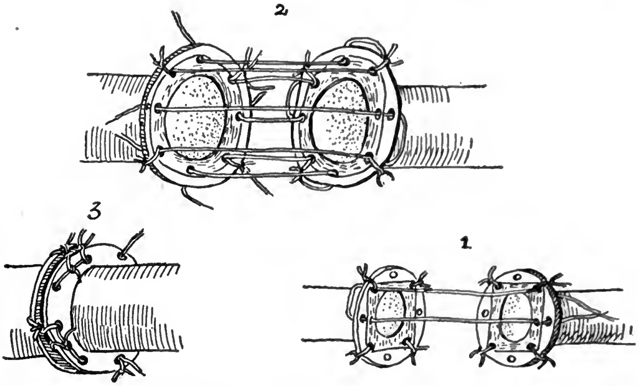



Fig. 27.—Lespinasse and Eisenstaedt Method of End-to-end Anastomosis, Method III.

lated pressure. (3) Drying of the endothelium or the presence of coagulated blood, fibrin ferment or foreign tissue, or tissue juices on the interior of a vessel may lead to thrombosis; therefore, the external sheath must be resected and the lumen of the vessels and the surrounding parts must be washed with

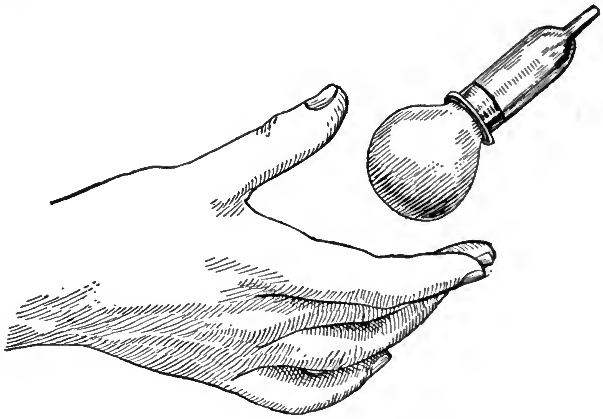


Fig. 28.—Gentile's Syringe (Carrel).

Ringer's solution and coated with vaselin. (4) To minimize trauma of the endothelium by the perforating sutures, the needles and suture material must be of the smallest size, sterilized in vaselin, and kept coated with it during the suturing. (5) To avoid stenosis, keep the arterial walls under lateral tension by traction sutures while putting in the continuous stitch.

*Instruments.*—Crile clamps (Fig. 3) or elastic forceps (Fig. 4), for temporary hemostasis in large vessels, as femoral artery; small Crile clamps or smooth-jawed serrefines (Fig. 2) without rubber covers, for small vessels, or narrow rubber strips held round the artery by serrefine or forceps; Gentile

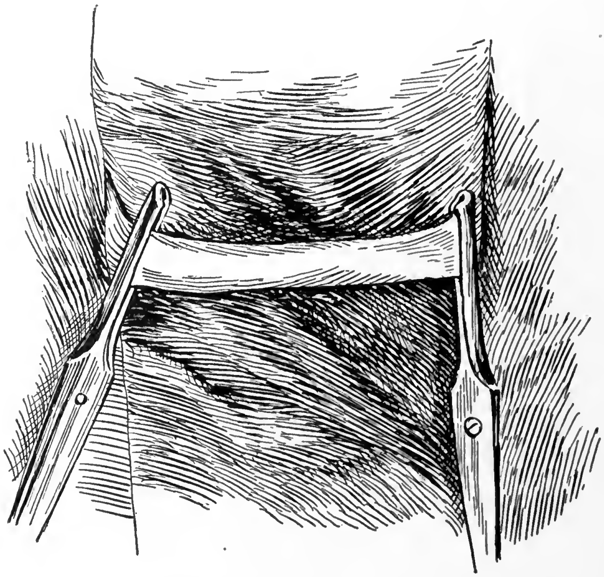


Fig. 29.—Artery Isolated on Black Field Sheet.

syringe and Ringer's solution for washing out the vessels (Fig. 28); round, straight needles, Kirby No. 16, for small vessels, No. 12 to No. 16, can be used for large vessels; they are threaded with very fine silk (Fig. 1) and sterilized in vaselin; Gentile forceps to hold the traction sutures; a black towel to lay the sutures on and a black japanese field sheet to surround the wound.

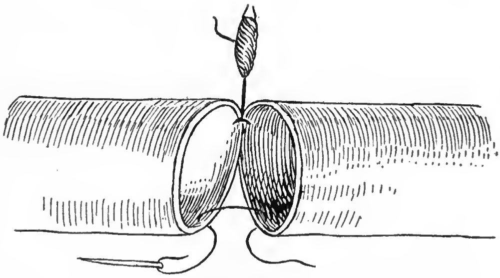


Fig. 30.—Carrel's Method of End-to-end Anastomosis: Application of the Two Posterior Retaining Stitches.

*Temporary Hemostasis and Preparation of Vessels.*—(1) Expose the vessels by a large incision and dissect them free, securing a large operating field. (2) Catch all bleeding points and make the wound as "dry" as possible. (3) Cause temporary hemostasis of the artery by clamps, forceps, or rubber bands placed a few centimeters from the site of the future anastomosis; clamping or ligating all collaterals that interfere. (4) Resect the sheath, and trim the ends of the vessels as may be necessary. (5) Introduce the ends of the syringe into the vessels and wash out the blood from them and from the operating field, and remove the fluid with dry gauze and forceps. (6) Coat the vessels and surrounding parts with warm vaselin. (7) Place the black silk field sheet around the vessel ends (Fig. 29).

*Suture.*—Place and tie the first posterior retaining stitch on the posterior aspect of the vessels' ends near the edges. Fix the short end in a small forceps and lay the long end in the needle upon the black towel to use for the continuous

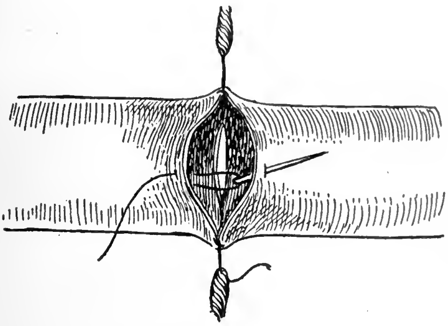


Fig. 31.—Carrel's Method: Application of Anterior Retaining Stitch.

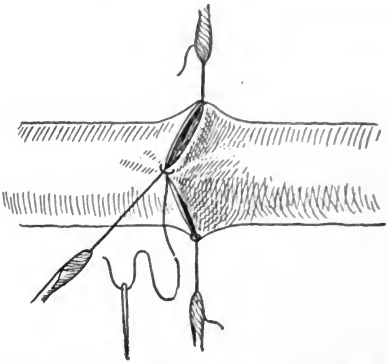


Fig. 32.—Carrel's Method: Circumference of Artery Transformed into a Triangle by Traction on the Retaining Stitches.

suture. Place the second posterior retaining stitch 120° from the first, cut a convenient length, and fix both ends in a small forceps (Fig. 30). Make a slight traction on both posterior stitches and introduce an anterior traction thread equidistant from them (Fig. 31). The ends of the artery must come together without strong traction.

Convert the circumference of the approximated ends into a triangle by drawing upon the traction threads (Fig. 32), and unite them by a continuous overhand suture (Fig. 33) with the original needle and silk, beginning near the first posterior traction stitch and carrying it around the vessel to the same point, squeezing out vaselin before closure is completed. Only a few stitches between traction threads are necessary; three, for example, in an artery the size of a dog's carotid. Take great care to approximate the divided surfaces exactly. They must not come into contact with the blood stream. Carefully examine the line of suture and close any gaps by an additional stitch.

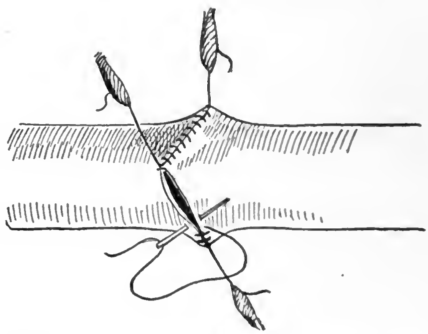


Fig. 33.—Carrel's Method: Continuous Suture Almost Completed.

*Reëstablishment of the Circulation.*—Place gauze sponges on the suture line and make gentle pressure while the clamps are removed. Expect some leakage during the first minute, but, if some bleeding persists when the sponges are removed, after two or three minutes, complementary stitches may be added.

Then wash the vessels and the wound with Ringer's solution, and close the wound without drainage.

Other Methods.—Guthrie's technic, as recently published, differs somewhat from Carrel's in minor points. He uses Kirby's needles, No. 12 to No. 16, and "bead silk," whole for larger vessels, and untwisted for small. He prefers to occlude the vessel by narrow tapes, held in forceps (Fig. 5), and he removes the blood from the divided ends on to a gauze sponge, by gently stripping them between the fingers instead of washing with a syringe, and wipes out his wound with a gauze sponge. After removing the blood, he applies a little oil to the cut ends instead of coating with vaselin. He uses one posterior and two anterior traction threads instead of the reverse, and lightly oils his fingers before affixing them. He places the stitches of his continuous suture about ½ mm. from the cut edges, and the same distance apart, and interrupts the circular suture twice by tying it at 120° intervals to the traction threads. Guthrie says suitable silk can be procured from James Pearsall & Co., 71 Little Britain, London; needles from Kirby, Beard and Co., Ravenhurst Works, Bradford St., Birmingham.

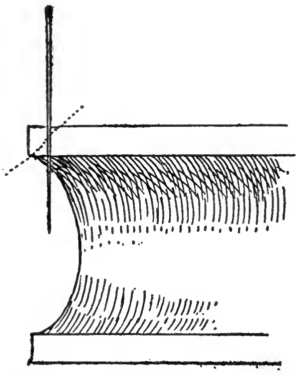


Fig. 34.—Correct Direction of Needle Introducing Stay Suture. Dotted line shows incorrect direction.

Jeger, in describing Carrel's method, emphasizes a practical point illustrated

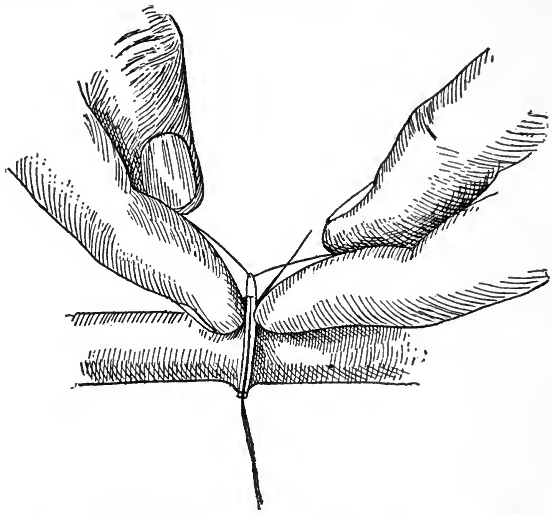


Fig. 35.—Tying the Stay Suture.

in Figure 34. The vertical introduction, rather than the oblique, of the needle through the vessel wall has the effect of slightly everting the cut edges of the vessel segment when the sutures are tied, as shown in Figure 35. He strongly advises against the use of forceps and says if they are absolutely necessary that they should grasp the vessel only between its cut edges and the suture line, *not* beyond this, so that the portion thus injured shall not touch the blood stream. He recommends angulating the vessel at the line of junction, as shown in Figure 36, to facilitate the insertion of the continuous suture. Like Guthrie, he ties the continuous suture to the tension suture. He places his stitches slightly closer together than Carrel in the continuous suture. If complementary sutures for a spurting point are necessary, he says that they should embrace all the coats of the vessel (Guthrie to the contrary), lest intima be not brought to intima. If further sutures are needed to stop oozing only, these he does not make through and through. And if they fail to control the bleeding he applies a bit of muscle to the place or wraps a strip of fascia or peritoneum around the anastomosis, as in Figure 37. He calls suture of the adventitia superfluous. For deep vessels he advises that the tension sutures be "U" sutures and of heavier silk, if intended for unusual tension. He recommends the use of Horsley's tension suture holder (Fig. 38), or Jeger's instrument (Fig. 39), for the same purpose.

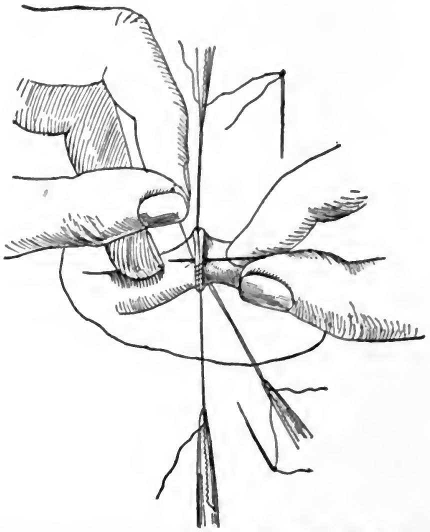


Fig. 36.—Angulation of the Vessel to Facilitate Insertion of Continuous Suture.

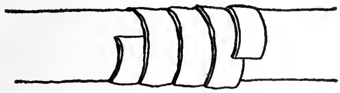


Fig. 37.—Reinforcement of the Anastomosis with a Strip of Fascia or Peritoneum.

Horsley has devised an ingenious instrument for holding the stay sutures, in end-to-end anastomosis (Fig. 38)—"a steel shaft, 1/16 inch thick, curving at one extremity into a shorter shaft and flattened at the angle to make it springy. There are five buttons to fasten the thread to." He employs a continuous mattress suture and everts the edges of the vessels.

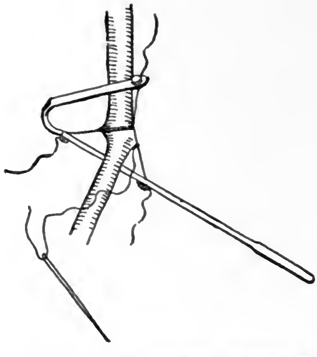


Fig. 38.—Horsley's Tension Suture Holder.

Dobrowolskaja has recently experimented with complicated incisions, in the effort to prevent narrowing of lumen in end-to-end suture of vessels of small caliber. The indented incision is the simplest. This is made triangular to the middle of the vessel (Fig. 40), one segment rotated 90°, and the long point brought together with stay sutures, leaving wide diamond-shaped defects.

The edges of these are approximated by lateral traction on the stay suture and then united by a continuous suture. This results in a widening of the lumen at the line of suture which, it is said, shows a tendency to disappear after a while. Human hair or silk No. 00 on straight needle were used and it is said that these complicated incisions and sutures apparently do not endanger the vessels. They may also be used to accommodate an artery to a larger vein, in end-to-end suture.

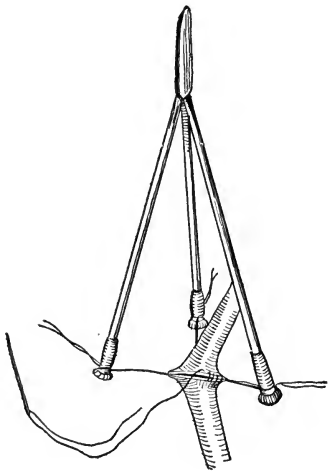


Fig. 39.—Jeger's Tension Suture Holder.

O'Day has recently reported a successful modification of Payr's invagination in which he used a circular ligature instead of a ring, to turn back a cuff on the proximal segment, and fastened the cuff by quadrant sutures tied to the ligature. He then invaginated the proximal into the distal stump and sutured the latter to the cuff by a running stitch. He draws the previously retracted adventitia toward the line of union before removing the temporary hemostatics, and, if complementary sutures are necessary, he advises that they should include only the outer coats.

**Choice of Methods.**—The invagination method of Murphy is objectionable in that it narrows the lumen and shortens the vessel itself and is liable to be followed by thrombosis because it leaves a raw surface in contact with the blood stream. With the exception of the last, Payr's method has the same drawbacks and, moreover, it requires a special implement, the ring, which may not be at hand, and may cause thrombosis by pressure necrosis of the ring on the vessel wall. Broad marginal confrontation, whether by suture or metal flanges, also somewhat reduces the vessel's length. The direct marginal approximation, on the other hand, neither shortens the artery nor appreciably narrows its lumen. Moreover, it can be done without any special equipment other than well-lubricated suture material and needles of requisite fine-

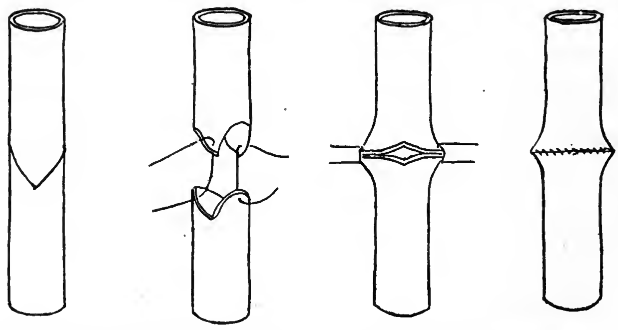


Fig. 40.—Dobrowolskaja's Flap Incision for Widening Small Vessels at the Line of Union.

ness. But above all in its favor is the excellence of its published results, as obtained in experimental work. It requires, perhaps, a higher degree of dexterity to accomplish than a union by invagination, or with metal flanges; but this need deter no one who is willing to spend some time in practicing its technic. Matas says: "The Carrel technique has become the method of election at the present time."

Jeger calls Carrel's the best technic for the surgeon skilled in blood vessel work, but points out that it is difficult and takes considerable time in the unpracticed hand, although Carrel can do a circular suture in five minutes. Further he says that Payr's method, while not offering the same safety (as regards thrombosis) as Carrel's, is far simpler, more rapid, and is especially applicable in accidents, in war time, etc. This method, with modifications as practiced by him, has given good results.

In regard to the restoration of vascular channels in general, Guthrie believes it is safe to say that, when patency of lumen can be preserved, it is better to repair the defect by suturing than to ligate the vessel. He adds that in the event of much vessel wall being destroyed, or if it has to be removed, then preservation becomes doubtful; and one of four things can be done:

(1) Ligate on both sides of the defect,
(2) Restore defect by a patch,
(3) Transverse excision with circular suture,
(4) Transverse excision with transplant by circular suture.

*The first* is safe on secondary arteries, like ulnar; less so on intermediate arteries, like brachial; unsafe on primary arteries, like renal.

*The second* is more complicated, difficult and liable to thrombosis than circular suture.

*The third* is preferable, if it does not cause too much tension.

If there is too much tension, use the *fourth procedure.*

With asepsis and careful suturing an arterial anastomosis involves no greater dangers than are encountered in any other class of operations upon important anatomical structures; and the difficulties, while considerable, are such only as can be overcome by patience and perseverance. The invagination methods would probably be found the easiest in the majority of hands; but this is not sufficient to prefer them over the direct marginal suture. The introduction of the least infection into the wound; any but the gentlest handling of the vessels; carelessness in allowing them to dry out or to be invaded by foreign tissue, or tissue juices; failure to remove blood and blood clots; these are the causes that may act to invalidate the operator's efforts by inducing thrombosis. An ill-placed, insecurely tied suture, or too great tension on the sutures, may permit of secondary hemorrhage, though this is rare; and a certain degree of stenosis may be produced by too small a ring or by a continuous suture too tightly drawn.

Carrel says of his method: "If the technique here described is followed, no complications occur." And his results bear out this bold statement.

**Results of Circular Suture of Arteries.**—Buchanan collected from the literature 29 cases (besides his own) up to Nov. 1, 1911. From an analysis of these cases it appears that the mortality was 6 2/3 per cent.; and complete recoveries with good circulation of the parts 83 1/3 per cent.; while the partial recoveries, in which gangrene requiring amputation gave incontrovertible evidence of failure to reëstablish a normal circulatory condition, were 10 per cent.

It is not apparent that either of the two deaths was directly attributable to the operation. One was reported as due to delirium tremens; and the other patient was said to be moribund from hemorrhage when operated upon. A better selection of cases would perhaps have resulted in lower mortality.

The only autopsy reported showed "artery pervious (after 5 days) with thrombus in part of its lumen."

Now, as to the recoveries, it is reasonable to suppose, if the pulse below the injury has been feeble or imperceptible before operation and becomes stronger soon after the anastomosis has been accomplished, that blood is reaching the distal portion of the vessel via the anastomosed segment; and, if the pulse remains strong without intermission, it is fair to believe that the patency of the lumen has been maintained. But if the pulse does not very rapidly return after anastomosis, or if, having rapidly returned, it later disappears or becomes very much feebler, it would appear probable that the lumen of the vessel has been narrowed or obliterated at the anastomotic site, and that collateral circulation was responsible for the healthy condition of the part distal to it. Naturally, if gangrene appears in the part distal to the suture, one supposes a failure due to complete or nearly complete occlusion of the vessel operated upon, as well, probably, as to a serious amount of damage in the collateral vessels, such as may have occurred in crushing injuries. Arguing on this basis, it is not clear that more than 11 of the above reported cases were successful in reëstablishing and maintaining the circulation through the injured segment, since in only 11 is the pulse stated to have returned within 24 hours; and Thoma says that return of pulse (due to collateral circulation) below the ligated main trunk of a vessel can occur as early as 24 hours postoperative, in young subjects, and proportionately later in older persons. This would be 36 2/3 per cent. of operative successes in a strict sense; but, since there were over 80 per cent. of recoveries with good circulation, it is just to say that the anastomosis had perhaps served its purpose by permitting a partial but sufficient flow of blood to reach the distal parts during the time required for development of the collateral supply.

The results of arterial circular suture in animals are more brilliant. An analysis of the results of Borst and Enderlen, Yamanouchi, Ward, Stich, Glasstein, and Carrel, as quoted by Jeger, shows 71.2 per cent. successes in a total of 148 cases done by the Carrel method.

Jeger quotes an interesting compilation by Sofoteroff which compares the relative percentage of successes in end-to-end anastomosis of vessels by Murphy's, Payr's and Carrel's methods:

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 90 | cases | of | end-to-end | anastomosis, | Murphy | method, | 15.5 | per | cent. |
| 96 | " | " | " | " | Payr | " | 17.6 | " | " |
| 352 | " | " | " | " | Carrel | " | 49.8 | " | " |

### Arteriovenous Anastomosis

Arteriovenous anastomosis is the procedure of forming a communication between an artery and a vein in such manner that the arterial blood is admitted to the vein for the purpose of displacing its contents and causing reversal of the circulation.

Thus far, this procedure has been used only in cases of expected or actual gangrene of the limbs due to (1) Raynaud's disease; (2) obstruction of the main artery from endarteritis, thrombo-arteritis, embolus, or trauma. The instruments required are the same as for suture of arteries. The anastomosis may be made end-to-end, side-to-side, or end-to-side.

**End-to-End Arteriovenous Anastomosis.**—MURPHY'S METHOD.—The steps in the invagination method are as follows: (1) Expose artery and vein; isolate both and provide temporary hemostasis. (2) Divide both vessels, the vein ½ inch to ¾ inch higher than the artery, if possible. (3) Ligate permanently the distal stump of the artery and proximal stump of vein. (4) Apply forceps (Fig. 18) around distal segment of vein near its end; evert and roll back open end of vein like a cuff upon it. (5) Suture cut end of artery to reflected border of venous cuff by interrupted stitches. (6) Pull reflected vein cuff forward over line of suture and stitch its cut edge to outer surface of artery. (7) Remove forceps and close wound without drainage. Murphy now uses this method in arterial suture also.

CARREL'S METHOD.—The procedure in end-to-end suture of artery to vein is the same as in his method of uniting artery to artery except that the cut edge of the vein is somewhat everted, so that its endothelial surface lies against the cut edge of the artery (Fig. 41). As the vein is usually larger than the artery, sufficient pull is exerted upon the three traction sutures to stretch the artery nearer to the size of the vein and each stitch of the continuous suture is made larger on the vein and at a slightly greater distance from its cut edge than the corresponding stitch on the artery. This has the effect of slightly puckering the vein and thus reduces its lumen to correspond with that of the artery. (Fig. 42.)

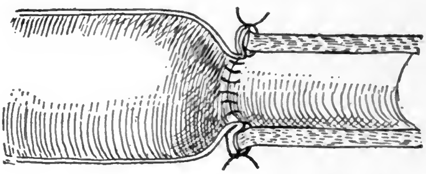


Fig. 41.—End-to-end Arteriovenous Anastomosis: Approximation of the Ends (Carrel).

**End-to-Side Arteriovenous Anastomosis.**—End-to-side (Carrel and Guthrie) anastomosis (for arterial or arteriovenous anastomosis) may be made by:

(1) Preparing the proximal stump of the artery as for an end-to-end anastomosis and ligating the distal end. (2) Temporary hemostasis is then applied to the corresponding segment of the vein, after being isolated, and an elliptical

opening made into it a trifle larger than the size of the arterial lumen by lifting up a bit of its wall in forceps and cutting it out with sharp scissors. (Fig. 43.) (3) The blood is then pressed out and the edges of the opening vaselined

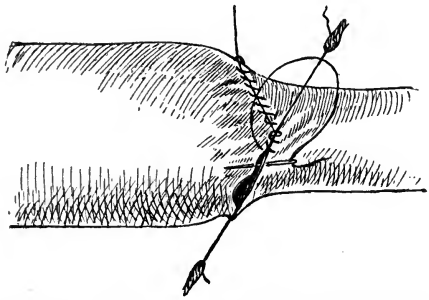


FIG. 42.—END-TO-END ARTERIOVENOUS ANASTOMOSIS: APPLICATION OF CONTINUOUS SUTURE (Carrel).

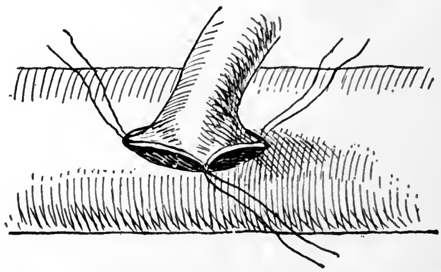


FIG. 44.—END-TO-SIDE ANASTOMOSIS: FIXATION SUTURES INTRODUCED (Carrel).

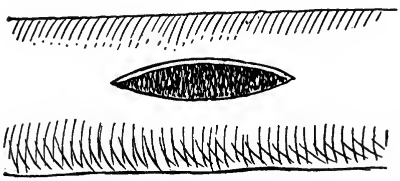


FIG. 43.—END-TO-SIDE ANASTOMOSIS: OVAL OPENING INTO VEIN (Carrel).

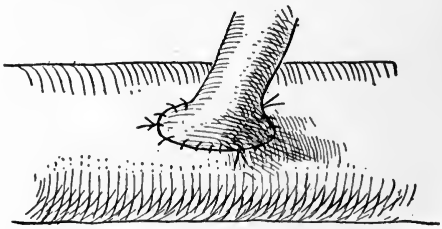


FIG. 45.—END-TO-SIDE ANASTOMOSIS: COMPLETED (Carrel).

and three or four traction sutures tied on the outside of the vessels are made to approximate the end of the artery to the side of the vein (Fig. 44). (4) Traction on these sutures triangulates or squares the junction of the vessels and a continuous suture is made to unite their edges (Fig. 45). (5) The vein is permanently ligated above the point of anastomosis, and the temporary hemostats on vein and artery removed.

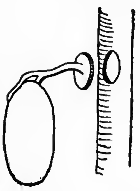


FIG. 46. — CARREL'S PATCHING METHOD: SMALL VESSEL EXCISED WITH PART OF LARGE (Carrel).

They also describe a "patching" method: If one of the vessels is too small to handle conveniently, it may be excised with a part of the wall of its parent trunk (Fig. 46) and the latter attached to the oval opening in the other vessel (Fig. 47) and united with it by continuous suture (Fig. 48).

WIETING'S METHOD.—Wieting's method of end-to-side anastomosis, practically similar to Van Hook's terminolateral ureteroureteral anastomosis, is open to the theoretical objection, at least, of leaving a raw edge in contact with the blood stream. The proximal cut end of the artery is introduced through a slit in the side of the vein and anchored there by one retaining suture that is tied on the outside of the vein, and a continuous suture unites the cut edges of the vein to the outer surface of the artery. The vein is then ligated closely proximal to the anastomosis.

JEGER'S METHOD.—Jeger has devised a method for end-to-side anastomosis far superior to Wieting's. It is described under operations on veins, but it might be applied to arteriovenous anastomosis.

**Side-to-Side Arteriovenous Anastomosis.**—CARREL'S METHOD.—(1) After proper exposure, isolation and hemostasis, both vessels are opened longitudinally, at corresponding points, for a distance a little greater than the diameter of the artery, by incision with a scalpel or excision of an elliptical flap with scissors, and the adventitia trimmed away. (2) Traction sutures are then placed, uniting the distal and proximal ends of these openings (or points close to them on the adjacent cut margins) and tied on the outside of the vessels. (3) While traction is made on these sutures, the needle on the long end of the distal one is made to penetrate the wall of the vessel from without inward and a continuous suture is carried by means of it along the adjacent margins of the openings, on their endothelial surface, and after piercing the wall at the proximal end of the opening is tied, on the outside of the vessels, to the proximal traction suture (Fig. 49). (4) A third, or anterior, traction suture is then made to approximate the distal margins of the two openings in the vessels at their middle and tied on their outer surface. (5) Traction on this, and upon the posterior proximal and distal traction sutures, angulates and approxi-

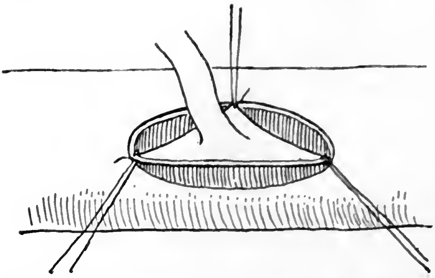


FIG. 47.—CARREL'S PATCHING METHOD: STAY SUTURES INSERTED.

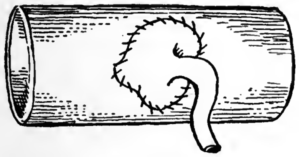


FIG. 48.—CARREL'S PATCHING METHOD: SUTURE COMPLETED.

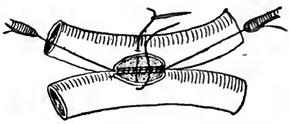


FIG. 49.—SIDE-TO-SIDE ANASTOMOSIS: END TENSION SUTURES TIED, ADJACENT MARGINS UNITED BY CONTINUOUS SUTURE, ANTERIOR TENSION SUTURE INSERTED BUT NOT TIED (Carrel).

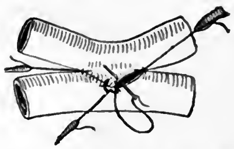


FIG. 50. — SIDE-TO-SIDE ANASTOMOSIS: ANTERIOR TENSION SUTURE TIED; CONTINUOUS SUTURE NEARING COMPLETION (Carrel).

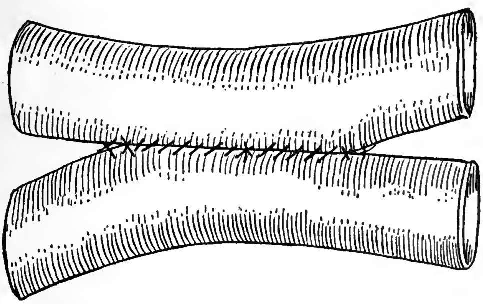


FIG. 51.—SIDE-TO-SIDE ANASTOMOSIS COMPLETED, SHOWING EXTRA END SUTURES OF GUTHRIE.

mates the anterior margins of the wounds, which are then united by a continuation of the suture, working upon the adventitial surface of the vessels, which has already been used to unite the posterior (or adjacent) margins of the vessel openings. This is tied, at its completion, to the distal traction suture (Fig. 50).

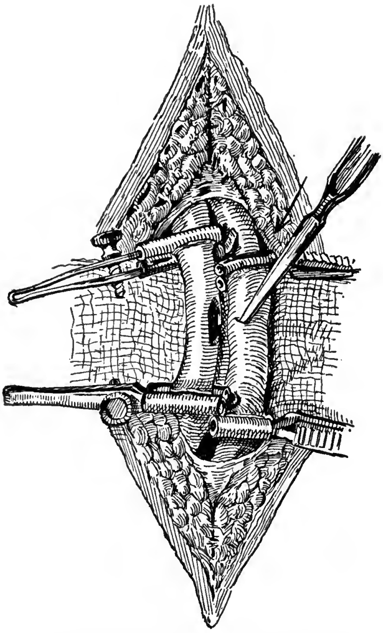


FIG. 52.—BERNHEIM'S ANASTOMOSIS: DIVIDING VESSEL FOR LATERAL ANASTOMOSIS AND RESULTANT GAPING OF INCISION.

GUTHRIE'S METHOD. — Guthrie's method differs from Carrel's in the following respects:

Guthrie makes the openings, in width, about 1/3 and, in length, about 1½ the diameter of the vessel, if the entire circulation of one vessel is to be diverted through the anastomosis. He places a temporary posterior traction loop midway between the proximal and distal traction sutures to aid in approximating the *adjacent* margins while they are being united with the continuous suture. This is placed on the internal surface, is not tied, and is cut and withdrawn before the anterior traction suture is introduced. He ties the continuous suture with the anterior traction suture as well as with the proximal and distal. If much strain is likely to be exerted upon the suture line, he reinforces it, at proximal and distal ends (Fig. 51), by a somewhat coarser single suture.

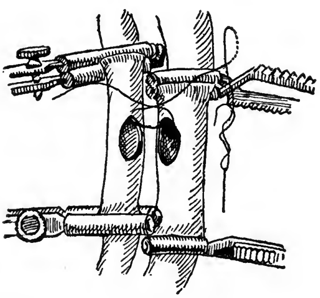


FIG. 53.—BERNHEIM'S ANASTOMOSIS: STARTING THE SUTURE. The knot is tied on the outside of the vessels.

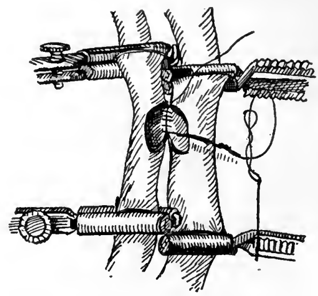


FIG. 54.—BERNHEIM'S ANASTOMOSIS: POSTERIOR ROW OF SUTURES BEING PLACED.

LESPINASSE AND EISENSTAEDT METHOD.—They have used oval magnesium plates, similar to those used for end-to-end anastomosis, but the method is less promising than that by simple suture.

BERNHEIM AND STONE METHOD.—(1) After dissection and clamping of the vessels with bull-dogs or Crile clamps (rubber-shod), "a sharp cataract

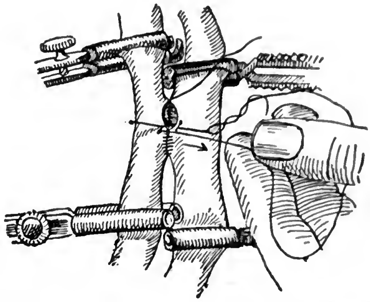


FIG. 55.—BERNHEIM'S ANASTOMOSIS: POSTERIOR ROW OF SUTURES COMPLETED, ANTERIOR ROW BEING PLACED.

knife, held transverse to the long axis of the vessel, is plunged through the artery in a direction oblique to the horizontal plane in which the vessel lies, so as to form a sector of the lumen with its arc equal to about 1/3 of the circumference. The knife is thrust in with its cutting edge up and toward the adjacent vein. The overlying 1/3 of the artery is then divided." (Fig. 52.) (2) Wash out all blood with saline and moisten lumen and other surfaces with liquid vaselin. (3) Protect the artery with vaselin-soaked gauze and make a similar incision in vein so that it looks toward the artery. (4) The suture is then (Fig. 53) started at the lower end of the two incisions, tied on the outside of the vessels, and made continuous (Fig. 54) back to the starting point, where it finishes by tying with the first end (Fig. 55). (5) Ligate vein on proximal side and loosen distal venous clamps (Fig. 56). (6) Loosen distal and then proximal artery clamps. (7) Reinforce, if necessary, for leakage.

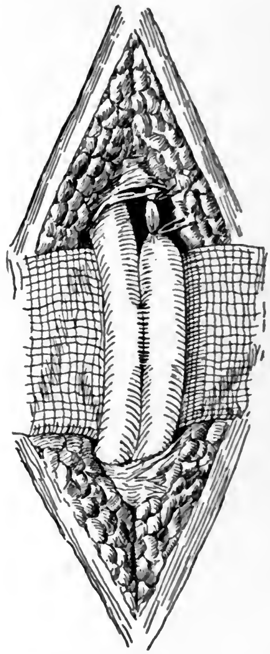


FIG. 56.—BERNHEIM'S ANASTOMOSIS: SUTURE COMPLETED, TIED AND CUT. Clamps removed. Proximal ligation of vein.

Bernheim thinks lateral arteriovenous anastomosis better than end-to-end because it allows some blood to continue down the artery and does not entirely cut off the circulation if the vein becomes occluded by thrombosis.

**Choice of Methods.**—If one judges by results, the choice of methods is difficult. In the series of cases collected by Halstead and Vaughan the technic used was specifically mentioned in 17 cases:

| No. of Cases | | Deaths | Partial Recovery | Complete Recovery |
|---|---|---|---|---|
| 6 | Wieting: lateral implantation artery into vein. | 3 | 2 | 1 |
| 6 | Carrel: end-to-end suture of artery into vein. | 3 | 2 | 1 |
| 5 | Invagination: end-to-end, of artery into vein. | 3 | 2 | .. |

In Bernheim's collection of cases there were 46 in which the technic used was specified:

| No. of Cases | | Successful |
|---|---|---|
| 23 | Carrel: end-to-end sutures.................................. | 34.78% |
| 12 | Lateral anastomosis.................................. | 33.33% |
| 9 | Wieting's intubation.................................. | 22.22% |
| 2 | End-to-end invagination.................................. | 50.00% |

So far Bernheim seems to have had the best results of any one operator, but his method has not been used by others sufficiently to judge its efficiency in general hands.

This is an operation by no means devoid of danger in the class of cases for which it has been employed. Halstead and Vaughan have collected 41 cases, with 42 operations, up to January, 1911, and of these 21 died, 11 after the primary operation, 9 after a secondary amputation, and 1 after opening a secondary abscess. Three of these 21 deaths were apparently directly attributable to the anastomosis operation.

The same causes of failure act here as in arterial anastomosis, thrombosis being by far the commonest. Hesse performed thrombectomy for a thrombus that formed while he was doing an arteriovenous anastomosis between the femoral artery and long saphenous vein. The thrombus at once reformed, however, and he had to make his anastomosis end-to-end with the femoral vein. In the series of 41 cases reported by Halstead and Vaughan there were 28 in which pathological findings at amputation or autopsy were included. Among these were:

Thrombus in all vessels.................................. 5 cases
Thrombus in femoral artery above and popliteal artery below .................................. 5 cases
Thrombus in femoral vein alone below.................. 5 cases
Short circuiting by collaterals of vein.................. 1 case
Occlusion of central end of artery...................... 2 cases

This shows thrombosis to be a fertile cause of failure.

**Results.**—In many cases the immediate result is good, but, more and more, the men who have had experience with this operation are coming to feel that little permanent benefit can be expected from it.

Oppel says that arteriovenous anastomosis is successful only in cases of slowly progressing ischemic gangrene, not complicated by thrombophlebitis or phlegmon; and he believes that the improvement is due to delayed venous return and suggests ligation of popliteal vein as a palliative measure (instead of arteriovenous anastomosis). Hesse, also, believes that Wieting's operation is inefficient and that the improvement following it is due not to reëstablishment of circulation, but to stasis, which follows stoppage of venous return. After 1½ months improvement, his patient came to amputation when it was noted that there was no pulsation in the femoral vein and that venous appearing blood flowed from the veins.

Perimow advises anastomosis of the artery with superficial veins because the latter have few or no valves, on the ground that the valves prevent reversal of circulation in arteriovenous anastomosis. This appears fallacious.

Bernheim says that he has successfully reversed the circulation in all four limbs of a young woman, as evidenced by cessation of gangrene of toes and fingers and presence of a palpable thrill below anastomosis; a bruit audible to the popliteal space, in legs, and to wrist, in arms; and pulsation of veins, felt, in lower, and seen in upper, extremities.

Halsted and Vaughan, of Chicago, in a splendid paper on arteriovenous anastomosis, have collected 42 operations, 11 for "threatened," and 31 for actual gangrene. They state that local changes, indicating an immediate improvement, were noted in 23 cases, in order of frequency: (1) Increased warmth in the affected parts; (2) improvement in color (often the only sign noted); (3) relief from pain; (4) improvement in sensation; (5) filling of superficial veins; (6) pulsation in veins of extremities below site of anastomosis (14 cases); (7) return of the part threatened by gangrene or the actual seat of gangrene, to the normal.

The case of Ballance is said to be the only one found where circulation was so far improved by anastomosis as to control an actually existing gangrene and bring about restoration of the part not actually gangrenous. In Wieting's case there was no sign of return of "threatened" gangrene for at least two months. In all the remainder of the cases the favorable signs were of short duration.

| | | | |
|---|---|---|---|
| There were 21 deaths: | after primary operations, | 11 | a mortality of 50 per cent. |
| | after secondary amputation, | 9 | |
| | after opening abscess, | 1 | |

Death was directly traceable to arteriovenous anastomosis operation in 3 cases,—7.1 per cent.

Their conclusions serve very well to exhibit the dark side of the picture.

"There is experimental evidence to show that in animals the circulation through the large veins of the extremities may be reversed, and that it is possible for the normal pressure in the arteries to overcome the resistance of the valves in the veins.

"Experimental and clinical evidence show that the anastomotic opening is not permanent, but that gradual obliteration by intimal overgrowth takes place in event of the failure of early occlusion by a thrombus.

"There is not sufficient clinical evidence in the reported cases to show that the pressure of blood in the arteries in the cases operated upon was sufficient to force the valves in the veins.

"It is also shown by the cases reported that early occlusion of the vessels about the anastomotic opening by a thrombus was the rule, and in many the opening never at any time functionated.

"In event of the arterial blood forcing the valves in close proximity to the anastomotic opening, it returns through the larger communicating veins in many, if not most, instances, and does not transverse the capillaries.

"A study of traumatic arteriovenous aneurysm shows that with a normal arterial pressure it requires weeks or months for the valves in the communicating vein to be overcome, as is evidenced by the gradual development of varicosities and the long delayed pulsation in veins remote from the seat of the aneurysm. Under these conditions, the arterial blood supply is maintained partly through the usual collateral channels which are unobstructed. In cases of gangrene from obliterating disease of the arteries, the collateral vessels are already occluded. In such a case, immediate reversal of the circulation is imperative. This cannot be accomplished at present: (a) because of the obstruction offered by the valves; (b) because in many cases the circulating blood must also overcome the resistance offered by a thrombosed vein; (c) because the blood returns through the nearest communicating vein and does not reach the peripheral capillaries.

"Our final conclusion is that there is but one indication for the application of arteriovenous anastomosis in surgery; i. e., in traumatic destruction of a principal artery, where end-to-end union of the torn vessel is impossible. In such a case, arteriovenous anastomosis might be attempted, and through it we might maintain a sufficient blood supply to preserve the integrity of the limb until an adequate collateral circulation was established."

This is a gloomy picture, indeed, and Coenen adds nothing cheerful to it; but all of the cases chosen for this procedure were bad surgical risks, and none of the operators had previously done more than 4 similar operations.

A criticism of their mistakes and a brighter view of the possibilities of the operation are given by Bernheim. He says "animal experimentation, and lots of it, is an absolute necessity to the surgeon who wishes to do clinical work in the field of vascular surgery." In a paper on arteriovenous anastomosis he collected 52 cases from the literature, up to 1912, not including 15 of the cases collected by Halstead and Vaughan, but including 25 cases not mentioned in their table. Of these 52 cases, he calls 15 successful. Of these "successes," 4 required amputation within 4 months. Another "success" died of erysipelas on the fifteenth day after operation. Another had been followed only 2 months. Another had pulsation in vein noted only for 8 days. In another there was only improvement in the pain. Halstead and Vaughan report two complete recoveries in their series of 42 collected cases, or 5 per cent., and 6 partial recoveries, or 14 per cent. While Bernheim reports 15 "successes," or 28 per cent.

It would seem from a review of these statistics that success means one thing to one operator, another to another. One is satisfied if the vein pulsates for a few moments, while another demands that there be arrest of the actual gangrene present, or a disappearance of signs pointing to the onset of an expected gangrene, with return of the part to normal. Between these extremes lie many possible chances for controversy that can never be settled until surgeons agree upon a definition of success in this procedure.

A middle ground seems safest as pointed out by Lilienthal, who makes no extravagant claims. He believes that there is a field for the operation in a certain few selected cases and that its attempt is justified in a considerable number as a palliative measure to delay amputation or make possible amputation at a lower level than could otherwise be done.

In a personal communication Lilienthal states that he has recently done 4 cases of ligation of femoral vein (as suggested by Coenen, Hesse, and Oppel) for expected gangrene in thrombo-angeitis obliterans, with absolute relief of pain in 3 cases. He says there is no swelling of the leg as a result of the ligation, but that, on the contrary, what swelling may be present is relieved.

## Arterial Section

Arterial section is the procedure of incising an artery for the removal of a blood clot and restoring the integrity of its wall by suture.

Binnie, pointing out the difference between an embolus lodged in an otherwise more or less healthy artery and a thrombus formed in a segment of injured or diseased vessel, wisely says in regard to the latter, "removal of the blood clot alone is valueless, as another clot will form immediately." But, "when the closure of the artery is due to the lodgment of an embolus, it is logical to open the vessel by a longitudinal incision after providing for temporary hemostasis, extract the clot, wash the interior of the vessel segregated by the hemostatic tapes or slips with salt solution, smear it with sterile vaselin and close the wound with sutures."

For arterial section on vessels of the extremities the same instruments are used as in arterial suture, including a sharp, small, thin-bladed scalpel.

**Technic of Operation.**—The operation is performed as follows: (1) The artery is cut down upon in the location of the embolus and palpated carefully. If it is pulseless and feels solid it is carefully and gently isolated from its sheath, temporary hemostasis applied, if necessary, a longitudinal incision made through its superficial surface and the embolus extracted by finger, or forceps (which must not touch the intima), or by means of milking the vessel toward the wound. (2) When blood flows freely from peripheral and central ends, temporary hemostasis is applied above and below the segment that contained the clot, the lumen washed out with warm saline or

Ringer's solution, and all the blood washed and sponged carefully out of the surrounding wound. (3) The interior and cut edges of the vessel are then moistened with liquid albolene and the incision closed in the same manner as described for lateral suture of arteries. (4) The wound is then closed without drainage. (5) If the circulation has been restored by the operation the pulse should be felt at once in the artery or its branches below the point of incision. (6) In case another embolus lodges, or a thrombus forms at the original site, it is perhaps better to perform arteriovenous anastomosis at a point below the embolus, if this is possible, than to repeat embolectomy.

The dangers and difficulties are no greater than in lateral arterial suture, but the operation is very likely to be unsuccessful on account of thrombus formation at the site of the embolus and the published results are therefore bad.

**Results.**—Matas mentions 7 cases that were reported previous to 1908. In four of these the embolism occurred in the lower extremity. In all 7 another clot promptly re-formed after removal. Later amputation had to be performed in all the cases.

The pulmonary artery has been sectioned for embolus 12 times (up to February, 1913) at Trendelenburg's Clinic. There were no permanent recoveries, but one patient lived 5 days after operation, dying of pneumonia. For such operations upon the pulmonary artery Trendelenburg has devised special instruments which are described with this operation.

I have been able to find but few recent cases of arterial section for embolus. One is reported by Key. Twenty days after an attack diagnosed as probable embolism or thrombosis of the mesenteric artery, with recovery after palliative treatment, a man 43 years old, with mitral stenosis of several years' duration, was suddenly seized with severe pain in left popliteal space, coldness and loss of sensation in leg. Seven hours after onset operation was performed. Incisions over dorsum of foot and in popliteal space revealed empty vessels. The common, deep and superficial femoral arteries were then exposed and resistance was felt in the common femoral from its bifurcation 2.5 cm. upward, which proved on incision of the artery to be an embolus completely filling its lumen. Clamps were placed upon the common and deep femoral arteries and the embolus removed with a consequent hemorrhage from collateral vessels through external pudic and from the tissue incisions which had not bled before. The limb was elevated after operation and during convalescence there were noted temporary paralysis of the femoral muscles and thrombosis of the external peroneal veins, with stricture of the gastrocnemius muscle, probably caused by slight ischemic contracture. He found three cases of operation for embolus in the literature, one success and two failures. He does not state whether the pulse became or remained palpable in the posttibial artery, but his case seems to have been successful in avoiding gangrene.

*Murad Bey* did an arterial section for embolus of left brachial artery, removed the clot and did a side-to-side anastomosis of artery and vein, central to the point of embolism. A new thrombus rapidly formed.

*Mosuy* and *Dumont* were able to remove an embolus from the left femoral artery 6 hours after its lodgment, through a 1 cm. incision in the vessel. The circulation returned and continued.

*Lejars* removed a soft, dark thrombus from the femoral artery after gangrene had set in following thrombosis. The gangrene, however, was not stopped.

Trendelenburg suggests the intravenous injection of hirudin to prevent the re-formation of thrombi in the vessels. Jeger says Bodong and Jacobi have shown that in animals the injection of considerable amounts of hirudin gave rise to no noticeable interference with respiration, circulation or general condition, and that the injection in the proportion of approximately 1 mg. hirudin to 5 c. c. blood delayed clotting for 4½ hours.

### Transplantation of Arteries

So far, for the reason that venous transplants are satisfactory in functioning and require no serious circulatory disturbance to procure, transplantation of arteries is not at present being done in human patients. In animal work, however, the following results are encouraging.

| | Arterial Transplants | Successes |
|---|---|---|
| Stich | 2 autoplastic | 2 |
| Yamanouchi | 8 autoplastic | 5 |
| Stich | 5 homoplastic | 3 |
| Borst and Enderlen. | 15 homoplastic | 7 |
| Yamanouchi | 5 homoplastic | 3 |
| Yamanouchi | 6 heteroplastic | 2 |
| Stich | 7 heteroplastic | 4 |
| Ward | 1 heteroplastic | 1 |

## II. OPERATIONS UPON VEINS

### ANATOMICAL CONSIDERATIONS

In planning or undertaking any operative procedure upon veins it must be remembered that we are dealing with collapsible tubes, generally larger in size than the arteries they accompany, with much thinner walls, and with lumina larger in proportion and guarded at intervals by valves; nor should it be forgotten that, in superficial veins, the anastomosing plexus is larger and denser than in arterial vessels. Moreover, it should be understood that, due to the very different internal pressures under which they exist in the living organisms, veins are normally not distended anywhere near to their elastic limit, while arteries frequently are so. Besides this, their walls, although primarily divisible into the same number of layers as those of arteries, contain much less muscular and comparatively far more elastic and fibrous tissue. Directly dependent upon these structural and functional differences we find that a vein, emptied of blood, collapses and its lumen becomes obliterated; that it can be stretched, transversely and longitudinally, to a comparatively greater degree than an artery; that, when its wall is partially divided by a transverse (or more especially by a longitudinal) wound, the edges of this tend to fall together or, at any rate, gape much less than in a similar arterial injury; and that, when transversely divided completely, their stumps do not retract nearly to the extent of those in a divided artery, nor does the periphery of the vessel contract, nor does its lumen remain patent.

## OPERATIONS TO CHECK BLEEDING

**Posture.**—Elevation of the part above the level of the rest of the body will, by facilitating venous return, help to check oozing.

**Bandages and Compresses.**—Bandages and compresses applied closely to the bleeding point will readily check venous bleeding by pressure obliteration of the lumen.

**Gauze Packing.**—Gauze packing inserted fairly tightly into a deep wound will control venous bleeding in most cases by partial obliteration of the lumen and mechanically favoring clotting.

**Digital Pressure.**—Digital pressure may be used in the same manner as to control arterial bleeding, except that it must be applied directly over the bleeding point or distal to it.

**Torsion, Forcipressure, Terminal Ligation and Ligation en Masse.**—These methods of treatment are used in the same manner as for arterial bleeding.

**Actual Cautery.**—The actual cautery at a red heat is useful, at times, where ligation is difficult on account of multiple bleeding points.

## OPERATIONS TO RESTORE OR REËSTABLISH THE CIRCULATION

### Lateral Ligation

Lateral ligation is the lateral application of a ligature to close a wound in the wall of a vein. It is permissible only in small wounds of large veins where the resulting plication of the wall will not considerably encroach upon the size of the lumen.

The margins of the wound are carefully grasped in a hemostat and drawn gently in a lateral direction while a ligature is tied around the base of the cone formed by that part of the wall drawn out in the grasp of the forceps. If the ligature includes the entire wound periphery and is properly tied, the result is satisfactory, as the low blood pressure in the veins will not force the ligature off.

### Suture of Veins

In considering the suture of veins certain anatomical points regarding their structure must be kept in mind. The wall is thinner, less elastic and more flaccid than in arteries and they are more easily torn. They require more stitches in anastomosis than do arteries to prevent leakage and their edges must be everted. They are more liable to thrombus formation on account of slower blood current and less liable on account of the constituency of the blood.

It is interesting to note the different opinions voiced regarding the relative ease of accomplishment of a vein suture as compared with the same procedure in arteries. Matas says, for example: "The suture may be applied to veins in continuity (lateral phleborrhaphy) in longitudinal, oblique and transverse wounds. The rules which govern the technic of arterial suture apply here with the same force and with greater advantage. The thinness, softness and suppleness of the vénous walls make them more amenable to the suture than the arteries. The low tension of the venous current also favors the maintenance of accurate apposition without tension and favors the work of repair. The suture of veins is, therefore, not only a much easier procedure than the suture of arteries, but the healing of the line of suture takes place with regularity, provided sepsis has been rigorously excluded." Jeger, on the other hand, says: ". . . suture of veins presents various difficulties not present in arterial suture.

"With the latter, the lumen remains wide open on account of the thickness of the wall; it is plainly visible even in very small arteries, and one may accomplish all the procedures (suture, adaptation of the vessel ends to each other, and so forth) with the fullest exposure of the vessel wall and almost without the use of a forceps; and if one has first properly inserted the three tension sutures, the margins of the vessels automatically rest properly together throughout the whole circumference. Quite otherwise is the case with veins. These collapse after being fully divided; the lumen is often only to be discovered after long search; the vein must be held open with instruments, so there is naturally much handling of the walls with forceps, and consequently numerous lesions of the endothelium itself are unavoidable. It is indeed true that the circular suture of veins, in the hands of many experimenters, has afforded as good or better results than circular arterial suture, but this is founded on the greater diameter of the veins and perhaps also on the somewhat less active tendency to coagulation in the venous blood. In order to proceed quite safely, one must absolutely refrain from the above-mentioned sources of failure."

Lateral suture of veins is indicated, to repair, in any important vein, a wound too extensive for lateral ligature. It is contra-indicated by any phlebitis, periphlebitis, or infection of wound.

The operative technic is the same as that for similar repair in arteries except that, instead of direct apposition of cut edges, care is taken to secure slight eversion of wound margins so as to insure fairly broad intimal approximation. This can be done with more certainty by mattress suture than by overhand stitch, either continuous or interrupted. The object is, of course, to avoid the possibility of inversion of the cut edges, which is much more likely to occur here than in arterial suture on account of the thinness and pliability of the vein wall. Such an inversion leads to rapid thrombus formation.

**Results.**—The results of lateral suture of veins are excellent.

## Venous Anastomosis

Venous anastomosis, like arterial, may be done end-to-end, end-to-side, or side-to-side, but in human beings the end-to-end is the only method that has been used with any frequency.

**End-to-End.**—The indications and contra-indications are the same (as applied to veins) as those given for end-to-end arterial anastomosis.

The technic of a circular venous suture is exactly similar to that of a circular suture of arteries, already described, except for the management of the cut margins of the veins; these should be somewhat everted instead of being brought edge to edge, so that intimal apposition is assured. To accomplish this Jeger recommends the following procedure:

Open the lumen of both segments of veins by grasping the margins of each in three mosquito clamps placed at equal intervals, and insert 3 traction

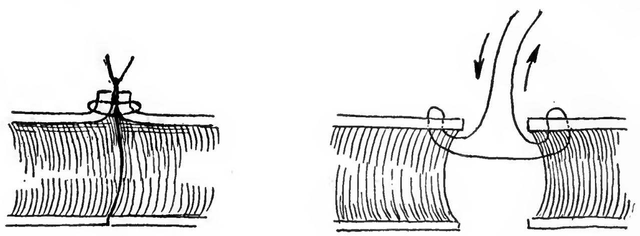


Fig. 57.—Vein Anastomosis, End-to-end; Application of Tension Sutures to Provide Eversion of Cut Edges.

sutures, at equal intervals, as shown in diagram (Fig. 57). These are longitudinal "U" sutures whose nearer limb is 3 mm., and whose further is 4 mm., from the cut edge. By first drawing tight and then tying these 3 sutures the lips of the approximated venous segments are slightly cuffed and the usual continuous suture along the three sides of the triangulated lumen completes the anastomosis. This method avoids including, in the surface that is to be exposed to the blood stream, any part of the intima that has been handled by forceps, and Jeger says the results are absolutely faultless.

Carrel, too, mentions the necessity of everting the edges of veins and says they are "united not by their surface of section, but by their endothelial surface." Murphy's or Payr's method of invagination may, of course, be used; but neither of them promises as good results as have already been achieved by the Carrel suture. The Lespinasse and Eisenstaedt method has not yet apparently been tried in a human.

Jeger and Janeway have both devised special instruments to facilitate the approximation of venous segments for end-to-end anastomosis.

RESULTS.—Theoretically, it would appear that the dangers of suturing a vein were more formidable and the chances of untoward sequelæ greater than in the sutures of arteries. In the first place the veins are apparently more susceptible to infection than the arteries. In the second place any foreign matter, as air, tissue, dirt, bacteria, etc., allowed to enter the vein at the anastomotic site, travels toward the central dangerous region instead of going toward the comparatively safe periphery, as it does when introduced into an artery. And, lastly, this same condition holds good with regard to possible loose portions of such a clot as unfortunately forms in a certain per cent. of cases at the anastomotic site. Thus we should expect local infection, thrombo-angitis, pulmonary embolism, and similar unfortunate results of blood vascular infection more often in venous than in arterial sutures. Such, however, is not apparently the case.

Statistics show little difference between the percentage of successful results in end-to-end anastomosis of veins and of arteries. Glasstein, for example, reckons 62½ per cent. successes for circular suture of veins, in a series of 53 collected cases in humans, and 68 per cent. successes for circular suture of arteries in a similar series of 37 collected cases. One hates to appear critical of optimism, but it would seem possible that he has not too high a standard of success, judging his deductions by those of others.

RESULTS IN VEINS OF ANIMALS.—The results of circular suture of veins in animals as quoted by Jeger are shown below and may be noted in connection with Glasstein's statistics:

Stich reports 2 cases, 1 successful = 50 per cent. successes; Borst and Enderlen report 14 cases, 7 successful = 50 per cent. successes; Yamanouchi reports 43 cases, 24 successful = 56 per cent. successes.

It is interesting to find that certain authors claim better results in venous than in arterial suture. Schiller and Lobstein claim over 40 per cent. success with arterial suture and 60 per cent. with venous circular suture.

**End-to-Side.**—The only practical application of an end-to-side venous anastomosis that has been made in human surgery so far is the re-implantation of the saphenous into the femoral vein; and the technic of the suture operation will be found, further on, among procedures designed to remove the cause

20

of circulatory disturbances due to varicose veins. The technic of Jeger's method, however, may properly be detailed here.

The anastomosis may be made by suture in precisely the same manner as described under arteriovenous anastomosis, end-to-side.

Jeger recommends, as simpler and giving absolute assurance of perfect

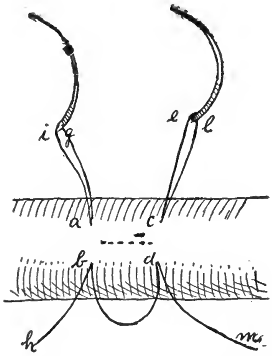



Fig. 58.—Vein Anastomosis, End-to-side. Jeger's method: 3-loop suture inserted in larger vein and dotted line showing incision.

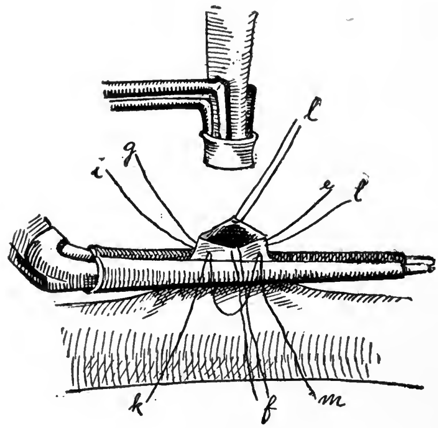



Fig. 59.—Vein Anastomosis, End-to-side. Jeger's method: introducing small vein into side of larger.

endothelial apposition, a method he and Wilhelm Israel devised, using a Payr's ring and a special Jeger clamp to manipulate it (Fig. 21) as follows:

The smaller vein is sufficiently freed, clamped and prepared and its cut end is then passed through, cuffed back over and tied upon the ring by a fine silk ligature. A three-loop suture is then introduced through the wall of the larger vein as shown in Figure 58 and the needles are cut off, leaving a middle and two lateral loops. A small incision is then made between the limbs of the middle loop after isolating this portion of the vein with a small, special curved clamp (Fig. 6). The clamped off portion of the vein is then washed and vaselined, its edges held up by traction sutures and the smaller vein placed within its aperture (Fig. 59). The middle loop is then carefully tightened and securely tied upon that part of the cuff of the smaller vein that contains the ring, the ligature fitting snugly into its furrow (Fig. 60). Lastly, the two lateral loops are tied and the ends of these and the traction sutures cut short.

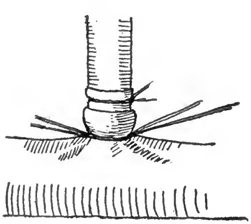


Fig. 60.—Vein Anastomosis, End-to-side. Jeger's method: smaller vein introduced, middle loop tied on ring and ends cut off. Lateral sutures being tied.

Jeger has done 23 implantations of renal vein into vena cava (on animals) by this method with only one thrombus.

**Side-to-Side.**—The only notable application of the lateral venous anastomosis in human surgery so far is the Eck fistula, done for hepatic cirrhosis by Rosenstein. The description of the operative steps in performing an Eck fistula operation comes properly under operations on the liver, etc., but the technic of the suture itself is exactly the same as that described under arteriovenous anastomosis, side-to-side, by suture.

Jeger has devised a three-bladed clamp, closely resembling a miniature Roosevelt gastro-enterostomy clamp (Fig. 61) by the aid of which he says he can do an Eck fistula on a dog in 35 minutes. Its mode of application is shown in Figure 62 and the technic of the suture is otherwise the same as before. Jeger advises oval pieces to be excised from the vein walls instead of mere slits being made, as the latter show a tendency to close spontaneously, just as in the case of arteriovenous anastomosis.

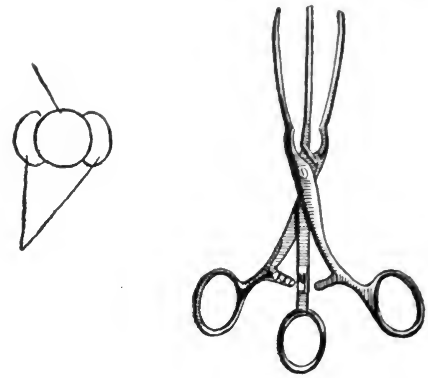


Fig. 61.—Jeger's 3-blade Clamp for Isolating Parts of Two Vessels without Interrupting the Circulation in the Remainder. Section of blades.

## Transplantation of Veins

The transplantation of veins, as regards vascular surgery, means the replacement of a defect in any vessel by a segment removed from some other vessel, practically always a vein and practically always of the same individual.

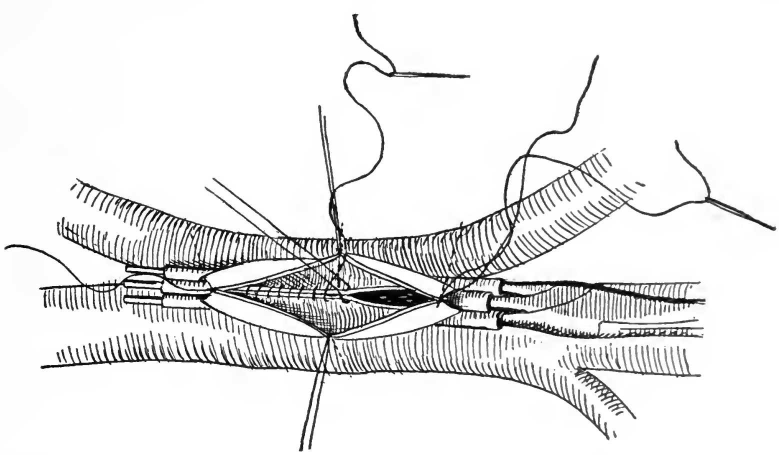


Fig. 62.—Vein Anastomosis, Side-to-side: Jeger's Clamp Shown Isolating Parts of the Vena Cava and Vena Porta without Interrupting Circulation through Remainder of Veins. End, middle and lateral traction sutures and posterior layer of continuous suture shown.

This is called autoplastic transplantation as differentiated from homoplastic and heteroplastic, and has been more successfully used than any other variety thus far. So many successful homoplastic and heteroplastic transplantations, however, have been done on animals that it is possible any day may see the report of some such cases in human patients. Transplantation may be used to fill a defect caused by excision, crushing, etc., of part of a vessel whose simple ligation would be dangerous to the life of the part.

Besides simple autoplastic, Guthrie suggests other material that might be used to fill defects in vessels:

(1) Similar vessels from another human being,—homoplastic;

(2) Vessels from a different species, sheep, etc.—heteroplastic;

(3) Cold storage tissues (not recommended on account of possible putrefactive autolytic change in them);

(4) Formaldehyd fixed tissue (safer than cold storage);

(5) Possibly, tissues not of animal origin might be used; tubes of celloidin, glass, etc.;

(6) Von Hagen, quoted by Jeger, advises calves' arteries fixed in the following manner: 10 per cent. formalin solution; water washing; increased alcohol strengths; absolute alcohol; xylol till fully cleared; liquid paraffin over night. Such vessels showed no sign of absorption after six months. They were encapsulated in connective tissue.

**Methods.**—The actual union consists of a double end-to-end suture as described under end-to-end arteriovenous or venous anastomosis, but several points are to be mentioned that do not come up for discussion under those operations.

To supply a defect in femoral, popliteal, brachial, or axillary artery, a piece of internal saphenous vein may be excised. This must be a little longer than the defect to be bridged and can be trimmed to suit with sharp scissors. Before final suture at both ends it should be between ½ inch to ¼ inch shorter than the arterial defect when artery ends are naturally retracted. If it is too short it will put too much strain on the sutures. If too long it will form a curve in the line of the artery when the blood is allowed to flow through it. If valves exist in the removed segment of vein it should be reversed, in its new position, so that the blood current may not be obstructed by the valves.

It is better to insert the 3 tension sutures at each end of the transplant before beginning the continuous suture at either end.

If the vein is much larger than the artery Jeger advises that the latter be cut after Dobrowolskaja's method to meet more nearly the size of the vein. (Fig. 63.) Guthrie and Carrel advise longer stitches in the vein than in the artery, all around the circumference, to accommodate its lumen to that of the artery. Jeger also advised, in excising the vein for a transplant, to cut partly through it and apply a mosquito clamp to the cut edge, cut further and repeat this procedure twice, so as to identify front and back or sides of the transplant, by the 3 or 4 clamps at equal intervals, which also serve to spread the lumen for application of tension sutures.

Unger has small, numbered clamps, 4 of which he attaches in this manner to the upper and lower ends of the transplant while excising it, and these serve to prevent the transplant becoming twisted on its long axis without the operator noticing it. These clamped portions must not come in contact with the blood stream when both lines of suture have been completed.

Boothby describes a method for setting stay sutures before the vein is removed for transplantation: (1) The vein is freed for 2 inches or more and is ligated at both ends. (2) Grasp vein with smooth forceps near upper ligature and cut very small aperture. (3) Insert a suture, from without in, near the aperture and make it emerge through this. (4) Repeat this procedure twice at upper end and three times at lower end of segment until 3 stay sutures are prepared at each end, at equal distances apart. (5) Then divide the transplant beyond these sutures and, by means of them, attach it to the ends of the defective vessel in its new position.

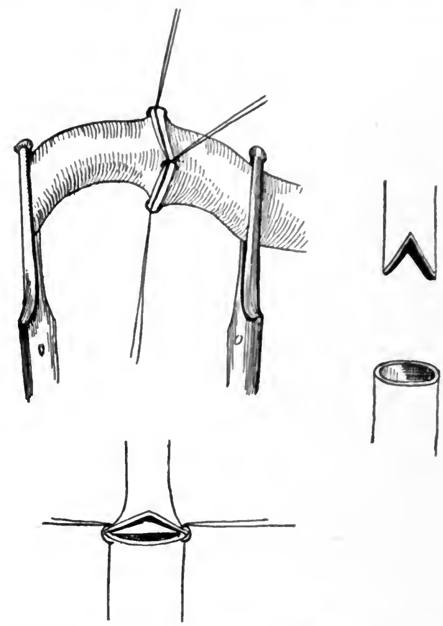


FIG. 63.—CUTTING ARTERY TO MATCH VEIN AND PUTTING IN STAY SUTURES.

**Operative Steps.**—The steps of operation of free vein transplantation to fill an arterial defect are: (1) Prepare ends of resected artery, as described in end-to-end arterial anastomosis by suture, and cover them with liquid albolene. Pack the tissue wound loosely with wet gauze sponges after measuring length of arterial defect. (2) Expose internal saphenous vein near saphenous opening by a liberal incision. Isolate it carefully and thoroughly from its bed for a sufficient distance and measure off on its freed portion a length ½ inch greater than the arterial defect. (3) Apply distal and then proximal temporary hemostasis beyond this portion and ligate and divide any intervening tributaries. (4) Fix and identify ends of transplant by Jeger's, Unger's or Boothby's method (previously described) and excise the included segment of vein. (5) Wash out all blood immediately, cover it inside and out with liquid albolene and protect it in moist warm gauze. (6) Uncover artery, reverse transplant, end-for-end (to obviate obstructing blood current by valves), and lay it in the arterial defect. (7) Connect each end to the arterial stump by three traction sutures, using care not to twist the vein on its long axis, and unite by continuous suture, as described in end-to-end arteriovenous anastomosis (Fig. 64). (8) Remove temporary hemostasis, apply pressure and add complementary sutures as indicated. (9) Close wound of exposure for artery and saphenous veins.

**Results.**—The results are exemplified in the report of these cases.

*Goyanes,* in 1906, excised popliteal aneurysm and filled defect with piece of vein. Successful result.

*Delbet,* in 1906, filled an 8 cm. defect due to removal of aneurysm in one person by a transplant of artery from another individual whose limb was being amputated at the same time. The operation failed as the transplanted artery was sclerotic and the sutures tore through. The femoral artery had to be ligated. Result: amputation.

*Lexer,* in 1907, transplanted 8 cm. of vein into a defect of axillary artery, caused by removal of aneurysm. Result: death from delirium tremens, fifth day.

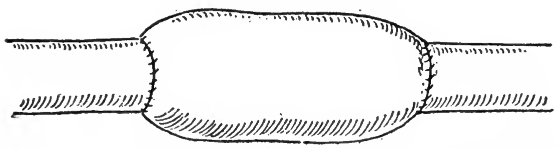


Fig. 64.—Arterial Defect Filled by Double End-to-end Suture with Venous Transplant.

*Doyen,* in 1909, in a patient with edema of leg following excision of part of popliteal vein for aneurysm, implanted the external jugular of a sheep, end-to-side in popliteal vein, above the obliterated area, and joined it end-to-end with the posterior tibial vein after making a subcutaneous canal for it. The operation resulted in complete healing, but he does not mention whether the edema was relieved.

*Enderlen,* in 1909, after resecting part of femoral artery for sarcoma, transplanted 15 cm. of saphenous vein from another limb. Result: smooth healing.

*Goeckes,* in 1912, reported the excision of a right popliteal aneurysm. An 8 cm. defect was filled by a 10 cm. transplant from left saphenous vein, set with valves favoring flow of blood. The operation was immediately successful. Pulsation in posterior tibial was felt strongly at once and beginning gangrene of foot healed. After 14 days, however, the tibial pulse grew weak and the wound broke down and a small fistulous tract persisted. The clinical result, however, was good and the patient was able to go freely about. He died 5 months later from abscess of knee-joint and endarteritis of coronary arteries. In the vessel, thrombi occluding it were found at both suture lines, on autopsy.

*Omi,* in 1912, reported that he had excised a right popliteal aneurysm leaving a defect of about 8 cm. This he filled with an 8 cm. piece of the left saphenous vein, by circular suture. He forgot to reverse the vein and the valves held the blood back. He then divided the vein at valve level, resected the valves and did a circular suture of the cut vein ends. Good pulsations appeared in vein and peripheral part of artery, but were not felt in posterior tibial or dorsalis pedis. Gangrene developed in foot in a few days; patient refused amputation and died in a short time.

After excision of popliteal aneurysm, in another case, leaving a defect of 7.5 cm., he filled it with an 8 cm. piece of femoral vein, reversed so as to favor passage of blood through valves, by Carrel circular sutures. Pulse felt after operation in dorsalis pedis and posterior tibial artery. Excellent result, apparently permanent.

Omi recommends autoplastic vein transplantation in human beings, at present, as safest.

RESULTS IN ANIMALS.—Venous transplantation in animals shows a higher percentage of success than in man. According to the reports of Fischer, Schmieden, Watts, Stich, Yamanouchi, Borst and Enderlen, as collected by Jeger, we find in autoplastic transplantation 42.8 per cent. and in homoplastic transplantation 28.6 per cent. successes, where the transplant was made into the cervical vessels of dogs.

## OPERATIONS FOR DRAINAGE OF CAVITIES, ETC.

The transplantation of veins for purposes other than that of repairing defects in blood vessels may here be mentioned, although the operative details belong, and will be given, under regional headings.

Ritter has reported the use of free transplanted veins and arteries, as covering for and connections for divided tendons and nerves, with some success.

Unger and Bettmann, in 1910, reported the use of pieces of transplanted vein (fresh or cold storage) to press upon a defect in the sinus longitudinalis with resultant closure of wound by adhesion of pieces of vein.

Jeger says that Tietze attempted unsuccessfully to cure a gonorrheal stricture by excising a 6 cm. portion of the urethra and replacing it by a 9 cm. transplant of saphenous vein; and that Becker attempted, with partial success, to construct a urethra in two cases of severe hypospadias by drawing a piece of saphenous vein through a canal made by a trocar in the penis; while Stettiner constructed a practicable urethra, in a case of hypospadias, out of a 12 cm. piece of saphenous vein. Taupas of Athens, Von Eiselberg and Mühsam have done similar operations.

Rouotte, in 1907, and Castle, in 1911, have reported two successful venoperitoneostomy operations. Henle and Bakay, Payr, and also McClure used pieces of saphenous vein (also of artery) to drain ventricles of the brain and a transplant of the external jugular vein to drain the subdural space.

## OPERATIONS TO ALTER BLOOD OR CIRCULATION FOR STIMULATION OR MEDICATION

### Intravenous Injection

By this is meant the injection of a soluble drug or other fluid through a hollow needle directly into a vein, usually of the arm. It may be used where the rapid and direct action of any soluble curative agent, as, for example, injections of salvarsan in syphilis and of blood serum in anemia and hemophilia, are required. The preparation of the solution will be described under the appropriate therapeutic heading, but the technic of the injection is as follows:

(1) The left arm, preferably, is bared to the shoulder and the antecubital region either cleansed, as in general operative field preparation, or painted with tr. iodin, which is washed off with alcohol after being allowed to dry. (2) A constricting band of rubber, gauze or muslin is placed around the middle of the arm sufficiently tight to obstruct the venous return and dilate the superficial veins. (3) The vein (median basilic usually selected) is steadied between thumb and finger of left hand and the needle, which must be very sharp and smooth, held like a scalpel between the thumb and fingers of the right hand, is thrust rapidly and carefully through the skin into the dilated vein. Free bleeding through the lumen announces its entrance, whereupon the constrictor is removed. The needle should enter the vein very obliquely so as to avoid puncturing the opposite wall and must be held steady after entrance to avoid scratching the intima.[1] (4) The shaft of the needle is steadied in the left hand; the syringe is held vertical, nozzle upward, in the right hand, and, after expelling all the air, is inserted carefully into the needle and the injection made slowly and steadily. (5) The needle is then rapidly and carefully withdrawn and pressure made with the fingers on a gauze pad over the puncture for two or three minutes. A dry dressing is then strapped on in its place. (6) Careless or unskillful introduction of the needle may wound the opposite wall of vein with a resultant hematoma and no free bleeding from needle. It is possible to wound the brachial artery which lies beneath the median basilic, separated from it only by deep fascia. If these accidents are avoided and proper asepsis practiced, there are no bad results.

## Intravenous Infusion

Intravenous infusion is the direct introduction through a cannula into the venous system of a considerable amount of solution for the purpose of increasing the fluid contents of the vessels and raising blood pressure.

**Solutions.**—So-called normal saline is most commonly used. This is prepared by adding 6 to 8 parts of sodium chlorid to 100 of filtered water. It is sterilized by boiling or by steam under pressure. Other solutions that have been tried are:

Ringer's Fluid:

| | |
|---|---|
| Potassium chlorid | 0.2 gm. |
| Sodium bicarb. | 0.2 gm. |
| Sodium chlorid | 9.0 gm. |
| Distilled water q. s. add 1 liter. | |

[1] Steps (1), (2), and (3) of this procedure may be followed to obtain specimen of blood for Wassermann test, etc.; in such case the constrictor is not removed until the required amount of blood has been obtained.

Locke's Fluid (more satisfactory in its effect):

| | | |
|---|---|---|
| Potassium chlorid | 0.10 to 0.20 | gm. |
| Sodium bicarb. | 0.10 to 0.20 | gm. |
| Calcium chlorid | 0.20 | gm. |
| Glucose | 1.0 | gm. |
| Sodium chlorid | 9.0 to 10.0 | gm. |
| Distilled water, 1 liter. | | |

Kuttner's Solution:

| | |
|---|---|
| Decinormal saline solution | 1,000 c. c. |
| Oxygen gas (approximately) | 20 c. c. |

These solutions are sterilized in the same way as simple saline solution.

TEMPERATURE OF FLUID.—Temperature of fluid should be from 105° to 120° F., in the container, depending on the size and length of tubing through which it has to flow to the cannula. Temperature of fluid leaving the latter should be not over 105° F.

PRESSURE OF FLUID.—Reservoir of fluid should be only about 12 inches (30 cm.) above vein. Greater height gives unnecessary and even injurious pressure.

TIME OF INFUSION.—Infusion should not be given faster than 1,000 c. c. in 10 to 20 minutes.

AMOUNT OF FLUID.—In adults 500 to 1,000 c. c. may be used or more according to patient's reaction as expressed in rise of blood pressure.

Much larger amounts of saline than of blood are tolerated. More can be given with benefit in treatment of hemorrhage than in treatment of shock, and Locke's solution is perhaps preferable for patients in an exhausted condition. Adrenalin 1:1,000 may be added to the solution in amounts of 10 to 20 minims or may be injected by a hypodermic syringe (after Crile) into the rubber tube near the cannula at the rate of 10 or 15 minims in one minute.

Infusion has been used for acute anemia resulting from operative or postoperative, traumatic, pulmonary, gastric, intestinal, uterine, etc., hemorrhage; in great loss of body fluid, as in Asiatic cholera; for flushing the vascular system, in acute poisoning, auto-intoxication, such as typhoid, diabetic coma, puerperal fever, eclampsia gravidarum, bubonic plague, uremia, and blood poisoning, following venesection; for resuscitation in suspended animation (Locke's solution injected into carotid artery with reversal of current); in chronic postoperative anemia and for artificial nutrition (Locke's and Lennander's glucose saline solution; or sterile isotonic sea-water, plasma de Quinton).

Binnie says (1912): "The principal indications for intravenous infusion of salt solution are shock and hemorrhage. Hypodermoclysis and proctoclysis have largely taken the place of intravenous infusion."

Certainly saline infusions are less commonly used, and hypodermoclysis and proctoclysis are more often employed than they were several years ago.

Infusion is contra-indicated, according to Matas, "in all cases where there is already a dilatation with distention of the heart and consequently general venous stasis." The condition is evidenced by cyanosis of face and extremities and overfilling of the superficial veins.

Instruments, etc., required are forceps, scalpel, ligature carrier, ligatures, cannula, tubing and reservoir, salt solution, skin suture, dressings.

**Method.**—(1) Select the arm least used by the patient and surround it by a constrictor midway between elbow and shoulder, sufficiently tight to dilate superficial veins. Prepare the skin of the antecubital region by washing or by applying tr. iodin. (2) Select the most prominent vein, usually median basilic or cephalic; anesthetize locally with 0.5 per cent. novocain and adrenalin, and incise skin and fascia over it longitudinally or obliquely for about 1 inch. Expose and isolate the vein by sharp dissection and free it sufficiently to pass a double catgut ligature around it in an aneurysm needle. (3) Tie the distal ligature permanently; set a loose friction knot in the proximal ligature. Cut a triangular flap in the superficial surface of the vein, between ligatures, with its apex pointing distally. Occlude the opening by finger pressure of left hand. (4) Grasp the cannula in the right hand; hold it vertical and allow fluid to flow till all air is got rid of. Then grasp the tip of vein flap with forceps in the left hand and introduce the cannula into the lumen while solution is flowing (Fig. 65). (5) Tighten the friction knot upon the cannula and place a finger on the vein, proximal to it, to regulate rate of flow. Let it be very slow at first, increasing gradually to the rate of 1,000 c. c. in 20 minutes. Allow the fluid to flow until observations of the pulse, taken every minute or two, show a return toward normal tension. In most cases less than 2,000 c. c. are enough to accomplish this if it can be done at all. (6) Remove the cannula, solution still flowing; tighten the friction knot in proximal ligature and reinforce it. Close the skin wound by sterile adhesive or silk suture, apply gauze dressing and bandage.

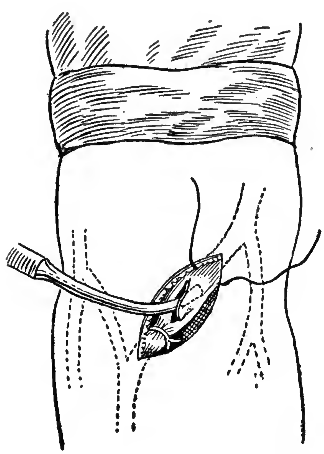


Fig. 65. — Intravenous Infusion: Cannula Introduced into Vein at Elbow.

The operation is a very simple one, except in fat people with small veins or when the superficial veins are empty on account of low blood pressure. In such cases it may be difficult to find a vein and the brachial artery has occasionally been opened in the search for the median basilic vein.

Too rapid introduction of saline may overwhelm an already weakened heart and do more harm than good. Too large an infusion may result in transudation into serous cavities.

Any superficial vein may be used instead of the antecubital.

Slowly and carefully given infusions are undoubtedly of value in cases of hemorrhage and shock, and bad results, such as every surgeon occasionally sees, are generally due to haste and carelessness. But, except in urgent cases, the results in raising blood pressure and replacing lost body fluids are no better than those from hypodermoclysis and proctoclysis, very much simpler and easier procedures.

### Blood Transfusion

Blood transfusion is the transference of blood from the circulation of one individual to that of another. It may be accomplished by joining the vessels by suture or tube (direct transfusion) or by withdrawing blood from one individual into a syringe or vessel and then injecting it into the other individual (indirect transfusion). In the recent past the direct method has been more used, but the indirect method is gaining ground at present on account of its ease, simplicity, and the ability to measure the amount of blood transfused.

In 1909 Crile wrote: "The question as to what pathologic condition may be suitably treated by transfusion of blood from one human being to another has not been definitely settled. The most that can be said at present is that it is clearly indicated in certain conditions and as clearly contra-indicated in certain others. With our present knowledge the author feels that it should be used only when all other resources at command have failed."

Since that time transfusion has been found serviceable in cases of acute anemia from hemorrhage of traumatic, operative, or other origin, such as gastric or typhoid ulcers, ruptured extra-uterine pregnancies, etc. It has been used with some success to raise the blood resistance of anemic patients as a preliminary to operation.

It has been used a number of times iu pernicious anemia without permanent benefit in most cases. In melena neonatorum it has proved most valuable and its use in hemophilia in general has been satisfactory. In illuminating gas and carbon monoxid poisoning, and others where methemoglobin is formed, Crile has resuscitated a number of cases by transfusion. Cole recommends it in pellagra. Surgical shock has been treated satisfactorily by transfusion. Certain toxemias (as of pregnancy) seem to be amenable to it.

Infectious diseases, such as scarlet fever, and septicemias, such as staphylococcus, have been treated, and perhaps improved.

Walter has tried infusing pernicious anemias with blood of polycythemics. Delbet has suggested infusing typhoid patients with blood of those who have had, and survived, an attack and show a strong immunity. Lilienthal says: "In transfusion in typhoid the donor should always be one with acquired immunity, to avoid replacing the, at least partially, immune blood of recipient by non-immunized blood." (Personal communication.) Bevan says there is evidence of its value in sarcoma. Jeger recommends it also in jaundiced people, before serious operation, to prevent bleeding.

E. H. Pool, in a personal communication in regard to the use of transfusion in jaundiced patients, says: "The case to which I referred was a woman about 35. She had extreme jaundice as a result of a stone in the common duct. She received calcium lactate for some days before operation, but we did not give her serum because she had received considerable serum a few months before for a very severe streptococcus septicemia, and I was afraid of anaphylaxis. About 48 hours after the operation for stone in the common duct she began to ooze extensively until she was practically moribund. Her coagulation time was 15 minutes. A transfusion, using her sister as donor, was made with marked improvement, but after three days the oozing recurred and the patient again got into extremely bad condition, so that a transfusion was again performed and the coagulation time dropped from 15 to 6 minutes; the oozing stopped and the patient made an uneventful recovery from that time.

"I am inclined to think that this is the first case in which transfusion has been performed for postoperative oozing in jaundiced patients. The drop in the coagulation time from 15 minutes to 6 was striking.

"Subsequently, a patient, an old man with a stone in the common duct, was markedly jaundiced and I did a preliminary transfusion and operated immediately afterward. He had no postoperative oozing."

Jeger says it is absolutely contra-indicated in the presence of organic heart disease, because the heart is not equal to any suddenly increased work, and Dorrance and Ginsberg say that it is contra-indicated in any case where hemolysis is taking place, as in purpura hemophilia.

For direct transfusion from artery to vein the radial artery of donor and one of the superficial veins at the elbow of the recipient are generally employed. Occasionally the internal saphenous, or some other superficial vein, may have to be employed on account of infection, etc., at elbow. Either left or right side may be chosen according as donor is right or left-handed.

The instruments required for any direct transfusion are the usual dissecting outfit of scalpel, dissecting forceps, scissors, artery forceps, serrefines, catgut, and silk ligatures and sutures. Special appliances, such as Crile's cannula, Brewer's tubes, etc., will be described in connection with the description of their method and use.

Whatever method of transfusion is employed, however, there are certain common details that should be observed preliminary to and during the operation. These we may now consider under the term

**General Management of Transfusion.**—In every case where time is allowed and facilities are at hand several blood pressure determinations should be taken and several pulse rate estimations made. A complete red blood cell count and white blood cell count and hemoglobin estimation should be secured on both donor and recipient before transfusion is begun; the last to serve as a basis for comparison with similar examinations after the operation is over and during the after care. The two former are to serve as standards for comparison with similar observations made during the progress of transfusion, observations upon which, in part, the operator bases his judgment as to the proper duration (or amount of blood transfused) for the transfusion flow.

Hemolysis and agglutination tests of donor's and recipient's blood should also be made, if possible; but the necessary omission of any of these preliminaries and precautions does not contra-indicate the operation by any means. (Bernheim.) Lilienthal thinks hemolysis and agglutination tests imperative.

A careful examination of the donor should be made to discover any signs of disease that might make the use of his blood dangerous for the recipient. This examination ought, if possible, to include serum reactions for syphilis and gonorrhea, unless the donor is known to be free from any suspicion of venereal disease.

Each patient should be given 1/8 to 1/4 grain of morphin (unless contra-indicated) 30 minutes before operation, and should be reassured as to pain, danger, etc.

During the transfusion Bernheim recommends controlling the inflow of blood by finger pressure on the vein throughout the whole operation, and, if assistants are at hand, taking observations of pulse rate and blood pressure of recipient every 3 minutes; of donor, every 5 minutes. His routine is "to attempt to bring a pulse of say 150 or 160 down to about 100 and to raise a blood pressure of 50 or 70 up to 110 or 120, figures well within the zone of safety." But he warns against the danger of raising too much the blood pressure of a patient suffering from the results of internal hemorrhage, as from typhoid ulcers. He adds that it is most difficult to judge at all exactly of the amount of blood transfused, but that the pulse and blood pressure observations, the knowledge gained by the fingers and thumb guarding the entrance to the vein, the general appearance of the recipient, and the actual time the blood has been flowing, all serve as guides to the proper time to end the transfusion. He estimates the duration of actual flow to average in most transfusions 20 to 40 minutes; the range being 3 to 5 minutes to 1 hour or 1 1/4 hours, according to the size of the recipient. He says donor's indications for ending transfusion are a "sudden fall of 20 to 30 points in blood pressure, or, lacking apparatus for blood pressure determination, sudden pallor, accompanied by nausea and vomiting, continued and increasing thirst, great restlessness, together with a decrease in blood pressure as shown by the finger of the operator, in the donor's radial."

Bevan recommends having such operating-tables that the Trendelenburg position may be used for the donor and the reverse Trendelenburg for the recipient in order to better manage a possible anemia of the donor or a cardiac dilatation of the recipient.

Jeger, too, insists upon the gradual beginning of the transfusion flow and warns one to stop if any sign of cardiac dilatation appears in the recipient, and wait 10 minutes before continuing the flow. Especially in little children, he says, are symptoms of cardiac weakness carefully to be watched for.

Lilienthal, who has had a wide experience in transfusion operations, does not think it necessary to slow the flow with the fingers as Bernheim does. He watches the recipient carefully for signs of dilated heart, and uses, as signs for stopping transfusion, dyspnea, cyanosis, rapid irregular pulse of recipient, and faintness of donor. He prefers the hemoglobin estimations as an indication of how much blood to transfuse, and has estimations taken every 3 to 5 minutes on recipient during the flow, and endeavors to raise the percentage to somewhere near double its original point. He does not think it safe to more than double it, and he has doubled it in 19 minutes in one case (personal communication).

In speaking of the donor, Crile says: "The best way of determining when to stop the flow is by watching his (donor's) symptoms. At first he will show loss of color in his mucous membrane, pallor of the skin, slight uneasiness, slight quickening of pulse and respiration, lowering of blood tension, and beginning shrinkage in the skin of the face. All of the symptoms are progressive, and as soon as they are well marked the flow should be stopped. Often the condition of the recipient will necessitate this long before the donor shows any symptoms at all." Concerning the recipient, Crile says that too rapid a flow may be prevented by partially narrowing the lumen of the artery by gentle finger pressure, shutting off the flow altogether, if necessary, for short intervals, to give the heart a chance to assume the added burden gradually. Crile mentions the possibility of infecting the donor in transfusions performed for infectious diseases, as typhoid, and advises selecting immune donors. He thinks there is little risk in cases of chronic infection like tuberculosis, or from an old septicemia or mixed infection. So far as the recipient is concerned, Crile says the chief danger is cardiac dilatation. Fortunately a certain amount of dilatation may occur and pass rapidly away, as shown by his series of cases.

He mentions that preliminary bleeding may be advisable in certain cases. Not in shock or acute hemorrhage, of course, and rarely in subacute hemorrhage; but in all other cases either preliminary bleeding is required or less blood must be transfused; for blood is retained in the vascular system where saline infusion, for example, passes rapidly out of it. Bleeding and transfusion may be practiced synchronously in feeble patients with marked reduction of red corpuscles.

Crile says: "When acute dilatation has once occurred it must be promptly recognized. Transfusion must be stopped, table tilted to put patient in head up position, and rhythmic pressure made over heart." If recovery is not complete in a short time the transfusion should be given up, patient put to bed in "head up" posture, given carefully graded doses of nitroglycerin to insure peripheral dilatation of vessels, and digitalin hypodermically in very small doses to stimulate heart muscles directly. Small doses of morphin also are advised.

Crile gives no very definite rule as to how much blood should be given the recipient. "Enough blood must be transfused to accomplish as much good as possible, and yet too much must not be given. Sometimes in cases where the patient does not suffer from the loss of a large amount of blood it seems to be as advantageous to transfuse a small as a large amount. The symptoms of the recipient give the best key to the situation."

AMOUNT OF BLOOD TO BE TRANSFUSED.—In children a small amount only is needed in most cases. Cooley and Vaughan report a recovery from melena neonatorum after the transfusion of only 20 c. c. of blood. On the other hand, Peck has transfused an amount of blood, in the case of an adult, estimated at 2,000 c. c. In general it would appear that 1,000 c. c. is enough for most adults, and children require correspondingly less.

The amount of blood passed may be measured:

(a) By bleeding donor's vessel into a test-tube for 30 seconds and multiplying the resulting amount by twice the number of minutes the transfusion flow lasts (direct method). This is inaccurate on account of variation in pulse rate and blood pressure and lumen of vessels.

(b) By receiving blood into a receptacle (syringe, pipette) which accurately measures it (indirect method).

**Methods of Direct Transfusion.**—ARTERY-TO-VEIN METHOD.—CRILE'S CANNULA.—Crile's cannula is one of the earlier and better known instruments for facilitating transfusion. It is on the principle of Payr's ring, but furnished with a handle, which may be grasped by a hemostat (Fig. 66). His description of the technic follows:

"Experience has shown that it is best to use a radial artery of the donor and any superficial arm vein of the recipient near the elbow. Usually the median basilic vein is the best on account of its size and easily accessible position. Local anesthesia is obtained by injecting cocain in 1/10 of 1 per cent. solution with a few drops of 1 to 1,000 adrenalin.[1] Several hypodermic syringes should be ready, so that there should be no delay on account of having to stop and refill a single one. The injections are first made into the skin and then more deeply around the vessels. After this, firm pressure is applied by the hand over a gauze sponge to insure spreading the cocain through the tissues. When carefully performed, there is absolutely no pain in any part of the technique until the sutures are placed in the skin at the end of the transfusion. By then the effect of the cocain has usually worn away.

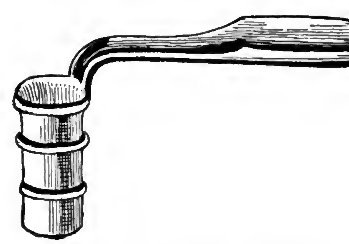


FIG. 66.—CRILE'S CANNULA. (Size greatly exaggerated.)

"In making the dissection, it is necessary to have good light. Mosquito hemostats are used to catch every vessel that sheds even a drop of blood. The field should be kept absolutely clean. The donor's radial artery is isolated for a distance of about 3 cm. at the point of injection in the wrist. Here there are a number of side branches which must be carefully isolated and tied with No. 1 Chinese twist silk (which has not been split up into strands) before being cut. The artery is then tied at its distal end and a 'Crile' clamp is gently screwed in place over the proximal part as near

[1] Other operators, Bernheim and Lilienthal, warn against the use of adrenalin chlorid solution.

to the place where it comes out of the undissected tissue as convenient. The clamp should be screwed up with great care.

"Just enough pressure should be used to control the flow of blood without causing injury to the vessel wall. The artery is severed with sharp scissors a short distance from where it is tied off, the end cut squarely across, the adventitia pulled down and cut off. The result should be that the operator has about two and a half cm. exposed radial artery free from branches. The next step is the dissection of the vein. It is exposed for the same distance as the artery, the branches tied off in the same way, and the ligature is also applied to the distal end. The second 'Crile' clamp is applied

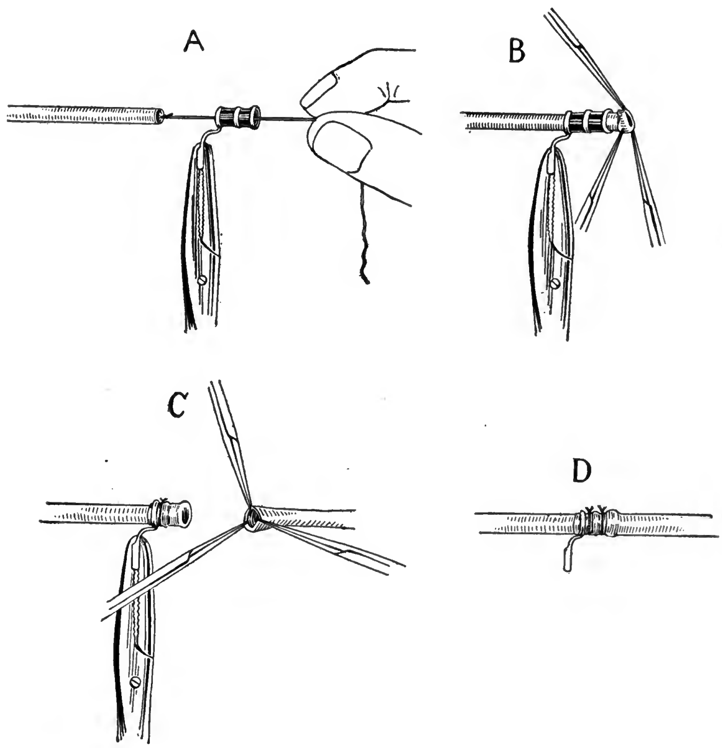



FIG. 67.—CRILE'S METHOD OF ANASTOMOSIS FOR TRANSFUSION WITH CANNULA.

just as before, the vein cut near the ligature and it, in turn, is ready for the completion of the anastomosis. After selection of a cannula of suitable size (as large a size should be used as possible without injuring the intima of the artery by stretching it too much), the end of the vein is either pushed through the handle end of the cannula with the help of fine-pointed forceps, or pulled through by means of a single fine suture inserted in its edge, the needle being left on the suture and passed through the cannula ahead of the vein. The handle of the cannula is then tightly seized by a pair of hemostats, three mosquito forceps are snapped at equidistant points on the end of the vein, taking care not to have the tips extend up into the lumen more than is necessary to get a firm hold. The end of the vein is then cuffed back over the cannula by gentle traction on the hemostat and tied firmly in place with a fine linen thread in the groove nearest the handle. The cuffed part is then covered with sterile vaseline, being careful not to get any in the open end. The three hemostats are then applied to the edges of the artery, just as with the vein; (it may be necessary to dilate the end very gently by inserting the closed jaws of a mosquito hemostat covered with vaseline and opening them very gently for a short distance) and the artery is gently drawn over the cuffed vein on the cannula and tied in place with another fine linen suture in the remaining groove. All the hemostats are removed. The venous and then the arterial clamps are removed and the blood allowed to flow. The exposed vessels should be kept moist with warm saline." (Fig. 67.)

Elsberg's objections to Crile's cannula are:

"Some experience is required before the Crile instrument can be handled with ease.

"The caliber of the cuffed vessel is decreased by the cannula.

"Sometimes there is difficulty in telescoping the artery over the vein.

"The steps of the operation with Crile's cannula are numerous and the application of the guide suture and tying of ligatures complicates the operation."

With the exception perhaps of the last, these objections apply also to Buerger's, Bernheim's, and Hepburn's modification of Crile's instrument.

Elsberg's Cannula.—Elsberg's cannula seems, by general consent, to be the most satisfactory instrument yet devised for the direct method of transfusion. His own description of it and of the technic of transfusion follows:

"The cannula is built on the principle of a monkey wrench, and can be enlarged or narrowed to any size desired by means of a screw at its end. (Fig. 68.) The smallest lumen obtainable is about equal to that of the smallest Crile cannula, and the largest, greater than the lumen of any radial artery. The instrument is cone-shaped at its tip, a short distance from which is a ridge with four small pin points, which are directed backward. The lumen of the cannula at its base is larger than at the tip. The construction of the cannula can easily be understood from the following description of the method of using it. The radial artery of the donor is exposed and isolated in the usual manner. The cannula, screwed wide open, is then slipped under and around the vessel. It is then screwed shut until the two halves of the instrument slightly compress the vessel.

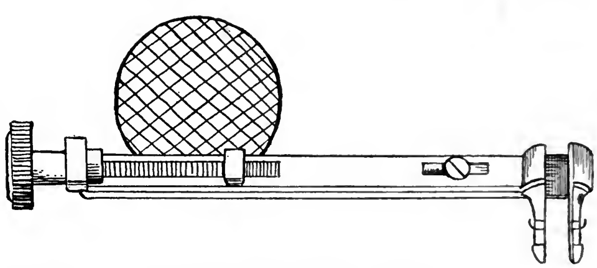


Fig. 68.—Elsberg's Cannula.

"The artery is then tied off about one centimeter from the tip of the cannula. Before the vessel is divided, three small eye tenacula are passed through the wall of the artery at three points of its circumference, a few millimeters from the ligature. Small mosquito forceps may also be used. These are given to an assistant, who makes traction on them while the operator cuts the vessel near the ligature. The moment the artery is cut, the stump is pulled back over the cannula by means of the tenacula or forceps, and is held in place without ligation by the small pin points. There is no bleeding from the artery even though no hemostat clamps have been used, because the cannula itself acts as a hemostatic clamp. The vein of the recipient is then exposed (but not freed), two ligatures are passed around it; one is tied peripherally in the usual manner. A small transverse slit is then made in the vein; the cannula with the cuffed artery inserted into the vein; a ligature tied around the vein and cannula; the cannula screwed open, and the blood allowed to flow. The rapidity of the flow can be varied as much as desired by the size to which the instrument is screwed or unscrewed, and the lumen of the artery is never diminished.

"It will be noticed that the artery is cuffed instead of the vein. This method I believe to be more correct. The vein is the larger vessel and can therefore be more easily telescoped over the artery. The vein is only exposed, not freed, and the artery is intubated into it. With this cannula I have been able to make the anastomosis in less than four minutes after the artery has been isolated and have found the entire procedure a simple one. The advantages of the instrument are the following: (1) The cannula will fit any vessel; (2) the cannula is applied around the vessel instead of the vessel being drawn through the cannula; (3) no ligature of the cuffed vessel is required; (4) the cannula itself acts as a hemostatic clamp; (5) the cuffing of the artery is easily accomplished without stripping back the adventitia, and therefore the traumatism to the artery wall is reduced to a minimum; (6) the vein needs only be exposed, not dissected out and cut; (7) as the cannula is unscrewed, the blood will flow; the flow can be regulated at will, and the lumen of the artery is not diminished."

Lilienthal and also Elsberg now prefer the direct vein-to-vein over the artery-to-vein method, and recommend Elsberg's cannula as being the best means for accomplishing the anastomosis.

Bernheim's Tube.—One of the most recently devised appliances for the direct artery-to-vein method is the transfusion tube of Bernheim.

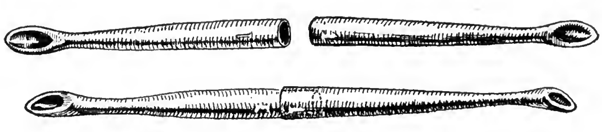


Fig. 69.—Bernheim's 2-piece Transfusion Tube.

"It is a two-pieced affair (Fig. 69) consisting of two hollow tubes, each 4 cm. long, and each bulbous at one end in order to form a neck for a retaining tie, and beveled to facilitate entrance into the vessel; the other ends are tubular and fitted for invagination."

He says that it is especially useful in transfusing infants where smallness of the parts makes actual union of vessels with Crile or Elsberg cannulæ difficult; and in emergencies where speed is desirable the separate halves of the tube can be inserted in the two patients at once by separate operators. This is his very excellent description of its use:

"The radial artery is dissected out as follows, novocain (0.5 per cent.) being the anesthetic of choice: (1) Expose the artery with its accompanying veins (just above the wrist joint) for a distance of about two inches; (2) free the artery from the veins and tie off all branches doubly with fine silk, cutting between the ties; (3) tie off the artery doubly at the distal end of the wound and cut between ties, thus allowing about one and one-half inches of the vessel to be free in the wound; (4) tie off all bleeding points in the wound, and keep a constant stream of warm salt solution flowing over the artery, all sponging being done with gauze moistened in the same solution; (5) place a bull-dog clamp on the vessel at the proximal end of the wound. A small cut is now made in the upper side of the artery with a pair of fine scissors, the opening being made at right angles to the course of the vessel and about half its width. Next, every visible trace of blood is immediately washed out in warm salt solution and liquid vaseline, the latter being injected into the lumen of the vessel with a medicine dropper at frequent intervals during the washing process. It keeps the vessel soft and pliable, and prevents too rapid evaporation and consequent drying. Any little bit of adventitia that may get into the opening should be carefully pushed away or cut off. (6) The vessel having been carefully prepared, the beveled end of the male half of the tube is inserted into the artery and held there by a tie thrown around its neck. (Fig. 70.) Liquid vaseline is again injected into the vessel through the tube, and the whole thing wrapped in salt solution gauze to await the comple-

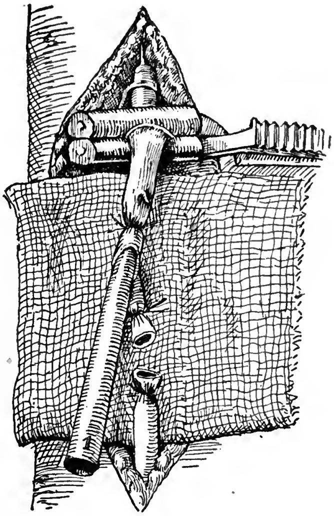


FIG. 70.—BERNHEIM'S METHOD OF TRANSFUSION: MALE HALF OF TUBE TIED INTO RADIAL ARTERY.

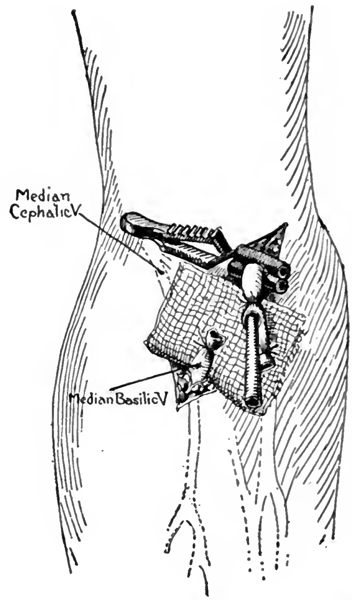



FIG. 71.—BERNHEIM'S METHOD OF TRANSFUSION: FEMALE HALF OF TUBE TIED INTO VEIN OF RECIPIENT.

tion of a similar preparation of the vein of the recipient. (7) It is hardly necessary to dissect out more than one inch of the vein, and, as this is always quite superficial, the time required for the whole procedure of dissection, cleansing and insertion of the female half of the tube (Fig. 71) amount to hardly more than five minutes. (8) When both patients have been prepared, their stretchers are brought into apposition and the two arms are placed on a table about one foot broad. With a little manipulation the wrist of the donor is brought into such proximity to the elbow of the recipient that the tubes can be invaginated to the proper degree. (Fig. 72.) (9) When this is accomplished, a steady stream of warm, saline solution is started flowing over the artery, tube and vein, and the bull-dog clamp is removed from the vein, its place being taken by the thumb and first finger of the operator. With great care the clamp controlling the arterial flow is now gradually released, coincidently with which the thumb and finger controlling the vein gradually ease up, thus permitting the blood to go over gradually, so as to prevent any possibility of swamping or embarrassing the circulation of the recipient by a sudden gush of blood under great pressure."

If clotting occurs, he removes both tubes, washes out the vessels with saline and liquid vaselin, and inserts a new set of tubes, the flow being started in the usual manner. When the transfusion is finished the tubes are removed, the vessel ligated, and the wound sutured.

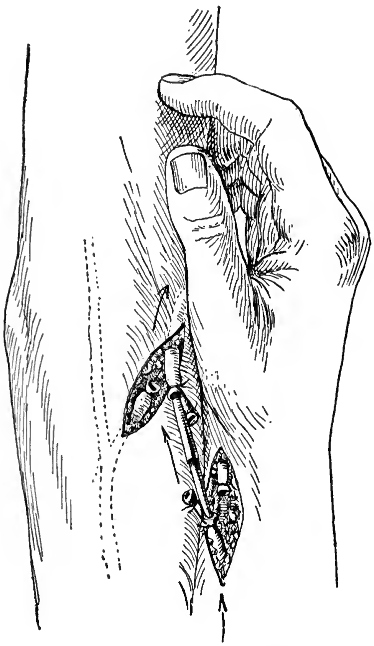


Fig. 72. — Bernheim's Method of Transfusion: Tubes Invaginated and Anastomosis Complete.

Carrel's Suture.—Carrel's suture was used by Crile before he devised his own cannula, and has been used by many other operators with satisfaction. The technic of the suture itself has been described under end-to-end arteriovenous anastomosis by suture. Pool reported a series of transfusions in 1910 by Carrel suture. Lilienthal (personal communication) says he has used the suture method successfully in several vein-to-vein transfusions. He dissects out about 3 inches of the donor's vein at the elbow, leaving a certain amount of superficial fascia around it to allow of easy handling, and after freeing about one inch of the recipient's vein (usually basilic or cephalic, at the elbow) he prepares the ends and anastomoses them by the method of Carrel.

Jeger says that the Carrel method is used by Enderlen, Hoercken, and Tuffier. Horsley also uses suture, but of mattress type instead of overhand. Jeger continues: "The use of the direct vessel suture in blood transfusion has, however, the disadvantage of being exceeding difficult. Tuffier informs us that Carrel in his case (at Tuffier's Clinic) completed the vessel suture in five minutes, but, in the hands of most other surgeons, this operation would require a very great deal more time."

Brewer's Tubes.—Brewer's tubes are of glass, lined with paraffin, about

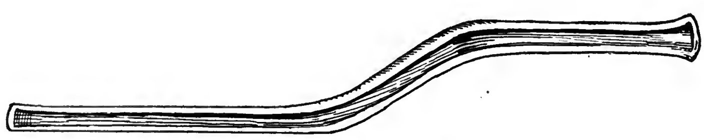


Fig. 73.—Brewer's Transfusion Tube.

3/16 of an inch in diameter at larger end, tapering to $\frac{1}{8}$ inch, and slightly flared at both ends. They are about $2\frac{1}{2}$ inches long and have a double bend (Fig. 73). The artery and vein are exposed in the usual manner, and the smaller end of the tube is slipped into the artery, the larger into the vein, and tied in with ligature. The flared ends of the tube keep the vessels from slipping off. The objection to these tubes, as stated by Brewer, is that the lumen is too small to allow of sufficient flow. This objection has apparently been obviated in the modification brought out by Fauntleroy.

Several years ago Dorrance and Ginsberg advised direct vein-to-vein transfusion; and later Fauntleroy reported the use of the Brewer tube in direct vein-to-vein transfusion. The method would seem an excellent emergency measure where special cannulæ were unobtainable.

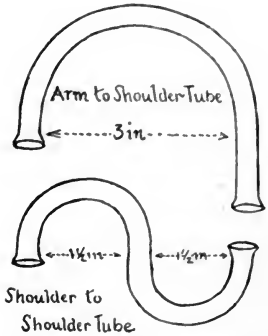



FIG. 74. — FAUNTLEROY'S MODIFICATION OF BREWER'S TUBES.

VEIN-TO-VEIN METHOD.—Flare the ends of a piece of thin glass tubing 1/8 inch inside diameter by heating them and pushing a pointed wire nail into the lumen while hot (Fig. 74). Heat the tube again and bend into an S- or U-shape with extremities 3 inches apart, as it is designed to have the hands of the patients pointing in the same or opposite directions. After boiling the tubes, drop them into melted paraffin; lift them out with a sterile forceps, shake excess paraffin out, lay in sterile gauze to cool, and wipe paraffin off their outside. They are then ready for use.

Make the superficial veins prominent by applying a constrictor above the elbow. Expose and free the chosen vein of the recipient for about 1 inch. Pass 2 ligatures around it at the ends of the freed portion; tie the distal one and remove the constrictor. Expose and pass ligatures around the donor's vein in similar fashion, and tie the proximal one. Temporarily occlude the distal end by serrefine, tape, and clamp, etc.; open the donor's vein (or divide it) far enough above this to slip the prepared tube distally into it, and tie it in place with the distal ligature. Lay the donor's and recipient's arm side by side on a small table with the elbows at the same level, and opposite each other. Open the vein of the recipient between ligatures, remove the temporary hemostatic on the donor's vein; allow the blood to flow through tube and expel the air, slip the free end into the recipient's vein, and tie in place with the proximal ligature (Fig. 75). The donor's constrictor is left in place to keep up his venous pressure. When sufficient blood has passed remove the tube, ligate the veins, and close the wound. Fauntleroy says it is as easy as a saline infusion: Movement of the patients' arms must be guarded against on account of angulating veins against ends of tube and causing clotting of blood.

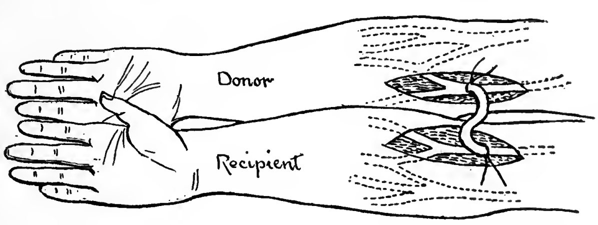



FIG. 75.—VEIN-TO-VEIN TRANSFUSION WITH S-SHAPED TUBE (Fauntleroy).

Vincent has used similar tubes with satisfaction.

**The Indirect Method of Transfusion.**—The indirect method of transfusion, in which the blood is passed from donor to recipient by the medium of some form of container, depends for its success upon the failure of the blood to clot in the interval between its withdrawal from the former's and its introduction into the latter's veins. Such a coagulation seems to be avoidable in three ways:

(1) By making the transference so rapidly that insufficient time for clotting elapses between the blood's withdrawal from, and its reintroduction into, normal vascular channels.

(2) By "the employment of an intermediate system, providing no point of contact with any moistenable surfaces, and at the same time minimizing as far as possible the exposure of broken tissue surface to the blood stream." (Satterlee and Hooker.)

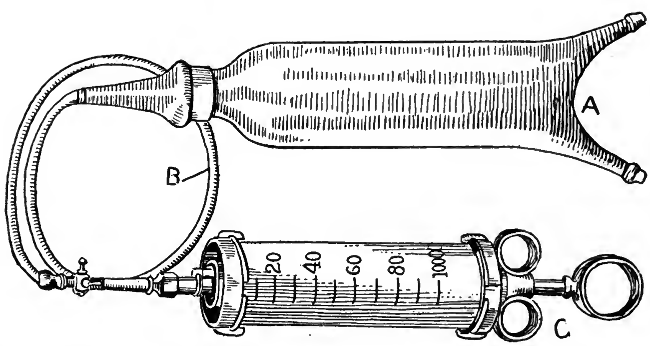



FIG. 76.—CURTIS AND DAVID'S APPARATUS FOR INDIRECT TRANSFUSION.

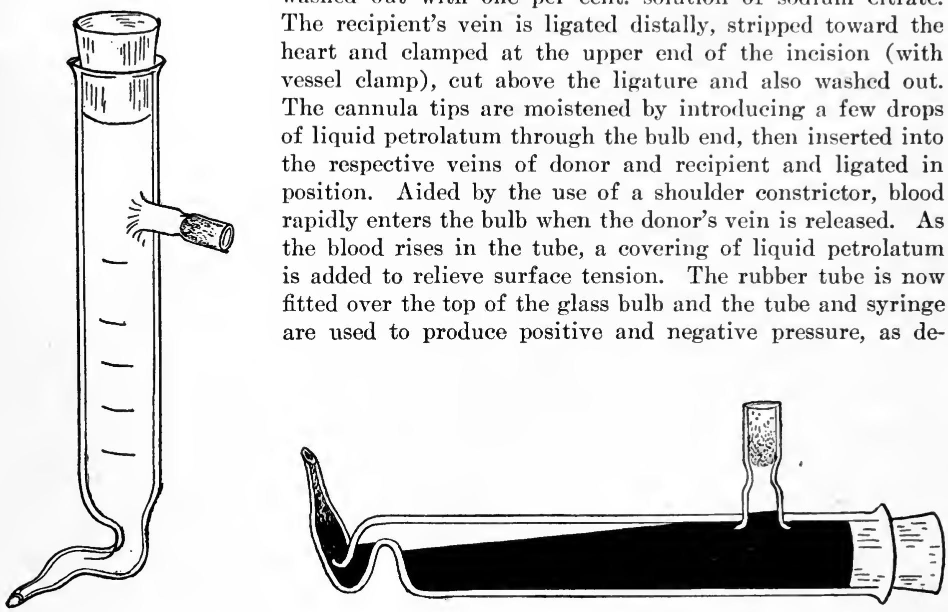
(3) By "the employment of a sufficient amount of some physiologic agent (antithrombin) to restrain or offset the initiative factors of coagulation during the time of the conveyance of the blood through a foreign system, such as glass and metal." (Satterlee and Hooker.)

Upon the first of these principles are based the methods of Moritz and Lindemann; upon the second, those of Curtis and David and Satterlee and Hooker. Experiments are now under way to determine the practical value of the third principle (by Satterlee and Hooker, and others).

The indirect method of transfusion has recently been taken up by a number of men, and the work of Moritz, Curtis and David, Risley and Irving, Lindemann, Satterlee and Hooker has done a great deal toward popularizing this method.

CURTIS AND DAVID METHOD.—Curtis and David use a 100 c. c. glass syringe with rubber tube attached and a double cannula tipped glass bulb of 100 to 400 c. c. capacity (Fig. 76). The glass bulb is sterilized by the dry method and the inner surface coated with paraffin. The paraffin coat is best applied by pouring hot paraffin into the open end and then rotating the bulb to secure a uniform coat. The two cannula tips are then heated and each in turn dipped into melted paraffin, and shaken to make a thorough coating so as to keep the excess from occluding the lumen. The syringe and rubber tube are prepared by boiling.

"With the apparatus now ready for use, a one-half inch incision is made over the most prominent vein of the elbow region in both donor and recipient (using constrictors if desired). The donor's vein is then clamped (with a vessel clamp) at the distal end of the incision, stripped, ligated proximally, cut below the ligature and washed out with one per cent. solution of sodium citrate. The recipient's vein is ligated distally, stripped toward the heart and clamped at the upper end of the incision (with vessel clamp), cut above the ligature and also washed out. The cannula tips are moistened by introducing a few drops of liquid petrolatum through the bulb end, then inserted into the respective veins of donor and recipient and ligated in position. Aided by the use of a shoulder constrictor, blood rapidly enters the bulb when the donor's vein is released. As the blood rises in the tube, a covering of liquid petrolatum is added to relieve surface tension. The rubber tube is now fitted over the top of the glass bulb and the tube and syringe are used to produce positive and negative pressure, as desired. (The bulb usually fills without resorting to suction.) The donor's vein is then held by the finger, the recipient's vein released and the blood introduced into the latter at any desired rate of flow. When the bulb is nearly empty, the recipient's vein is held and that of the donor released, thus allowing the bulb to again become filled with blood, after which the process continues as before."



No. 1. No. 2.

FIG. 77.—KIMPTON'S CYLINDER FOR INDIRECT TRANSFUSION, NOS. 1 AND 2.

They had done 4 or 5 human transfusions by this method successfully when they published this report, passing over 1,050 c. c. of blood in one case.

Jeger says that a certain advantage of the Curtis and David apparatus over others exists in its ability to transfer blood into the arterial (against the current) as well as into the venous system. Such an ability might possibly be made use of, he thinks, in a centripetal arterial transfusion by which the blood would tend to be forced into the aortic bulb and so fill the coronary arteries and resuscitate an enfeebled heart. This procedure has been mentioned by Crile and Dolley.

KIMPTON METHOD.—Kimpton has recently published a method very similar to Curtis and David's. He uses a 250 c. c. paraffin-lined cylinder of his own pattern, having a lateral tube and a terminal cannula tip (Fig. 77). He exposes the antecubital veins of donor and recipient in the usual manner, allows the tube to fill from the former by venous pressure, and then injects the blood into recipient's vein by pressure from an actual cautery bulb pump which he attaches to the lateral tube of the cylinder. If more than 250 c. c. of blood are required he uses a fresh tube for each subsequent injection. He reports 15 successful transfusions by means of this apparatus, and Turnure, in a personal communication, tells me of 4 additional successful operations.

COOLEY AND VAUGHAN METHOD.—Cooley and Vaughan injected 120 to 150 c. c. of human blood and saline (about 20 c. c. blood) into the median basilic vein of a baby exsanguinated by intestinal bleeding of melena neonatorum. An attempted vein-to-vein anastomosis by Crile cannula having failed on account of small size of child and lack of blood in father's veins, one of the operators acted as donor and the other withdrew from his basilic vein about 8 c. c. of blood through a sharp needle into a 10 c. c. glass syringe into which 1 c. c. of saline solution had previously been drawn. One-half c. c. of saline was then sucked in and the mixture of blood and salt solution injected through a blunt needle into the baby's already exposed vein, the wound being held open by two sutures of catgut. About 2 minutes elapsed from the time when the sharp needle was inserted into the donor's vein until the injection of blood into the recipient's vein was completed. The injection was repeated in 15 minutes and the child recovered.

LINDEMAN'S METHOD.—Lindeman describes his present technic as follows:

"The entire apparatus consists of two sets of cannulas, two tourniquets and twelve syringes. . . .

"Two sets of cannulas are employed, one for the donor, the other for the recipient. (Figs. 78 and 79.)

"There are three cannulas to each set. Each cannula telescopes within the other, as shown in Figure 79.

"The innermost cannula is practically a hollow needle. The hollow needle (Fig. 79) is fitted snugly into Cannula 2. Cannula 2 is 5 mm. shorter than the needle and is fitted snugly into Cannula 3. Cannula 3 is 5 mm. shorter than Cannula 2. The proximal ends of 1 and 2 are capped with stationary thumbscrew caps.

"The proximal end of 3 is capped with a receiver to fit any Record syringe.

"Cannula 3 is 2 inches long. The caliber of this cannula is the same as the tip of a Record syringe.

"In very small infants with very small veins, only cannulas 1 and 2 are employed, 2 being capped with the receiver to fit tip of syringe.

"The cannulas I now use are made of platinum.

"The syringes used are Record syringes of new, improved type with a capacity of 20 c. c. and can be sterilized with 95 per cent. alcohol, 20 minutes. . . .

"One operator manages syringe of recipient. Another operator manages syringe of donor. An assistant stands between operators, who are in position close to the assistant. Donor and recipient are placed in the recumbent posture.

"A table is arranged conveniently between them so that a nurse can wash syringes as rapidly as they are used. For this purpose two basins of sterile water and one basin of normal saline solution are used. The normal saline solution is used in the last rinsing; the syringes are so well cleaned in the first two rinsings that the rinsing solution remains practically clear.

"In adults and most children over 2 years of age the median basilic vein is easily accessible. In infants the external jugular or one of its tributaries is entered more


FIG. 78.—LINDEMAN'S CANNULA, ASSEMBLED.

advantageously. In some cases the internal saphenous may prove the vein of preference.

"A tourniquet is placed in position, and the skin is sterilized with iodin. The cannula is then held in a position almost parallel to the vein with the thumb on the thumb-screw of the innermost cannula (Fig. 78, 1). The skin is then punctured and the cannula is forced into the vein. After the first joint (A) has entered vein, Cannula 1 is withdrawn a distance of about one-half inch. (This prevents the vessel wall from being injured or punctured by the needle after the vein is entered.)

"With the thumb now on the thumb-screw cap of 2 the cannula is forced further in until the second joint (B) (Fig. 78) has entered the vein. Cannula 2 is then withdrawn a distance of about one-half inch. (Cannula 3 alone can come into contact with the vessel wall.) Cannula 3 is then gently pushed into the vein to a desirable length; usually three-quarters to one inch will suffice.

"Cannulas 1 and 2 are now withdrawn entirely. If the vein has been successfully

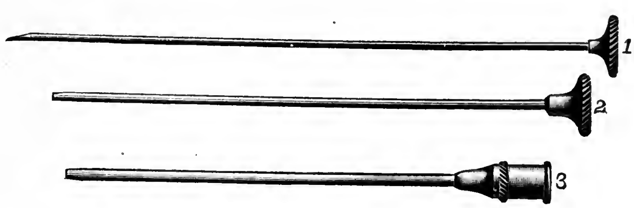



FIG. 79.—LINDEMAN'S CANNULA, SEPARATED.

entered, blood will flow through the cannula. When the first drop appears a syringe containing warm saline solution is immediately attached and a very slow flow of saline is maintained through cannula.

"(When the innermost needle, No. 1, has entered the vein, blood is seen to trickle through the proximal end.)

"There is no need of haste at this stage.

"A cannula is next inserted in vein of donor in a like manner; an empty syringe is attached to this cannula. Everything is now in readiness for the transfusion, and blood is withdrawn from donor as rapidly as possible. When the syringe is full the assistant passes it to the operator on the recipient, who removes the saline syringe, attaches the syringe containing blood and evacuates the contents gently but speedily into the vein.

"One syringeful of blood is followed by another in rapid succession until the desired quantity of blood has been transfused.

"A little normal saline is injected through cannula of recipient after every 2, 3, 4, or 5 syringefuls of blood, depending upon the speed of flow from donor. This keeps cannula free of blood and precludes the possibility of clotting.

"Some 25 tests have been made to determine the length of time required for blood to coagulate in a syringe. This was found never less than 6 minutes. The length of time required for the complete filling and evacuation of a syringe is from 6 to 12 seconds.

"It has been found advisable for the assistant (or third man) to remove the syringe of the donor as soon as filled. The operator can thus hold the cannula in place with one hand, while with the other hand he may at once adjust an empty syringe into the cannula. Loss of blood is thus reduced to a minimum.

"Rules.—(1) Bright polished surfaces of syringe and cannulas are requisite. (2) A syringe used once should not again be employed until thoroughly cleansed with sterile water. (3) Air must be avoided. This, however, offers no difficulty. (4) Tourniquet of recipient must be removed after vein is entered with cannula. (5) Tourniquet remains on donor throughout operation. (6) Tension of the tourniquet should not impede the arterial flow, but should be sufficient to block venous return to a point at which the highest venous pressure is obtainable. If the tension be too great the first syringe will fill rapidly, the successive ones will fill very slowly. If the tension be too little, syringes will fill slowly. If the tension be adjusted correctly, syringes are filled very rapidly. (7) Dexterity and speed are requisite for success. (8) Before beginning a transfusion syringes are cleaned with hydrogen peroxid and then washed in a 10 per cent. sodium carbonate solution and rinsed. They are then ready for a sterilization in alcohol. . . .

"The time elapsing in filling and evacuating the syringe is so brief that blood does not undergo any alteration from donor to recipient. For this reason larger receptacles for conveying the blood have been discarded.

"No lubricant is employed. Cannulas are lined with a film coating of albolene.

"Larger syringes with larger calibered cannulas may be used, but the present sizes have worked satisfactorily and fittings of syringes and cannulas are of universal gauge.

"Syringes and cannulas may be kept sterile in individual metal containers. They are thus in readiness for immediate use and no preparation for operation is required.

"When hemolysis occurs, even when only slight, the symptoms appear immediately, so that in the actual performance of the work I introduce some 20 or 30 c. c. and then pause to await any symptoms of hemolysis appearing. Should none occur the transfusion is completed. Should symptoms appear the cannulas are withdrawn and no harm is done to either recipient or donor. In that case another donor is procured.

"The merits of this method may be summarized as follows: (1) Simplicity for the recipient. (2) Simplicity for the donor. (3) No pain, other than a skin puncture. (4) No disturbance of the recipient or change of position is necessary and the work can be done in the home as conveniently as in a hospital. (5) Any quantity can be transfused. (6) The quantity is definitely known at the time of transfusion. (7) The same vein may be used repeatedly. One recipient was transfused 7 times through the same vein and same skin puncture. One donor was tapped nine times through the same vein and same skin puncture. (8) No scar remains after operation. No skin incision is necessary. (9) The danger from hemolysis is practically eliminated by this method. (10) The facility of application makes possible its application over a wide therapeutic field. . . .

"Up to date I have performed 137 transfusions by this method. There were no failures. . . .

"The youngest case transfused was 6 weeks old; weight 6 lbs. 6 oz. The oldest case transfused was 73 years. In no case was there thrombosis, embolism or sepsis; in no case was a skin incision made; in no case was anesthesia given; in no case was death due to any untoward effects of transfusion.

"Post-mortem examinations were made in two cases several weeks after transfusion. Vein punctures were examined by Dr. Charles Norris, Director of Laboratories of Bellevue and Allied Hospitals, who could find no evidence of the puncture. These venous puncture wounds heal by first intention and no thrombosis occurs at the site of the puncture. . . .

"In the total number of transfusions there were 243 cannula insertions into veins; 218 into median basilic; 25 into external jugular. In 208 insertions the median basilic vein was entered on first puncture.

"In one case six transfusions were performed at different intervals of time, using the same vein through the same skin puncture in each operation. One donor was used for eight transfusions at different intervals of time; the cannula was inserted into the same vein through the same skin puncture on each occasion. . . .

"Judgment of the amount of blood to be transfused will depend upon the size, weight, age, physical condition of the patient, the type of disease to be treated, the object to be gained by transfusion, the presence of other complications, and, lastly, experience. The largest amount I have transfused into one individual in one sitting is 2,000 c. c. This quantity was taken from two donors. . . .

"The quantity of blood that can be drawn from a donor varies. The largest quantity I have taken from one individual in one sitting is 1,400 c. c. The largest was 5 feet 8 inches in height and weighed 170 lbs. I have frequently taken 900 to 1,000 c. c. in one sitting.

"If the case be not one of infectious disease, two-thirds quantity of the blood drawn from donor is replaced with normal saline through the cannula with which transfusion was performed. When infection is present the same cannula is not used.

"If at any time the blood pressure in the donor should fall so that blood is withdrawn with great difficulty, it is an indication that no more blood can be spared at that time.

"The reaction—chill, fever, etc.—after transfusion from a blood relative in most instances is less than from an alien. In three cases of transfusion from aliens, hemolysis occurred from which patients recovered. (It should be borne in mind, however, that hemolysis can occur with family blood.)

"Providing the same donor be used there is frequently no reaction after the second and succeeding transfusions. And if any reaction occurs it is usually very mild.

"A given donor of alien blood will cause a chill and a temperature in one patient and none in another, though the transfusions be done on the same day and both patients have the same disease, and the same quantity be given.

"The chill and temperature reactions may be associated with slight degree of hemolysis incident to serum reaction. I have occasionally observed such hemolysis in a few cases evident only by a slight jaundice tint disappearing within 24 hours. In such case in the succeeding transfusion, the same donor being used, this tint is absent or less.

"In the actual performance of the work I introduce a small quantity of blood and then pause for a short period of time before continuing transfusion. Opportunity is thus afforded for observing the compatibility of the blood introduced.

"Should an undesirable reaction ever occur indicative of incompatibility, transfusion is discontinued; no harm is done and another donor is procured. Danger from hemolysis is thus eliminated."

McGRATH'S METHOD.—McGrath has recently described a modification of Aveling's method, in which he uses a 30 c. c. rubber bulb having two long polar processes, or cannulæ, of suitable size to enter the veins. The latter are exposed in the usual manner and the tips of the processes are inserted into them, after filling the bulb with salt solution, and held by ligatures. Alternate filling and emptying of the bulb by compression and release from the donor into the recipient transfer the desired amount of blood. The apparatus is made without joints. No anticoagulant is used and the method has proved successful in experimental work.

SATTERLEE AND HOOKER'S METHOD.—Satterlee and Hooker have recently published an account of a method which appears to be an improvement on Curtis and David's. See Volume I, Chapter IX.

**Choice of Methods.**—No absolute decision can at present be made as to which is the best method of transfusion. Unquestionably the direct method has received more attention and has been practiced a greater number of times in the past 10 years than has the indirect method. The possibilities of the latter, however, are at present being more thoroughly investigated, and it is probable that the next decade will see a reversal of the proportion of direct to indirect transfusion.

Curtis and David, in a recent communication, summarize their objections to the direct method as follows:

"The operation requires delicate technic such as is possessed only by those who have had experience in blood-vessel surgery. Considerable time is consumed in performing anastomosis of the vessels. The rate of flow and the amount of blood transfused are not measurable. The flow of blood sometimes ceases before the desired amount has been transfused, even though the operative technic is excellent. Movement of either donor or recipient may tear the vessels apart at their point of union in spite of watchfulness on the part of the operators. In infectious patients there is always danger of transfer of infection from the recipient to the donor. This is most liable to occur through the rubbing of the raw surfaces which are held or bound together during the entire procedure."

The third objection of this series is the only one that can be held to apply against the direct method of transfusion by glass tubes as originated by Brewer and modified by Fauntleroy. The others apply no more to this method than to Curtis and David's own.

Risley and Irving have (in 1911-12) carefully and critically tested Crile's cannula, Soresi's cannula, Frank's (dog's carotid), and Hartwell's (simple invagination of artery into vein) methods, Brewer's tubes and Curtis and David's syringe and receptacle with a view of settling which is at present the most generally useful method of transfusion. They say: "In so far as purely mechanical metal devices go, this admirable little adjustable cannula (Elsberg's) is still the best." They call the paraffined glass tubes "far ahead of any of the other more complicated devices proposed, but also by far the most satisfactory for all round transfusion work, artery-to-vein, or vein-to-vein, adult or infant, and for skilled or unskilled operators."

They also speak favorably of Curtis and David's method.

Just at present, then, it would appear that direct transfusion by the paraffin-lined glass tube is the most generally available and simplest, but it lacks the advantage possessed by the indirect methods of accurately measuring the amount of blood transfused. In as much, however, as the effect upon the recipient, as observed in his general appearance, raised hemoglobin index and increased blood pressure and in the reduction in rate and the improvement in quality of his pulse is the real indication of the effect of transfusion, rather than the accurate measurement of the amount of blood passed, this lack cannot be considered of the first importance.

If, however, the indirect method with syringe, as practiced by Moritz, Lindeman, Cooley and Vaughan, and others, or with the paraffin-lined glass receptacle of Curtis and David and Satterlee and Hooker, proves as safe as the direct method, it will doubtless become the method of choice; and in this city it is probably more used now than the direct method. If the direct method be used there is still some question as between the artery-to-vein and the vein-to-vein practice of it. Dorrance and Ginsberg state the advantages of artery-to-vein procedure as: giving sufficient blood pressure to introduce blood quickly from donor into recipient; that blood from artery is richer in oxygen than that of vein. They believe, however, that vein-to-vein procedure is simpler and safer and recommend its use.

Lilienthal states the advantages of the vein-to-vein method as follows: The dissection does not open the fascial planes of the wrist to possible infection. The radial pulse is not interfered with. The dissection and manipulation of the vein is easier than that of the artery. The donor's vein generally used is larger than the radial artery. The vein is less susceptible to external influence (for example, contraction of artery and resulting slow, or no, flow). The flow is rapid and steady.

Elsberg also (personal communication) prefers the vein-to-vein procedure. Among the difficulties of the operation may be mentioned: refusal of radial artery to bleed; inability to find sufficiently large vein in arm; clotting of blood in cannula; piercing vein.

Peck mentions an instance where the donor's radial artery absolutely refused to bleed.

Peck, Lilienthal, Warren, and others have mentioned the difficulty of finding a suitable vein in the arm of the recipient. In a few cases this resulted in failure of the operation, as the patient would not allow any other vein to be used.

Peck, Lilienthal, Bernheim, and others mention the occurrence of clotting in the cannula, or at the point of anastomosis.

Warren and others mention the possibility of thrusting the point of the needle, or trocar, through the opposite wall of the vein while attempting to introduce it into the lumen.

**Dangers of Transfusion.**—Among the possible dangers of the operation should be mentioned: transmission of disease from donor to recipient; transmission of disease from recipient to donor; hemolysis; agglutination; acute dilatation of the heart; air embolism; blood embolism; suction changing gaseous tension of blood; laking red cells and setting free toxic substances.

TRANSMISSION OF DISEASE FROM DONOR TO RECIPIENT (Syphilis, Gonorrhea, Malaria, etc.).—This can be entirely avoided by a thorough preliminary examination of the donor.

TRANSMISSION OF DISEASE FROM RECIPIENT TO DONOR (Typhoid, Septicemia, etc.).—This can be avoided by using an immune donor, or by avoiding any actual contact between donor and recipient. (Brewer's tube or indirect method.)

HEMOLYSIS.—Hemolysis is regarded as a real and ever-present danger by many surgeons, but Bernheim remarks: "The danger of hemolysis following transfusion has always been vastly overrated and unwarrantably feared. In a rather large series of transfusion, done for the relief of many and varied conditions, I have never seen it occur, and I know of but one authentic instance where it complicated matters.

"It must be remembered that hemolytic tests, even at best, are not entirely conclusive and do not absolutely protect against hemolysis. The blood of one individual may hemolyze that of another in the test tube, but not in the body after transfusion; and, vice versa, the laboratory tests may pronounce an individual a suitable donor, and yet hemolysis may occur after transfusion."

On the other hand, Elsberg, Lilienthal, Peck, Lindeman, and others emphasize the extreme importance of it. Elsberg has done 2 successful cases without preliminary test in emergency cases. Peck mentions a case in which it was impossible to get a hemolysis test beforehand. The patient was transfused by the Lindeman technic with 33 syringefuls. She died within 48 hours with signs of obscure blood changes.

Lindeman mentions one case where the laboratory reported hemolysis test negative, but hemolysis was noted after 75 c. c. had been given. Transfusion was stopped, and another serologist reported hemolysis test: slight hemolysis of donor's cells with recipient's serum.

Another case: no hemolysis in first transfusion. Second transfusion 5 days later, with same donor. No hemolysis test done. Hemolysis showed at transfusion, however, and test then made showed hemolysis of donor's cells with recipient's serum.

Another case: laboratory report negative; yet hemolysis occurred at transfusion; no opportunity to check up laboratory report; all 3 cases recovered.

AGGLUTINATION.—Agglutination of red cells is apparently less to be feared than hemolysis; but Lilienthal emphasizes the importance of making the test beforehand. Warren mentions a case of pernicious anemia in which he failed in an attempt at transfusion by the Lindeman method on account of the small size of vein in the arm. Two days later Lindeman himself successfully transfused this case through the external jugular. The patient died within 48 hours. In this case there was a very slight positive agglutination reaction obtained beforehand, although the hemolysis test was negative.

ACUTE DILATATION OF THE HEART.—Acute dilatation of the heart during transfusion is another rare accident. Crile mentions several instances in his book, none of which were fatal. It has been difficult to find any positive evidence of fatal cases. Lilienthal and Peck had not observed the accident in their practice. Elsberg mentions one case who died shortly after the transfusion by the direct artery-to-vein method. He believes that they gave her too much blood. She was a woman suffering from malignant endocarditis.

AIR EMBOLISM.—I have been unable to discover any deaths thought to be referable to the entrance of air into the veins at transfusion. Theoretically one would expect it to be a fairly common accident in the syringe class of operations. But, as a matter of fact, it is highly probable that small amounts of air, so introduced, do not give rise to untoward symptoms.

BLOOD EMBOLISM.—No positive evidence is obtainable of any fatalities due to this cause following transfusion, but Warren speaks of one case of pernicious anemia that died of pneumonia within a week following transfusion by the Lindeman method. Warren thought the pneumonia might be attributable to pulmonary infarction.

ALTERATION OF THE GASEOUS TENSION OF THE BLOOD.—Alteration of the gaseous tension of the blood due to suction, and laking of the red cells with setting free of toxic substances, from contact with syringe or cannula walls, have been mentioned by Warren and Connell as possible dangers in those methods that use syringe suction and employ no paraffin to line the cannula. No definite evidence is obtainable of the reality of such dangers.

## Intravenous Injection

Intravenous injection for purposes of local or general anesthesia is described in the chapter on Anesthesia.

## Venesection

Venesection is an operation little used at present except when it is desired rapidly to lower blood pressure, as in certain cases of cerebral hemorrhage, uremic coma, etc.; or where it is desired to remove a certain amount of toxic or deteriorated blood before replacing it with healthy blood or saline solution, as in illuminating gas, carbon monoxid poisoning, etc.

The vein selected may be the external jugular, the internal saphenous, or, more commonly, the median basilic or cephalic. The latter is perhaps preferable on account of its greater distance from the brachial artery and its freedom from nearby cutaneous nerves. A constrictor is applied at mid arm tight enough to distend the superficial veins. The skin over the anterior surface of the elbow is then painted with iodin, which is allowed to dry and then washed off with alcohol. The vein is then steadied between the thumb and forefinger of the left hand while a sharp scalpel divides it transversely, together with the overlying skin, to about one-half of its diameter. Local anesthesia may, of course, be used if desired. The flow of blood may be increased by causing the patient to grasp a stick tightly. It may be lessened by digital pressure over the vein. The amount of blood removed usually varies from 8 to 16 ounces. When sufficient blood has been removed the flow of blood is arrested by removing the constrictor, and strapping a pledget of sterile gauze over the phlebotomy wound.

## OPERATIONS TO REMOVE THE CAUSE OF CIRCULATORY DISTURBANCE DUE TO VARICOSE VEINS

Binnie says: "The principle of treatment of varicose veins is the transference of the venous circulation from the superficial to the deep veins, but before attempting to do this it must be shown that there is neither thrombosis of the deep veins nor marked obstruction to the return of the blood through them.

"Mayo, in doubtful cases, applies an elastic support to the limb for a week; if this gives comfort it is fairly evident that the deep vessels are capable of doing their duty."

### Methods of Treatment

The methods usually described are: injection, ligation, excision, incision, suture.

The treatment of varicose veins by injection, acupressure, and subcutaneous ligation is antiquated, and should not be employed. Incision, excision, and suture are the methods commonest at present.

**Treatment by Excision.**—Excision is the method most in use. The dilated veins are marked upon the skin, while the patient is in the standing position, with tr. iodin, silver nitrate, or some other stain; or scratches are made in the skin over them with a sharp scalpel. At the same time a test is made as to the free communication of the varices with the deeper veins. With the patient recumbent, the surgeon places his finger upon the saphenous vein just below its entrance into the femoral and causes the patient to stand up. If, while the varices are thus relieved of the weight of the superimposed blood, they still dilate from below the Trendelenburg operation alone is useless. It may, however, be used in addition to the excision in continuity.

After a very careful preparation of the operative field an incision is marked over the dilated vein. If the vein is broadly adherent to the skin it is often easier to excise a portion of the latter with it. Otherwise, the incision is deepened carefully just through the skin and flaps are raised on each side of the incision by thrusting blunt scissors beneath the skin and forcing the blades apart. This, added to a little necessary sharp dissection, will expose a considerable area of vein which is ligated together with its tributaries, above and below, and excised for a distance of several inches. All bleeding is then stopped, the wound carefully cleansed, and its edges united with fine silk, continuous suture; or, perhaps better, by interrupted sutures alternating with narrow strips of sterile adhesive. This procedure may be repeated until the continuity of the dilated venous channel has been interrupted at 3 or 4 levels. Sometimes the dilated trunk vein and its tributaries arrange themselves in a sort of nest or plexus 2 or 3 inches in diameter, especially just below the knee, in front, internal, or behind. It is more satisfactory in such cases to excise a considerable area of skin, together with the whole mass of dilated tortuous veins and their surrounding fat, right down to the deep fascia. The defect may then be closed by loosening superficial fascia around the edges of the wound from the deep fascia and drawing the wound edges together with several deep tension sutures of silk-worm gut. Proper coaptation of the margins then follows, with silk, as before. Better approximation is secured in this way, and the tendency of thin, extensive flaps to slough is avoided.

Dry dressings are applied, the limb is elevated and closely bandaged from toes to groin. A well-padded posterior splint of wood, or a more comfortable one of moulded plaster, is then added, and the patient kept in bed for at least ten days, or preferably two weeks, as the experience of the Mayo Clinic has shown that practically all the cases of embolism complicating this operation have occurred within 14 days after operation. If the varicosities have been extensive the patient should be recommended to wear a woven bandage of the "Ideal" type or a well-fitting elastic stocking for a few weeks after the operation.

If the varicosities are the result of weight pressure from the superimposed column of blood, the veins do not distend when the limb is allowed to hang down while pressure is made upon the upper part of the saphenous vein by the examiner's finger, which has been previously placed there with the limb in the horizontal position.

TRENDELENBURG'S OPERATION.—In such cases Trendelenburg's operation may be sufficient. It consists of the excision, between ligatures, of an inch or two of the saphenous vein at the upper part of the thigh. A rubber constrictor placed around the limb near the groin may be used to dilate the vein and make its localization easier, and in fat patients a transverse incision may discover the vein more readily than a longitudinal one.

MAYO'S OPERATION.—Mayo devised a dissector with accompanying forceps to facilitate the excision of the varicose vein through small skin incisions. It is exceedingly efficient if the vein is thick-walled and not too tortuous, but is apt to tear thin-walled, tortuous vessels. It is used as follows: expose and isolate about 1 inch of the saphenous vein near the saphenous opening. Divide it between double ligatures and thread the distal end through the eye of the probe dissector (Fig. 80a) and put an artery clamp on it. Hold the clamp in one hand and push the dissector downward beneath the skin, guided by the vein, to a point near the knee. It may be advantageous to have an assistant press the skin upward against the advancing dissector. If its progress is obstructed by adhesions around the vein pass the adhesion forceps (Fig. 80b) over the vein down to the point of obstruction. Tear the adhesions by gently opening the blades of the forceps and then proceed with the dissection. When the eye of the dissector has reached a point near the knee make a small incision over it, push it out through the skin, clamp the vein, and withdraw the dissector. Rethread the vein in the dissector, reintroduce the latter through

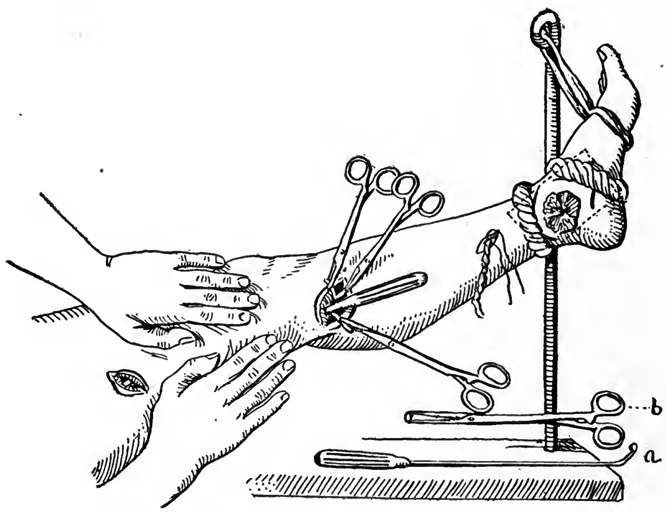



Fig. 80.—a, Mayo's Dissector for Varicose Veins; b, Mayo's Adhesion Forceps for Varicose Veins.

the lower incision, and continue the dissection downward. Remove as many other veins as is deemed necessary in a similar way. Binnie calls special attention to the advisability of making the dissection from above downward to avoid the danger of detaching thrombi and setting them free in the circulation. The bleeding from the tributaries that are torn off can readily be stopped by pressure with gauze pads. The wounds are closed by suture; dry dressings are applied and a snug bandage, applied from below upward (toes to groin), with a posterior splint, is added.

Excision by Inversion.—Mamourian elevates the limb, exposes and divides the internal saphenous vein near the saphenous opening, ligates the proximal end, and clamps the distal. Traction on the clamp indicates the position of the vein near the knee, and it is exposed and divided again through a small incision at this point. The distal end is clamped and a long probe is passed, eye first, into the proximal end upward and out of the upper incision. The upper end of the vein segment is fastened to it by a silk suture that penetrates the vein wall through and through and is tied through the end of the probe. Strong traction on the lower end of the probe extracts the segment of vein, turning it outside in. Mamourian says a gum elastic catheter may be used instead of a probe, if the veins are very tortuous. This method is not applicable to general or cirsoid varicosities.

BABCOCK'S OPERATION.—Babcock devised a long, pliable probe with a small olivary tip at one end and a larger oval tip at the other, cupped underneath so as to catch the cut end of the vein. It is used as follows: expose and isolate about 1 inch of vein at the upper end of the segment whose removal is intended. Grasping it in a hemostat, make a small incision into the wall and introduce the small end of the probe. Pass it downward within the vein, as far as possible, and tie the upper end of the segment tightly around it just below the large end. Cut the vein between this and the hemostat and replace the latter by a ligature. Make a small incision through the skin, fascia, and vein wall upon the small ends of the probe. Grasp this and make traction combined with a series of short jerks. The vein comes away, pleated in a small mass against the cupped surface of the larger tip; hemostasis; wound closed; dressings; bandage, and splint as usual.

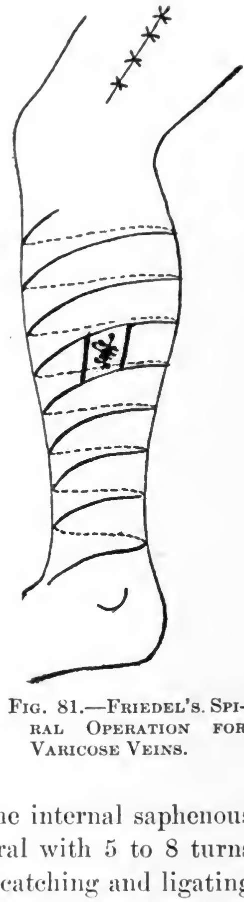


FIG. 81.—FRIEDEL'S. SPIRAL OPERATION FOR VARICOSE VEINS.

FOSTER'S METHOD.—Foster in a similar way uses 2 feet of No. 4 copper wire, bent at one end into a loop, or neck, around which the cut end of the vein to be stripped out is tied.

**Treatment by Incision.**—CIRCULAR INCISION.—Schede has advocated a complete circular incision dividing all tissues down to the deep fascia in the upper third of the leg, double ligating each vein as it is cut. Von Wenzel adds a second similar circular incision at the junction of the lower and middle third of the thigh.

SPIRAL INCISION.—Reindfleisch and Friedel divide the internal saphenous vein between ligatures high up in the thigh; mark a spiral with 5 to 8 turns around the leg; deepen this by incision to the deep fascia, catching and ligating the divided vessels; pack the wound to hold the edges of the spiral apart and force it to heal by granulation and epidermization. This leaves a deep spiral gutter in the leg (Fig. 81). Where ulcers exist they include them, between turns of the spiral, joining these by vertical incisions on each side of the ulcer.

Kayser reported 18 cases done by this method, all of the most severe type. He declared that the size of the leg diminished and remained smaller, existing ulcers were healed, there were no sensory disturbances of the skin, and his patients were well satisfied with the results. He makes 6 to 12 spiral turns according to extent of varicosities, beginning on dorsum of foot, with 3 parallel incisions on dorsum, which, he says, prevents edema; and if ulcers are large he carries the incisions through them. He keeps the patient in bed 4 weeks after operation.

Geinitz, reporting the late results of this operation performed for varices at Garré's Clinic, says they are surprisingly good. The ulcer only recurred in one case. He recommends it highly for diffuse varices and cases where simpler methods have failed.

**Treatment by Suture.**—DELBET'S OPERATION.—Delbet, in 1906, suggested and carried out by suture a re-implantation of the saphenous vein into the femoral 10 or 12 cm. below its original entrance. His object was to cure varices by relieving them of the weight of the superimposed blood column through the interposition of one or more sets of competent valves. He reported 8 cases, and Hesse and Schaack collected 48 cases in all. There was 1 death out of Hesse and Schaack's 23 own cases, and they called the other 22 cured.

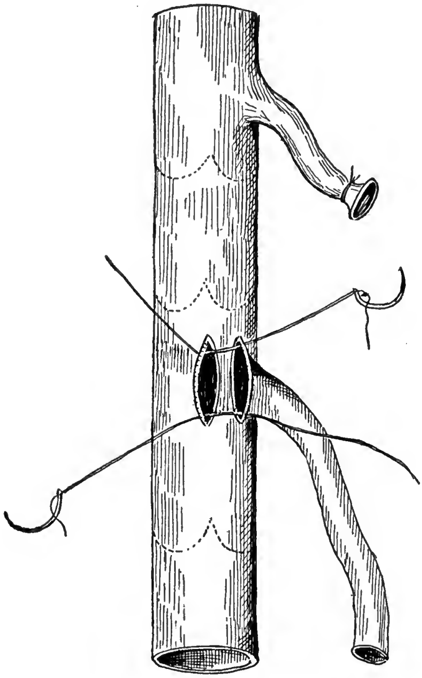


FIG. 82.—DELBET'S OPERATION AFTER HESSE AND SCHAACK.

HESSE AND SCHAACK'S OPERATION.—Hesse and Schaack operated as follows: An incision 12 to 15 cm. long was made through skin and superficial fascia at Scarpa's triangle in the direction of the internal saphenous. This vein was isolated, and all but the largest branches were ligated. They then exposed and freed the femoral vein for a sufficient distance, ligated the saphenous at its entrance into the femoral vein, put a temporary hemostat on it a little below, and divided the vein between ligature and serrefine. They then reimplanted the distal cut end of the saphenous into the femoral vein at least 10 cm. distal to its original entrance, using a traction suture at the upper and lower ends of the anastomosis, and then completing it by a continuous suture (Fig. 2). After operation no immediate improvement was apparent, but soon the Trendelenburg's symptom disappeared. In 21 of the 23 cases the patency of the anastomosis was established.

JEGER'S METHOD.—Jeger suggests the advisability of minimizing the danger of thrombosis by employing for the anastomosis his own method of end-to-side implantation of veins which approximates the endothelial surfaces very exactly.

COENEN'S METHOD.—Coenen originated an operation similar to Delbet's for relief of varices of the external saphenous. He ligated and divided the upper part of the small saphenous and united its distal end by circular suture to the central end of the ligated and divided posterior tibial. His end results are not available, but he saw the tibial vein fill with blood from below upward, indicating that he had accomplished his object of affording another exit for the blood in the saphenous system.

KATZENSTEIN'S METHOD.—Katzenstein, reasoning that the varicosities of the saphenous system are due to lack of muscular support, originated a procedure in which he frees the internal saphenous as widely as possible, lays it on the sartorious muscle, and builds a muscular canal for it by suturing the latter around it. His results are said to be good.

### Choice of Method

The choice of method depends largely upon the extent and type of the varicosities. Subcutaneous removal by Mayo's dissector, Babcock's probe, or the inversion method of Mamourian works very well if the veins are thick-walled and not very tortuous and adherent. But thin-walled veins, tortuous and adherent, are best removed by open excision. Where the skin is thinned out and the subcutaneous fat that normally lies between it and the vein has been replaced by fibrous tissue resulting from chronic periphlebitis it is more satisfactory to remove the skin and veins *en masse* down to the deep fascia, freeing the flaps sufficiently to bring them together without tension. The high ligation in the thigh may properly be added to any of these procedures where Trendelenburg's symptom is present; and, in mild cases, it alone may be sufficient. The reimplantation of the saphenous is suitable only for cases exhibiting Trendelenburg's symptom; and, inasmuch as the other simpler operations are safer and more satisfactory in almost all cases, if properly and thoroughly carried out, the saphenofemoral anastomosis by suture seems hardly justifiable. It has been practiced little, if at all, in this country. The circular incisions of Schede and Von Wenzel do not appeal to me as being much more rational than the wearing of one or two tight, circular garters; but the complete spiral of Rindfleisch and Friedel has given good results in properly selected cases, and should be reserved for those where there are extensive varicosities with marked periphlebitis, varicose ulcers, and edema.

The operation of excision is simple but tedious and, with the exception of the suture anastomosis, all the other methods are easily performed. The only dangers that are to be feared are infection, which, of course, is more liable to occur in ill-nourished tissue, such as that in the varicotic area; and embolism, which is fortunately very rare. A certain amount of necrosis of the edge of the wound margins is not infrequently seen, due probably to the destruction of their blood supply in undermining them.

Goerlich reported 2 cases of pulmonary embolism in 147 operations done by Trendelenburg's method, and collected in all 8 cases, following various operations for varicose veins.

Wilson says that (1) from 1 to 2 per cent. of all cases of blood vessel operations give more or less distinct clinical evidence of emboli, over 70 per cent. of which are pulmonary; (2) probably about 10 per cent. of cases of postoperative emboli are fatal; (3) autopsy shows about 80 per cent. of these emboli to rise from venous thrombosis; (4) in over 12 years at St. Mary's Hospital only 1 fatal case of embolism followed phlebectomy of varicose veins of leg; (5) in 1,372 operations on blood vessels during the same period there were only 2 deaths from embolism. One of these was cerebral, the other pulmonary.

### Results of Treatment

Matas quotes Goerlich, who wrote that in 1,425 cases reported by 42 operators he found 65 per cent. to 85 per cent. of cures after ligation of the internal saphenous.

Miller reports 79 per cent. of cures by Trendelenburg's operation in 41 cases at Halsted's Clinic.

Perthes reported 78 per cent. of cures by Trendelenburg's operation in Trendelenburg's Clinic.

The Schede operation in Johns Hopkins Clinic gave 33 per cent. of cures in 19 cases.

"Relapse," says Matas, "is more likely to follow the single linear division of veins than the more thorough extirpation." Nevertheless, the secondary dilatation of small superficial tributaries of the extirpated veins, the reestablishment of direct end-to-end communication through the scar, especially after ligation, and the regeneration of veins will cause a certain percentage of relapses even after extensive resection of veins.

Jeannel is quoted by Binnie as taking the high conception of "cured" to mean the restoration to the patient of a "healthy, vigorous, painless limb." He says that out of 697 limbs operated on by (1) Trendelenburg's operation, or its variants, 56 per cent. were cured; (2) out of 23 limbs in which was done resection of the whole femoral part of the internal saphenous, 52 per cent. were cured; (3) in 70 limbs excision of isolated varices cured 74 per cent.; (4) resection of all or most of either the internal or the external saphenous (but *not* both) cured 46 per cent. of 57 limbs; (5) Trendelenburg's (or variants) plus multiple resection and ligation cured 60 per cent. of 95 limbs; and (6) complete saphenectomy cured 95 per cent. of 77 limbs.

## OPERATIONS TO PREVENT EMBOLIC INFECTION

It should be well understood that venous thrombi are potentially far more dangerous than those in arteries. The latter, if we except the pulmonary artery, can, at worst, lead immediately only to the destruction of the part supplied by its branches; while venous thrombi, by fragmentation, may cause instant death through embolism of cerebral vessels. Moreover, they may, if infected, give rise to pyemic abscesses from septic emboli in the most distant parts and tissues, or furnish the bases of an infective endocarditis.

For these reasons considerable attention has lately been given to the operative treatment of infective phlebitis. Ligation and excision of the internal jugular to prevent dissemination of infection in cases of sigmoid sinus thrombosis is a well established procedure; while similar treatment of the ovarian and uterine veins, in cases of pelvic thrombosis of septic origin, has recently been reported by Jellett. Moreover, Neuhof has done some experimental work in testing the practicability of ligation of the portal vein with a view to its application in the treatment of suppurative pylephlebitis.

Whatever its situation, the principle in the operative treatment of infective thrombophlebitis is the same: to ligate the vein on the cardiac side of the diseased process, and evacuate the clot, or to ligate it both centrally and distally and excise the segment between. Binnie quotes Trendelenburg as recording a case of "general, chronic puerperal infection which recovered after ligation of the inflamed and thrombosed right internal iliac and spermatic veins."

Faix mentions 20 cases reported operated for pelvic thrombosis from the clinics of Freund, Trendelenburg, Michel, Bumm, Hackel, Opitz, and Friedman, of which 7 recovered—a 65 per cent. mortality. Bumm puts the mortality of non-operated cases at 85 per cent. Bremmer reports 32 cases operated for mesenteric thrombosis with 5 recoveries—85 per cent. mortality.

## III. OPERATIONS UPON CAPILLARIES

### OPERATIONS TO CHECK BLEEDING

**Local Coagulants.**—Local coagulants may sometimes be used with advantage to check capillary oozing. Of these the most commonly used at present are hot water, hydrogen peroxid, and adrenalin. Gelatin is excellent also, but not so simple to prepare and use.

ADRENALIN.—Adrenalin is used as a solution in the strength of 1:1,000 applied on a gauze or cotton sponge, or sprayed from an atomizer. It is particularly useful in capillary bleeding from the mucous membrane of ear, nose, and throat, or abraded skin surface.

HYDROGEN PEROXID.—Hydrogen peroxid is useful in oozing of large wound surfaces upon which it may be poured or applied by sponges.

HOT WATER.—Hot water should be used at a temperature not over 140. It may be sponged or poured on the oozing surface.

GELATIN.—Gelatin in 5 per cent. or 10 per cent. solution, dissolved in normal saline heated from 40° to 60° C., is applied to the bleeding surface, or packed into the wound on a saturated gauze compress. The possibility of tetanus infection from this source necessitates the previous perfect sterilization of the gelatin. Equal parts of tannin and antipyrin in a gauze sachet have been recommended by Park as a local hemostatic in bleeding ulcers of malignant neoplasms. Matas advises gauze compresses wrung out of a 5 per cent. solution of antipyrin to cover oozing surfaces or pack cavities, and sachets of compound alum powder (Squibb's surgical powder) to pack bleeding cavities. Combined with any of these local coagulants, calcium chlorid, 1 to 2 grains in a neutral solution of 1: 20 strength injected deeply into the tissues, and in 5-grain doses by mouth or rectum, will materially aid in reducing coagulation time of blood.

Gelatin, in the form of Carnot's solution, is said to have the same effect when injected intravenously (100 to 200 c. c. daily at 37° C.), and thyroid extract, taken internally, has been recommended for the same purpose by Taylor.

**Packing.**—Packing with sterile gauze is undoubtedly one of the most efficient means employed to check oozing from the walls of a wound or cavity. It should not be too tight, and should be soaked with peroxid or sterile saline before being removed on the second or third day. The actual cautery, heated by burning benzin, or by electricity, is a most efficient agent in controlling capillary hemorrhage. The object of cauterization is to produce a burned crust sufficiently strong to withstand the pressure of the blood, and for this purpose it should be used at a cherry red, not white, heat, in order to cook the tissue slowly and thoroughly, rather than reduce it to an ash. This crust must not be disturbed until the vessels beneath it have filled up with clot, or bleeding will recommence.

**Ligation en Masse.**—Ligation *en masse* may be practiced as described in ligation of arteries *en masse.* This for the purpose of checking capillary oozing in parenchyma of organs such as liver, spleen, and kidney.

## OPERATIONS TO OBLITERATE THE VASCULAR CHANNELS IN SMALL ANGIOMATA AND NEVI

**Excision.**—Excision of small nevi is easy, the flaps of the wound being readily brought together with sutures. Larger nevi, when excised, may leave an area denuded that has to be covered by a plastic operation, or by skin graft. The incision should pass only through healthy tissue, and hemostasis must be carefully attended to.

**Freezing.**—Freezing is the treatment *par excellence* for ordinary nevi. The freezing may be done by liquid air or by carbon dioxid snow. The latter is easier to obtain. If liquid air is to be used make a firm pad of cotton on a small stick. Dip the pad into the liquid air. Shake off any loose drops of the liquid. Press the charged pad with moderate firmness on the nevus for a few seconds. Repeat the process in every part of the lesion. Apply no dressings. All scabs must be removed prior to the treatment, and if any raw surfaces are present they must be covered with thin gauze, otherwise the applicator would freeze to them.

If carbon dioxid is to be used, a cylinder of the liquid is obtained, a paper cone constructed and held in front of the outlet while the valve is slightly opened. The liquid condenses immediately into snow, which is deposited into the cornucopia, making a cone-shaped mass of snow. It may be whittled to a sharp point and held in a thick layer of paper with the point protruding.


FIG. 83.—KROGIUS'S SUBCUTANEOUS LIGATURE FOR LARGER ANGIOMATA.

This should be pressed firmly against the growth in several places for a few seconds at a time. No anesthesia or dressings are necessary. With liquid air or carbon dioxid the treatment may have to be repeated several times. Too long application may cause extensive sloughing.

**Ligation.**—Angiomata of the scalp may be surrounded by a chain of subcutaneous ligatures (using full-curved needle for advance and quarter-curved for return part of stitch), which cure by cutting off the blood supply in the main vessel (Fig. 83), or a purse-string suture with 4 loops may be used to strangulate the growth (Fig. 84).

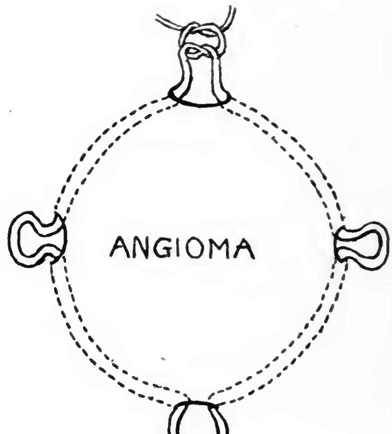



FIG. 84.—PURSE-STRING LIGATURE FOR SMALL ANGIOMA OF SCALP.

**Injection.**—Injection of astringents, cauterization, and scarification, methods formerly much in use, are not approved at the present time. Acupuncture, or needling of the nevus, is a method still occasionally used. It is painful and gives rise to a certain amount of scarring, but it is efficient. The needle is heated to redness by electricity. It should be introduced slowly and cautiously to avoid bending, and should be removed slowly to avoid hemorrhage on account of the cooked tissue sticking to the needle and being torn away with it.

Wyeth has treated arterial, venous, and capillary angiomata with injections of boiling water, under general anesthesia. For capillary growths he advises water at about 190° F., throwing in 2 to 6 minims at a puncture, and beginning at the periphery of the growth and working toward the center. A surgical dressing is then applied and the part kept at rest. The injection may be repeated in 7 to 10 days.

**Desiccation.**—Desiccation, the electric desiccation of vascular nevi by high-frequency currents, is said by W. L. Clark to give very excellent results. He advises that the destruction of the nevi, unless very large, should be completed at one sitting. In superficial lesions new skin is formed. Deep lesions are replaced by scar tissue and skin. To avoid cupping, irregularities of the surface, and possibly keloid formation, care must be taken to destroy the tissue perfectly evenly, and not too deeply. The desiccation action is apparently a rapid dehydration of the tissue, rupturing the cell capsule and converting the treated area into a dry mass. Penetration of the tissue is said to be from a small fraction of an inch to 1 inch or more, depending upon frequency, distance of electrode from body, time of exposure, and density of tissue. It destroys tissue without opening blood or lymph channels and acts as a styptic when there is oozing of blood. The dry crust acts as a dressing and separates in 3 to 7 days and skin regeneration is said to take place beneath it.

The treatment is not very painful if applied with the proper technic, but local anesthesia may be needed, or, in rare cases, general anesthesia.

A. Schuyler Clark recommends the *Kromayer light* as being excellent for "port wine marks."

**Choice of Method.**—The choice of method will undoubtedly vary with the individual operator. Liquid air, carbonic snow, desiccation, etc., all give excellent results in the majority of cases, but all three require some experience for their proper application. Excision is far less used now than it was formerly, and should only be employed in those cases that prove refractory to the less radical forms of treatment. Needling is painful, and hot water injections are too risky to be recommended.

There is little danger in operating upon these capillary growths, for hemorrhage from them is usually moderate in amount, and easily checked by pressure. Oozing may be obstinate, however, after excision, and hemostasis must be carefully attended to on account of the bad effect of loss of blood in young children.

Results are excellent, cures being practically always possible, but not always possible without scarring.

## OPERATIONS UPON THE LYMPHATICS

### HANDLEY'S OPERATION

For the reëstablishment of lymph drainage; intractable edema of the extremities, due to blocking of lymphatics, following chronic inflammation; presence of filaria; Le Dantec's "dermodoccus" (diplodoccus); scar formation after excision of lymph-nodes, etc. The operation consists in establishing artificial channels for lymph drainage from the edematous parts as substitutes for the natural vessels which have become obstructed.

Beside the usual dissecting instruments, several long-eyed probes and several lengths of No. 12 tubular, woven silk are needed.

**Upper Extremity.**—(1) Make a 1-inch incision through the skin in the mid line of front of forearm immediately above wrist (a, Fig. 85). (2) Introduce a probe through it and pass it upward and outward in the subcutaneous areolar tissue to the point b (Fig. 85) near the elbow. Incise the skin over it there and push the point of probe out. (3) Take a double line of No. 12 silk twice as long as the arm; catch its mid point with hemostat and wrap one-half up in sterile towel, threading free end of other half through eye of probe. Pull probe and silk with it out of incision b (Fig. 85). A double line of silk now lies in subcutaneous tunnel a-b (Fig. 85) made by probe. (4) Reintroduce probe through incision b and bring silk out through incision d made near insertion of deltoid. (5) Pass a second probe through incision a upward and inward, and make it emerge through incision c. The half of silk line which was wrapped in towel is now unwrapped and threaded through the eye of the probe. Pull probe and silk out through incision c (Fig. 85). Remove hemostat from silk so that loop becomes buried under skin at a. (6) In same fashion pass silk under skin from c to d. Reintroduce both probes through d and pass them, under the skin, round the shoulder to emerge through incision f at posterior border of deltoid (Fig. 86). (7) In similar fashion, bury a double line of silk under skin of back of arm along lines of j, h, f (Fig. 86), and j, k, f (Fig. 86). There are now 8 threads emerging through f. (8) Take a long probe, cut ends of two of emerging threads so that they are 4 inches shorter than it, and thread them into the eye. Thrust probe, eye first, through incision f and make it penetrate under skin of back. The probe, being longer than silk, unthreads itself. Withdraw probe carefully, leaving thread to occupy its track. Repeat the maneuver until all the threads emerging

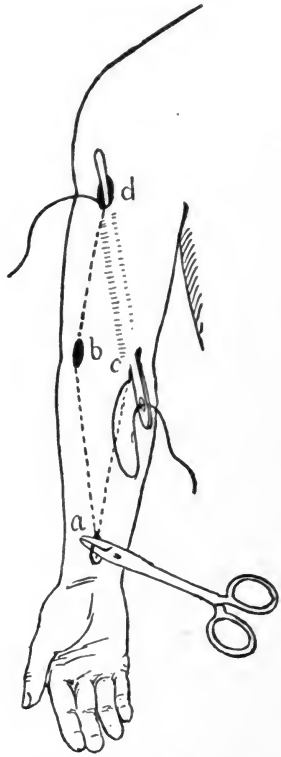



Fig. 85.—Handley's Operation for Lymphatic Drainage: Upper Extremity, Anterior View.

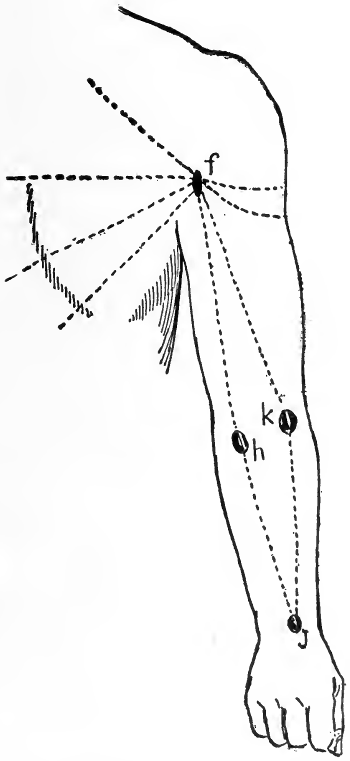



Fig. 86.—Handley's Operation. Posterior View.

at f are buried in various directions into subcutaneous tissues of back. (9) Close all incisions with sutures.

Handley states the contra-indications to the operation (after carcinoma of breast removal) to be:

(1) When general anesthetic cannot be given.

(2) Where threads would have to pass through cancerous tissue.

(3) When there is growth present about the shoulder, and pain in axilla, or lancinating pain shooting down arm (i. e. nerve plexus pain).

(4) He says that benefit is transient in cases where secondary growths, or pleural effusion, are present.

(5) It should be reserved for severer cases of lymphostasis.

**Lower Extremity** (Elephantiasis, Milroy's Disease, Congenital Edema, etc.).—The technic of the operation is similar to that in upper extremity, but its accomplishment is more difficult on account of the thickened, irregular nature of the skin; and infection is more liable to follow on account of mechanical difficulty of getting a clear operating field.

**The Face.**—Mitchell did Handley's operation on a case of solid edema of eyelid, following a severe attack of erysipelas that had resisted all ordinary treatment. The operation was performed as follows:

By means of a small curved incision in upper and lower eyelid, near mesial part, and another lateral to outer canthus, coarse strands of silk were carried beneath the skin of both eyelids beyond the outer canthus. From there they were led subcutaneously downward, by means of an incision lateral to the angle of the mouth, and finally the buried ends left beneath the skin of the cheek near the ramus of the lower jaw.

Mitchell performed a similar operation on a patient with solid edema of the side of the face and the lips, following erysipelas, by burying 2 silk threads with their upper ends in the masseteric region and their lower ends tucked into the loose tissue behind the clavicle. Results were good in both cases.

**Ascites.**—Gerrish says: "In a case of atrophic cirrhosis with ascites Handley passed a stout needle, threaded with silk such as he used in lymphangioplasty, in and out at a number of points through the peritoneum and subjacent tissues of right iliac region, leaving several series of short loops projecting into the cavity. The ends of these threads were pushed into the areolar tissue of the front of the thigh, passing near the anterior superior spine of the ilium, and behind the inguinal ligament. The immediate result was not satisfactory and another paracentesis was needed, but ultimately great benefit ensued, seeming to justify extensive trial of the method."

The operation of lymphangioplasty is simple and easy, and the dangers are relatively slight. Infection occurred in one of Handley's cases done for lymphedema of the lower extremity; and in one of Mitchell's cases done for edema of the eyelid one line of silk had to be removed on account of the "irritation" it caused.

The results, however, were good in almost every case, and it is unquestionably the best treatment now known for the relief of the painful, intractable lymphedema following operations for carcinoma of the breast.

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# A SPECIAL METHOD FOR THE TRANSFUSION OF BLOOD WITH THE USE OF PARAFFIN AND HIRUDIN

# CHAPTER IX

## A SPECIAL METHOD FOR THE TRANSFUSION OF BLOOD WITH THE USE OF PARAFFIN AND HIRUDIN

Ransom S. Hooker and Henry S. Satterlee

For the purpose of the present discussion it will be sufficient, after a short historical outline, to summarize the main theoretic principles underlying the authors' methods of transfusion, to briefly indicate the experimental data which support these principles and which have served as a basis for the development of their apparatus and technic, and finally to describe the practical operation of transfusing blood by these methods. For those who seek general information on this and correlated subjects, there is appended a classified bibliography of the references which we believe to be of most interest and importance.

### HISTORY

The idea of transfusing fresh human blood through the agency of an intermediate receptacle, or carrying system, appears to have originated in the minds of several persons shortly after the discovery of the circulation of the blood by Harvey. To Francesco Folli, in 1652, is ascribed a plan of transfusion, by means of two cannulas united either by a piece of intestine, or by part of an artery having a collateral outlet to provide for the escape of air (Casse). Chereau quotes Robert des Gabets, a Benedictine monk, as proposing, in 1658, the employment of a transfusion apparatus which he had constructed 7 years previously. The apparatus was described as 2 silver tubes united by a small leather purse, the size of a nut, each tube provided with a valve so that the leather bag would serve as a pump to propel the blood from one blood vessel to the other; it was also mentioned that the bag would serve the purpose of measuring the amount of blood transfused. There is, however, no record that this device was ever actually employed for transfusion.

The first authentic account of the transfusion of blood through a foreign carrying system was the experiment performed by Richard Lower (37) of Oxford in 1666; and, in the following year, the report of a similar experiment by Jean Denys (20) in Paris. Lower successfully transfused blood from the carotid artery of one dog into the jugular vein of another dog by means of several quills fitted together to form a tube. This quill method was later modified by Lower to a conducting system composed of 2 silver cannulas united by a section of the carotid artery of a horse or ox, and by this means Dr. Lower and Sir Edmund King (33), in 1667, transferred blood from the artery of a sheep into the arm vein of a man. Denys and Emmeretz (21) reported 3 successful transfusions by a similar method in the same year.

Aveling (2), in reviewing the history of transfusion in the eighteenth century, says that the recommendation of vein-to-vein transfusion by Tardy (52) of Paris and by Harwood (28), Professor of Anatomy at Cambridge, in 1785, led to the need of a motive power to effect a transfer of blood from donor to recipient; and that Boehm (8) used for this purpose a piece of duck's intestine to unite the two cannulas, propelling the blood from one vein to the other by stripping this vessel with his fingers from the donor toward the recipient. Coluzzi (14) used, for the same purpose, 2 glass tubes as cannulas, connected in the middle by a small bladder holding about an ounce. In operating, he allowed this bag to fill with the blood and then forced the blood into the recipient's vein by compressing the bladder while shutting off communication with the donor's vein. These operations, probably on account of the difficulty of performance, appear to have been attempted only in great emergency by the bolder spirits of the time, and gradually fell into disuse.

In 1818, James Blundell (6) revived the subject of transfusion by reporting to the Medico-Chirurgical Society of London a series of experiments upon animals, in which he made use of an entirely new method of transfusion, the blood being received into a cup from a vein of the donor, and injected into a vein of the recipient by means of a piston syringe. In the sixth experiment of his series Blundell reported that without causing any harm to the animal he had transfused 4 pints of blood from the femoral artery into the femoral vein of a 12-pound dog in 8 minutes, and had repeated this procedure twice, with intervals of half an hour, making 12 pints of blood transfused in an aggregate time of 24 minutes. Several years later Blundell developed a more complicated instrument which he called an "impellor."

Scott (51) of Newington Causeway invented a transfusion apparatus about this time which is described in the *Lancet* of May 13, 1826, as a "Read's syringe into the extremity of which slides a hollow flexible tube 14 or 15 inches long, armed with a silver pipe for entering the vein of the emitter. A similar tube is screwed to the lateral branch of the syringe, and has a silver pipe which is inserted into the vein of the receiver or patient. The pipes being inserted, and the syringe put in action, the blood is made to pass freely from one person to another . . . the velocity and the power of the current being regulated by the syringe at the discretion of the operator." A successful case of transfusion with Scott's apparatus was reported in 1826 by Joseph Ralph (49), who says: "However formidable and difficult the operation may have hitherto seemed, it may be performed by this instrument with the greatest ease."

In 1829, Blundell (7) introduced a further development of his instrument which he called a "gravitator," and which is illustrated and described in the *Lancet* of June 13, 1829.

The period from 1830 to 1880 was signalized by the development of many methods for transfusing both animal and human blood, fresh and defibrinated. Numerous ingenious instruments were devised for this purpose, the forms of apparatus conforming to four general types.

(1) A simple conducting system providing a direct passage from one blood vessel to the other, usually with some contrivance to allow the escape of air.

(2) A receiver to collect the blood from the donor and a means of quickly injecting this blood into the recipient's blood vessel; or, if the blood were defibrinated, simply the means of injecting defibrinated blood into the circulation of the recipient.

(3) A conducting system in direct communication with a piston or bulb syringe, or with some other means of pumping the blood from the donor to the recipient.

(4) Syringe-cannula methods, having cannulas in both donor's and recipient's veins and a syringe or syringes, fitting both cannulas, to draw the blood from the donor and inject it into the recipient.

Inventions corresponding to these four types were advocated and employed during this period as follows:

**Type 1.**—These instruments conform essentially to the original apparatus of Richard Lower (1666). Other instruments of this class were those of Gesellius, Albini, Casselli, Morselli, Luciani and Oré, two varieties.

**Type 2.**—The apparatus of Blundell (1818) was the forerunner of this class of instrument. Varieties of this type were developed in the period from 1864 to 1877 by Hamilton, De Belina, Moncoq, MacDonnell, Collin, two varieties, Copello, Hasse, Gendron, Hüter, Casse, Uterhart and Oré.

**Type 3.**—The apparatus of Scott in 1826 was the first practical instrument of this type to be developed and was soon followed by an adaptation by Weiss in London. In the period 1864 to 1874 varieties of this class of instrument were employed by Aveling, Roussel, Grecco, Leblond, LeNoël, Collin, Oré, Manzini and Rodolfi, Moncoq and Mathieu.

**Type 4.**—Probably the first instrument of the syringe-cannula class was that of Moncoq (45) in 1862; others were those of Mathieu and Oré both in 1863, and of Graily Hewitt (30) in 1864. Hewitt's apparatus is probably the best representative of this type and warrants a brief description. It consisted of a simple piston syringe of 2-ounce capacity used in connection with 2 silver cannulas. Having exposed the veins of the donor and recipient, Hewitt extracted with the syringe 2 ounces of blood from the donor as rapidly as possible, and gently injected 1 to 1½ ounces of this blood into the recipient's vein, taking about 1 minute for the injection. Hewitt stated that the transfer of blood must take place within 3 minutes to escape the danger of coagulation.

### SYRINGE METHODS OF RECENT TIMES

In more recent times Cripps (17) improved Aveling's method by uniting 2 silver cannulas with rubber tubing to opposite sides of an oval rubber ball of 2 drams capacity. This conducting system, which was without valves, was completely filled with warm salt solution before being connected with the blood vessels, and served as a pump, which, by properly compressing the tubes and rubber ball, drew the blood from the donor's vein and injected it into the vein of the recipient. The Cripps-Aveling method has been revived again very recently by McGrath (88).

In 1892, v. Ziemssen (90) advocated a syringe-cannula method which required one operator and 3 assistants. A vein of the donor was punctured without skin incision by means of a hollow cylindrical needle and blood withdrawn into a 25 c. c. piston syringe. While the syringe was being filled, another needle was likewise introduced into the recipient's vein; when the syringe was full of blood it was detached from the donor's needle, then connected with the recipient's needle and its contents discharged. Meanwhile a second syringe was attached to the donor's needle, as soon as disconnected from the first syringe, and the same procedure was repeated. A third syringe followed in the same way, the first one being meanwhile washed out with salt solution by an assistant. V. Ziemssen reported that the transfer of from 250 to 300 c. c. of blood by this method took not longer than 15 to 20 minutes. In the first series of 7 cases he stated that he observed chills and elevations of temperature in 3 instances and that in one of these cases he had trouble with a clot in the recipient's needle which had to be removed. He, however, considered the method less liable to the risk of causing dangerous coagulative changes in the circulating blood, than transfusion by end-to-end anastomosis, or the use of defibrinated blood.

Moritz (89), in 1911, recommended a method which did not materially differ from v. Ziemssen's except that the needles were fitted with stop-cocks and were connected with the syringe by means of an intermediate tube of glass and rubber which also was provided with a stop-cock. Immediately after each withdrawal or injection of blood, sterile normal salt solution was forced through the needles; the stop-cocks were closed. Strips of adhesive plaster were used to prevent as far as possible movement of the needles while within the vein. Hürter (69) recommends Moritz's method and claims to have had success with it, although he refers to it as involving a delicate technic.

More recently Freund (86) has devised a somewhat similar syringe method combining the use of salt solution with an apparatus which is similar to that of Manzini and Rodolfi. Freund's apparatus consists of a 20 c. c. piston syringe connected by a two-way stop-cock, with a cylinder of salt solution and with a piece of rubber tubing leading to another two-way stop-cock which communicates by short connections with 2 hollow cylindrical needles, one larger than the other. Donor and recipient are close together and the apparatus, fastened upon an inclined support, is placed between them. The connecting tubes and needles are filled with salt solution and the larger needle is introduced into the donor's vein. Both needles are held in place with strips of adhesive plaster. In operation, the blood is pumped from donor to recipient, 16 c. c. of blood mixed with 4 c. c. of salt solution, being withdrawn and delivered at each stroke of the piston.

Lindeman's (87) method differs from that of v. Ziemssen and of Moritz in that he has devised a special set of invaginated cylindrical cannulas and that a dozen or more syringes of 20 c. c. capacity are employed in rapid succession to convey the blood from one cannula to the other. An improvement over the v. Ziemssen and Moritz technic is the avoidance of traumatizing the intima of the veins by the many abrading movements within the blood vessel of a sharp-pointed instrument, incidental to the frequent connection and disconnection of the syringes. This feature is lessened by Lindeman in that the sharp innermost cannula of his set is withdrawn from the vein as soon as it has done its work of penetration. It should also be mentioned that the cannulas receive a preliminary internal coating of liquid paraffin. Syringe methods without special apparatus have also been reported in recent years by Cooley and Vaughan (84) and by Crotti (85).

Except for the admixture of salt solution no attempt is made, in this class of operation, to prevent the clotting of blood while in the intermediate receptacle and no special measures are taken to prevent or neutralize thromboplastin formation. Success in getting the blood transferred while still in liquid state depends therefore upon speed in conveying it from the vessel of the donor to that of the recipient. The element of safety is inversely proportionate to the amount of thromboplastin which is injected with the transfused blood, and this again depends upon the degree of contact with traumatized tissue and with moistenable foreign surface during the process of transfusion, and is probably also influenced by the degree of pressure to which the blood is subjected by the action of the syringe.

## DEFIBRINATED BLOOD

In regard to the transfusion of blood after defibrination a very brief historical note will suffice. Transfusion by this method was proposed as a result of the researches of Dieffenbach (60), Prévost and Dumas (77), and especially Bischoff (58), in the early part of the nineteenth century. Various methods of infusing defibrinated blood were advocated, and the procedure was from 1830 to 1880 employed to a considerable extent, if, indeed, it was not considered the method of choice. The intravenous use of defibrinated blood, however, fell into disrepute after 1880, on account of the researches of some investigators of the Dorpat school (notably Köhler) (70) which called attention to dangerous coagulative changes likely to be induced by the injection of defibrinated blood into the circulation. For a full consideration of the arguments for and against the use of defibrinated blood see Bibliography, Sec. II.

### PARAFFIN METHODS

The use of paraffin as an anticoagulant for transfusion apparatus was introduced by Brewer and Leggett (93) in 1909, in their direct conduction method by means of a paraffin-lined glass cannula. In this variety of operation, paraffin has also been employed by Vincent (100) and others.

Of the methods of transfusion with paraffin-coated receptacles, that of Curtis and David (94) (95), the Risley and Irving modification of this method (97), and the method of Kimpton (96) should be mentioned. The first two methods are very similar; the apparatus comprises a paraffin-lined cylinder connected by an opening at its upper extremity with a pump for exhausting or forcing in air, and at its lower extremity by two openings, one leading to the donor's blood vessel and the other to that of the recipient. Donor and recipient are placed close together and the apparatus connected by directly introducing the two tips of the cylinder within their respective blood vessels. In operation the recipient's vessel is shut off by pressure, and the exhaustion of air from the cylinder draws the donor's blood into it. When 50 c. c. are obtained, the donor's vessel is shut off by pressure and the recipient's vessel released. The forcing of air into the cylinder then drives the blood out of the cylinder into the blood vessel of the recipient. In a discussion of their experimental comparison of various methods of transfusion Risley and Irving report very favorably on this apparatus.

Kimpton's method is by means of a paraffin-lined glass cylinder with an elongated and twisted neck. He obtains blood from the donor by incising a clamped artery or vein with a cataract knife. The glass tip of his instrument is inserted directly into this incision. The clamp is then removed and the cylinder is allowed to fill by the force of the blood current. When the cylinder is full the clamp is reapplied, the tip is removed from the artery or vein, and the cylinder is carried to the recipient in the horizontal position, the twisted neck acting as a trap and preventing the entrance of air through the tip. The recipient's vein is entered in the same manner as the donor's blood vessel and the blood is delivered by forcing air into the cylinder with a cautery bulb.

## THEORETICAL CONSIDERATIONS AND PRINCIPLES UNDERLYING THE AUTHORS' METHOD

It is apparent to anyone who has given it consideration that a large field of usefulness would be open to the operation of blood transfusion if it could be performed safely, quickly, and surely by anyone possessing ordinary surgical skill, and, if possible, without expert assistance. The one serious obstacle in arriving at a safe and simple method of transfusing blood is the element of coagulation. If this obstacle can be fairly met and overcome all difficulties are solved.

With these considerations in view, and from a study of the more recent investigations on the nature and significance of the factors concerned in blood coagulation, there appear to be two ways of approaching this problem which offer some promise of success. (139-142, 177-178, 127-130, 154.) The first way is to preserve the antithrombin-prothrombin balance of the carried blood by preventing access or formation of thromboplastic substance, which is the initiating factor in spontaneous coagulation. The second way is to affect the antithrombin-prothrombin balance of the carried blood by neutralizing the thromboplastic substance and thus preventing its diverting action upon the normal antithrombin, or, in other words, to reinforce the antithrombin side of the balance by addition of the necessary element to offset the anticipated action of thromboplastin.

The authors of the present methods accordingly planned two lines of experimentation, based on these premises, to overcome the clotting difficulty, and at the same time to develop a practical technic of operation.

The *first* of these alternatives is to employ an intermediate carrying system for the blood, lined throughout with paraffin, and thus to provide no point of contact with any moistenable surface; and at the same time to minimize as far as possible the exposure of broken tissue surface to the blood stream in the process of obtaining blood.

The *second* alternative is the employment of a sufficient amount of some physiologic agent, as antithrombin or hirudin, to restrain or offset the initiative factors of coagulation, during the time of the conveyance of the blood through a foreign system, such as glass and metal.

For a detailed description of the experimental work which has led to the development of the authors' methods of transfusion, the reader is referred to previously published work (98, 99, 209). As a result of the earlier part of this work there appeared to be two main influences which tended to produce coagulative tendencies in blood transfused through the agency of an intermediate receptacle.

(1) The admixture of thromboplastin derived from wounded tissue, and more particularly from the wounding of the donor's blood vessel.

(2) The liberation of thromboplastin from the formed elements of the blood itself, especially the platelets, caused by disintegration or abrasion of these elements while in process of transfer.

With the present methods and apparatus the *first* contingency is avoided by penetrating the donor's vein with a cannula which, by a jet of salt solution, is immediately washed clear of any contaminating tissue juices which may be carried into it by the act of removing the obturator or trocar. This cannula serves as a protective sheath through which to introduce the tip of a pipet directly into the blood stream of the donor without contact with the wounded wall of the blood vessel. To avoid abrasion of the intima of the donor's vein by the tip of the pipet while drawing the blood, this tip has a blunt extremity with its opening in the direction of the blood current.

The *second* set of factors just mentioned has been met by having the tip of the pipet of as large caliber and as short a length as practicable, and by expanding its channel as rapidly and as evenly as possible (Fig. 1); also, by having an intact paraffin lining throughout the instrument to provide a non-

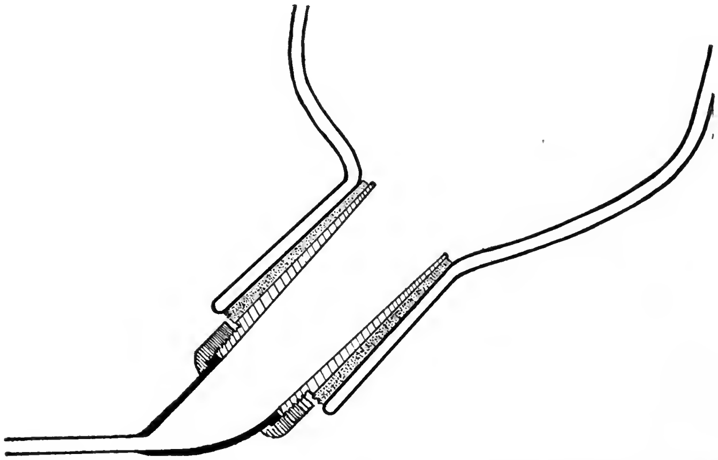

Fig. 1.—Sectional View of Lower Part of Pipet. *Tip (cylindrical portion)* of 14k. gold, seamless drawn tubing 17.0 mm. (0.67 in.) long; ext. diam. 2.32 mm. (0.091 in.); int. diam. 2.03 mm. (0.080 in.); soldered into the funnel portion of the tip at an angle of 45°. *Tip (funnel portion)* of coin silver, interior tapered from 2.03 mm. (0.080 in.) to 10.20 mm. (0.402 in.), flanged externally at larger extremity to fit coupling. *Coupling* of brass nickel-plated, made from a section of 15.875 mm. (0.625 in.) hexagon rod, drilled and threaded to fit bushing, and flanged to form swivel union with tip. *Bushing* of same material as coupling, tapered internally from 10.20 mm. (0.402 in.) to 12.75 mm. (0.502 in.); ext. diam. 13.71 mm. (0.540 in.), threaded at lower extremity to fit coupling. *Cylinder* blown from Jena glass tubing 54.0 mm. (2.126 in.) ext. diam. Neck of cylinder 25.4 mm. (1.0 in.) long, with internal diameter tapered from 18.26 mm. (0.7187 in.) to 16.67 mm. (0.656 in.). Angle of neck with long axis of cylinder is 30°. Asbestos packing made by wrapping around the metal bushing a piece of asbestos tape 25 mm. (1.0 in.) wide and about 0.4 mm. ($\frac{1}{64}$ in.) thick.

moistenable wall which reduces surface friction in the carrying vessel to a minimum. As an alternative to the paraffin coating, we have employed a coating of hirudin solution, to act as a neutralizing agent for thromboplastin derived from the formed elements of the blood at the zone of contact with the wall of the pipet. To diminish friction, we have also limited the speed and the force with which the blood can be drawn into and expelled from the pipet, by employing a method of mouth aspiration by the operator. It may be stated in this connection that we have tried various mechanical means of withdrawing and injecting the blood, such as Politzer bags, piston plunger syringes, etc., and that mouth aspiration is to be preferred to any of these more forcible methods.

## METHOD OF OPERATION WITH PARAFFIN-COATED PIPET

### INSTRUMENTS

An ordinary scalpel, a small and very sharp knife for incising the blood vessels, scissors, serrated forceps, mouse-tooth or fixation forceps,

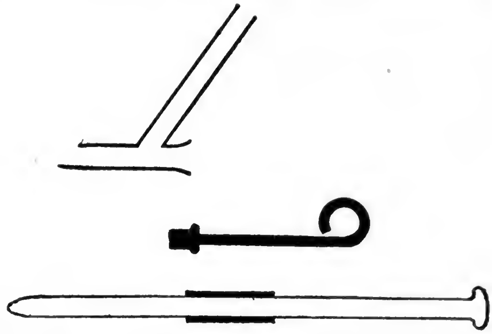

FIG. 2.—DONOR'S CANNULA. 14k. gold seamless tubing, 2.80 mm. (0.110 in.) ext. diam. and 2.34 mm. (0.092 in.) int. diam. Cannula is 15 mm. (0.59 in.) long, bevelled at distal end and flared at proximal end. Lateral arm 20 mm. (0.79 in.) long, joining cannula at angle of 30°, at 5 mm. (0.197 in.) from proximal end. *Plug* of 10k. gold, diameter to fit proximal end of cannula snugly; wire handle. *Obturator* of glass rod, 2.25 to 2.30 mm. (0.089 to 0.091 in.) in diameter.

several mosquito clamps; donor's cannula with obturator and plug (Fig. 2); recipient's cannula and obturator of appropriate size (or 2 sizes may

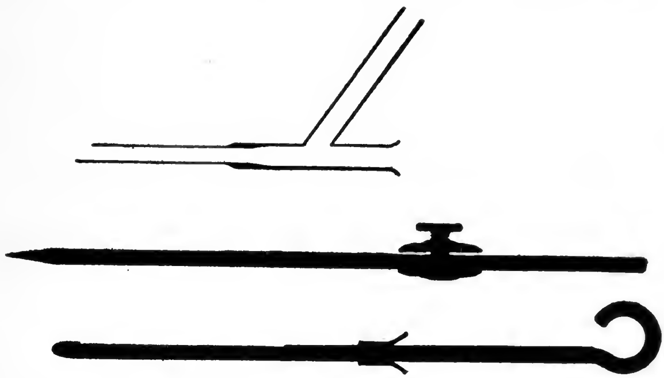

FIG. 3.—RECIPIENT'S CANNULA. Proximal part is of 14k. gold seamless tubing, same diameters as donor's cannula and of similar construction. Into the distal end of this is soldered a platinum-iridium cannula of smaller caliber which may vary in size and length according to requirements. The size found most useful is 15 mm. (0.59 in.) long, 2.05 mm. (0.080 in.) ext. diameter and 1.78 mm. (0.070 in.) int. diameter. Cannulas of smaller diameter may be used for smaller veins and for penetrating the skin. *Obturator* is made of 10k. drawn gold wire of a diameter to fit the platinum cannula and of a convenient length for handling. The stop on the obturator is made to fit into the flared end of the cannula. From a point 5 mm. from the stop to a point near its extremity, a flat surface is ground upon the obturator 0.5 mm. (0.02 in.) deep. When the obturator is fully seated in the cannula, this surface provides a channel extending 0.5 mm. (0.02 in.) beyond the shorter lip of the bevelled end of the cannula when the handle of the obturator is turned in the same direction (see Fig. 6). With this arrangement it is apparent that the distal opening of this channel can be regulated by rotating the obturator within the cannula, and this provides a means of controlling the discharge of salt solution. When fully open, about 60 drops of salt solution will flow per minute with 5 feet of hydrostatic pressure. *Trocar* is made of 10k. gold wire of same diameter as the obturator, and is provided with adjustable stop.

be prepared in readiness) (Fig. 3); needles and silk for suturing skin; hypodermic syringes and needles for local anesthesia. A Michel forceps is also useful for holding the cannulas.

## APPARATUS

One or more pipets, coated with paraffin under sterile precautions and provided with cotton air filters and aspirating tubes as shown in Figure 4. An irrigating apparatus for 2 liters of salt solution with a system of rubber tubing, having a double distribution by means of a Y connection and separate stop-cocks for donor's and recipient's cannulas as shown in Figure 5; or a separate supply of salt solution may be used for donor and for recipient if in separate rooms. An ordinary 2-quart rubber douche-bag may be sterilized and used for this purpose. The salt solution should be prepared as for any intravenous saline infusion and the source of supply should be at a height of from 4 to 5 feet from the outlet. A pneumatic cuff, similar to that of a blood-pressure apparatus but about half as wide, with an inflating pump, is useful for constricting the donor's

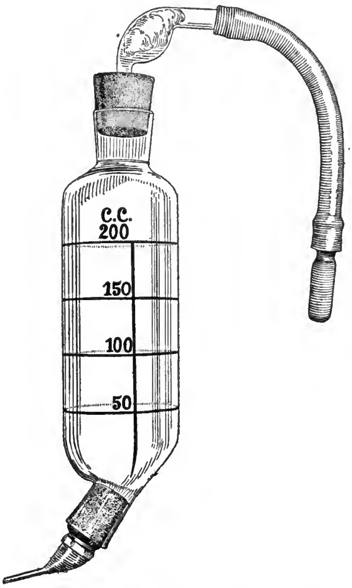


Fig. 4.—Pipet and Aspirating Tube with Air-filter Containing Sterile Cotton.

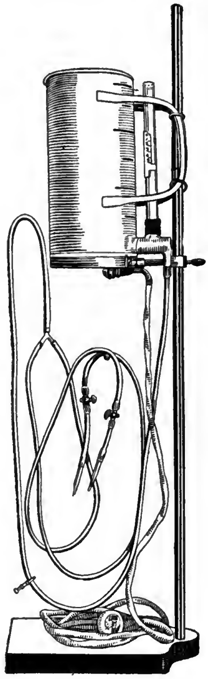

Fig. 5. — Irrigating Apparatus. Copper vessel, heavily tinned inside and outside, of three liters capacity, with outlet made from block tin. Outlet has a larger tubulation above for insertion of glass gauge-tube and thermometer and a smaller tubulation below for attachment of rubber tubing. An electric heating plate serves as a support and is attached by an arm and set-screw to an iron rod, which latter is fastened into a cast-iron foot-piece. A sliding sleeve of celluloid can be moved to any position on the glass gauge and is graduated in c. c. to measure the discharge from the vessel at any level of the fluid.

arm; or a piece of heavy rubber tubing with a large clamp may be used for this purpose.

### OPERATION

The donor's and recipient's vessels are selected for their size and prominence and the close proximity of a valve should be carefully avoided, as this may interfere with the satisfactory action of the cannulas. The field of operation is painted with tincture of iodin and then washed off with alcohol. The veins at the bend of the elbow are usually the most serviceable. If the recipient is a young child the external jugular vein is often the best vessel to select and this may be entered by a small size trocar and cannula without skin incision, or through a very small nick in the skin.

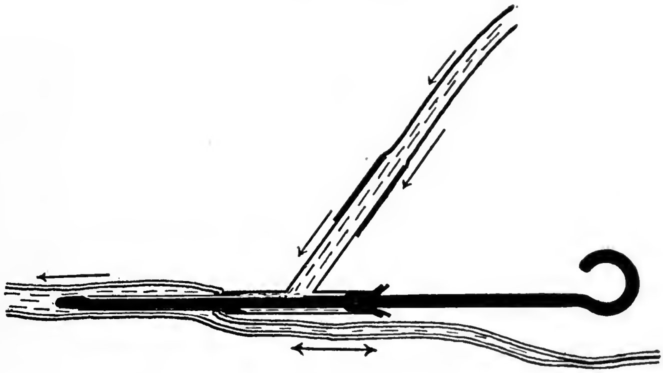

Fig. 6.—Recipient's Cannula with Obturator in Vein. Showing drop-instillation of salt solution.

Local anesthesia for the exposure of the veins in recipient and donor is produced in the usual way with a 2 per cent. novocain solution and about 2 to 3 cm. of both veins are exposed to view and the vessels thoroughly denuded of their fascial sheaths to facilitate penetration.

The recipient's and donor's cannulas are now connected to their respective ends of the irrigation apparatus by rubber connecting tubes of small caliber, all stop-cocks are opened, and salt solution is allowed to flow through the cannulas to expel air. The obturators are then inserted in their respective cannulas, and the cannulas dipped in sterile liquid paraffin. The recipient's vein is first entered with the recipient's cannula in the direction of the current. See Figure 6.

It is important to enter the vein at a point well away from the center of its exposed portion, so that the position and direction of the cannula when inside the vein may be seen and controlled.

The most simple and certain way of entering the blood vessels of both donor and recipient is by means of a small incision through the wall of the vessel. This incision may be made with the point of a small sharp knife. The size of the incision should be gauged according to the diameter of the cannula to be introduced. Another method of entering the blood vessel of the recipient is to pierce it with a trocar which fits the cannula; this, however, requires some force, and therefore is liable to result in more trauma to the vessel wall; the trocar method also requires, with small veins and in cramped situations, some dexterity to enter the lumen of the vessel cleanly on the first trial.

When entrance of the recipient's vein has been effected with the recipient's cannula, the two ends of an elastic band, previously passed under the arm distal

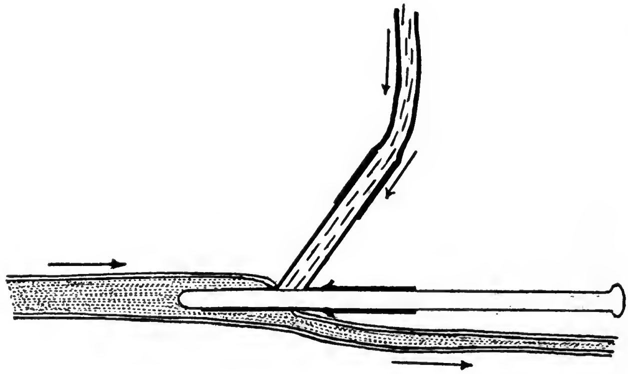

Fig. 7.—Donor's Cannula with Obturator in Vein.

to the incision, are united by a hook over a gauze pad resulting in light compression of the vein just distal to the point of entrance of the cannula. The obturator is then withdrawn and, by covering the flared opening of the cannula with the finger, the flowing salt solution is allowed to flush out the recipient's vein. A moment's flushing will fill the vein with salt solution, and this perfusion is maintained by drop instillation, which takes place automatically when the obturator is replaced in the cannula with the hook turned toward the lateral arm (see description of recipient cannula and obturator, Fig. 3). This exclusion of blood from the vein is to prevent the possibility of clot formation, which may be induced by a prolonged presence in the blood current of the metal cannula.

When the recipient's vein has been prepared with the cannula in situ, the donor's arm is constricted and the operator, through a small incision as already described, penetrates the donor's vein with the donor's cannula against the direction of the blood current (Fig. 7). The mouth-piece of the aspirating tube is next grasped in the teeth, and the pipet allowed to hang thus for a moment while the donor's obturator is withdrawn, using both hands for this purpose. With a clamp or forceps in the left hand steadying the cannula in the vein, the right hand grasps the pipet and introduces its tip (Fig. 8) against the outpouring stream of salt solution, through the donor's cannula, into the blood stream of the donor. The aspiration of blood (Fig. 9) is begun immediately, and suction should be strong enough to get about the maximum flow without undue collapse of the vein wall against the cannula. A speed of withdrawal greater than 100 c. c. per minute should not be attempted. It is well

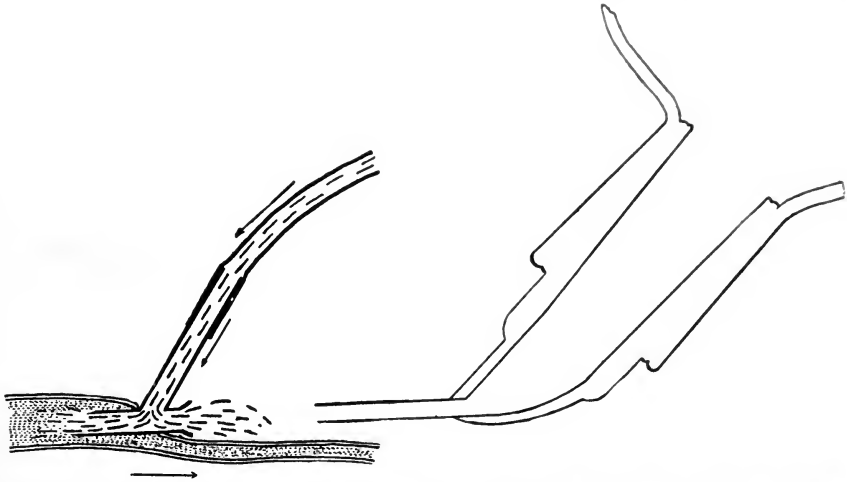

Fig. 8.—Obturator Removed from Donor's Cannula and Pipet About to be Introduced into Donor's Vein.

to mention here that the general precaution should be followed, as in all blood-vessel surgery, of treating the vessels gently in every manipulation; and this is especially true of the donor's vein. A bystander may take the time from the be-

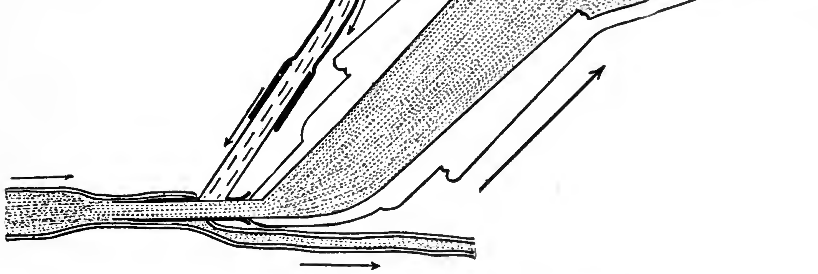

Fig. 9.—Aspiration of Blood from Donor's Vein.

ginning of the blood flow, so that there may be some guide to the speed of withdrawal and delivery.

Two hundred c. c. of blood can be obtained from a good donor in 1½ to 4 minutes and this amount may be delivered through the large and medium-sized cannulas in from 2 to 4 minutes, making a total of 4 to 8 minutes. We have considered 12 to 15 minutes a conservative limit of safety for both paraffin and hirudin methods; and even with 10 minutes as a limit there is an ample margin of time, so that there is no need for haste.

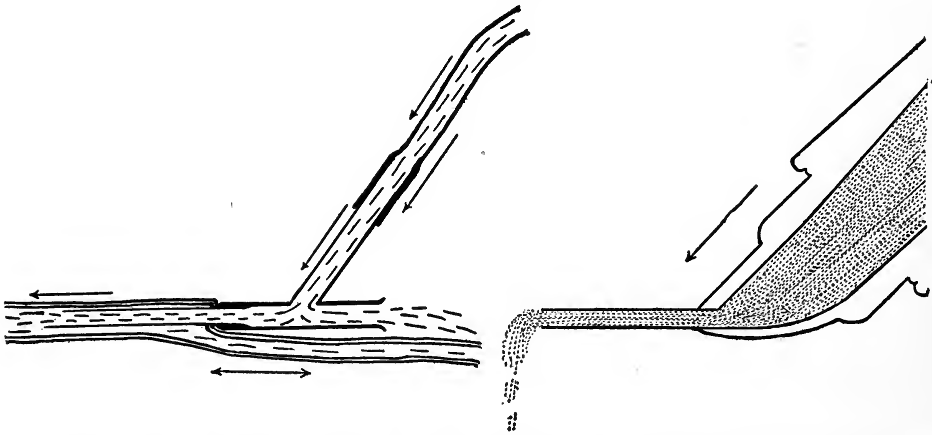

FIG. 10.—OBTURATOR REMOVED FROM RECIPIENT'S CANNULA AND PIPET, FULL OF BLOOD, AT THE MOMENT OF INTRODUCTION.

When the amount required is obtained (200 c. c. or less) the pipet is withdrawn and the donor's obturator inserted, the tip of the pipet being stoppered as soon as withdrawn by a gloved finger of the operator. It is important to stop suction *before* withdrawal of the pipet so that no air bubbles may be

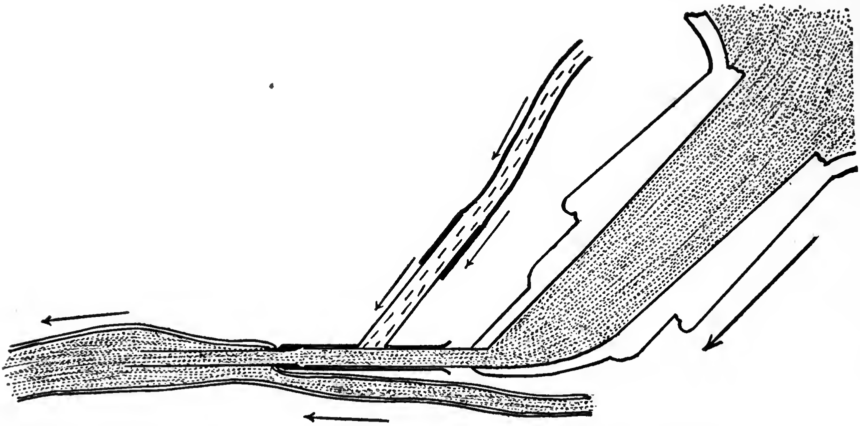

FIG. 11.—BLOOD BEING DELIVERED THROUGH RECIPIENT'S CANNULA.

drawn through the blood at the moment of removal from the vein. The pipet containing the blood is now carried to the recipient, the obturator of the recipient's cannula is withdrawn,[1] and the tip of the pipet is inserted against the

[1] If working without assistance, the recipient's obturator may be extracted by means of a wire hook attachable to the fourth finger of the operator's right hand.

outflowing stream of salt solution into the recipient's cannula. Figure 10 shows the outflowing stream of blood released by the removal of the finger of the operator from the tip of the pipet just at the moment of introduction into the recipient's cannula. Figure 11 shows the tip of the pipet within the recipient's cannula while the blood is being delivered. The last 10 or 15 c. c. of blood are not discharged from the pipet in order to avoid risk of injecting air. When this point is reached the pipet is withdrawn from the recipient's cannula and the obturator replaced.

If more blood is needed, another transfusion may be done in precisely the same way, using another pipet; or an assistant may collect a second pipetful of blood from the donor immediately following the withdrawal of the first pipet. This rapid sequence of withdrawing blood from the donor is of course more expeditious, and is advisable if more than 400 c. c. (2 pipetfuls) of blood are required. Where the interrupted method is followed, care should be taken to remove the constriction of the arm so as to allow a free circulation of blood through the donor's vein during the intervals when the blood is not being withdrawn.

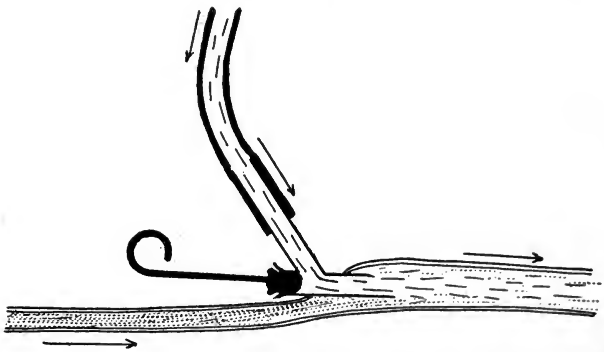

FIG. 12.—USE OF PLUG IN DONOR'S CANNULA WHEN GIVING SALINE INFUSION.

When the transfer of blood is completed, the recipient's cannula is removed and pressure applied with a compress for a few minutes. Pressure and suturing the skin will usually suffice to stop oozing from the vein. If desirable the donor may be given a saline infusion to replace his lost blood, by substituting a short plug in the donor's cannula for the obturator, which stops the outlet of the cannula, but does not shut off the passage of the salt solution through its lateral branch into the vein (Fig. 12).

Hemorrhage from the donor's vein after the cannula is withdrawn can sometimes be stopped by pressure; but usually the puncture should be sutured or tied off laterally with fine catgut. During the course of the operation neither the donor nor the recipient receives more than an inconsiderable amount of salt solution, unless more is desired. It will be seen, however, that with this arrangement any amount of salt solution can be immediately directed into the circulation of donor or recipient if required. In giving salt solution to the donor in any considerable amount it is advantageous to reverse the direction of the cannula within the vein. This may easily be done while the solution is flowing without removing the cannula from the vein.

### PREPARATION OF PIPETS WITH PARAFFIN COATING

The preparation of the pipets and the method of lining them with paraffin should be carefully followed. The threaded bushings of the cylinders are first wrapped with thin asbestos tape and securely seated in the cylinders. The air-filter tubes with cotton filling and the cylinders are then sterilized by dry heat in an autoclave or ordinary oven. The rubber aspirating tubes, mouth-pieces, and perforated rubber stoppers are sterilized by boiling. When sterilized, each cylinder is connected with an air-filter by means of a perforated rubber stopper, and the aspirating tube with mouth-piece is attached. The cylinders are then ready for coating. The rubber stoppers and aspirating tubes should be thoroughly dry before being connected with the cylinders.

The process of coating the pipets must be conducted with aseptic precautions. The coating is best done from a cylindrical vessel, about 3½ inches (8.4 cm.) in diameter and 7 or 8 inches (17.5 to 20 cm.) high, filled to within an inch (2.5 cm.) of the top with the sterile paraffin mixture. The mixture which we have found most satisfactory is:

| | |
|---|---|
| Grübler's filtered paraffin, m. p. 60° to 62° C. (140° to 143.6° F.). | 56 parts by weight |
| Pure white petrolatum........................................ | 44 parts by weight |

This mixture has a melting point of 49° to 50° C. (120-122° F.) and can be sterilized by heating to 120° C. (248° F.) for an hour. We have found that a convenient vessel for melting, sterilizing and holding the paraffin is an electric warmer for a 10-ounce nursing bottle, with heating coil immersed directly in the paraffin.

**First Coating.**—For the first coating the paraffin is heated to from 77° to 80° C. (171° to 176° F.); the neck of the cylinder, with a threaded bushing securely seated in it, is then immersed beneath the surface and the paraffin sucked up into the cylinder by means of a tube, air filter, and mouth-piece to within about 1 cm. of the rubber stopper. The paraffin is maintained at this level until its heat has spread to the cylinder, which is shown by the film over the glass becoming transparent. As soon as this occurs, the paraffin is allowed to flow out and the cylinder is placed aside to cool.

The pipet tips and couplings may be sterilized by boiling or by dry heat. If boiled a short time before coating, they should be freed from moisture before being attached to the cylinder. This can easily be done by drying over an alcohol flame. The coated cylinders may be wrapped in sterile towels and kept in this way until needed, or the pipet tips may be attached and a second paraffin coating applied at once, the completely coated pipets being then wrapped in sterile coverings ready for immediate use.

**Second Coating.**—The second coating, with the tip attached to the cylinder, is done at 60° to 61° C. (140° to 142° F.) by dipping the tip of the pipet beneath the surface of the melted paraffin and aspirating sufficient paraffin to reach about 2 cm. above the neck of the cylinder and immediately expelling it again. When the excess of paraffin which has been taken into the pipet is blown out in this manner, bubbles of air will be seen to escape from the submerged tip of the pipet. The pipet is then raised out of the paraffin, its tip is tilted upward, and air is drawn through it. This latter precaution is to prevent a narrowing of the lumen of the tip by the congealing at this point of the last few drops of excess paraffin. The lumen of the tip can easily be inspected by transmitted light; if it has not a good clear opening it should again be immersed in the paraffin and the operation repeated until satisfactory. It requires very little practice to do this successfully.

## METHOD OF OPERATION WITH HIRUDIN

Oxalated and citrated plasmas are well known in the physiological laboratories and sodium citrate is reported to have been used as an anticoagulant for small quantities of transfused blood. Oxalates and citrates act by fixing the calcium of the blood, which is a necessary factor in spontaneous coagulation. This decalcification is, of course, a change produced by a chemical reaction in the blood, and is, theoretically at least, undesirable. The use of hirudin as an anticoagulant is not open to this objection.

Hirudin is derived from the buccal glands of the pond leech and has been classed by Franz (196) as a secondary albumose. Its physiological properties are variously regarded by different investigators. Morawitz (204) believes that it acts by neutralizing thrombin or prothrombin (thrombogen). Mellanby (203) concludes, from what appears to be substantial experimental evidence, that hirudin contains an antibody for prothrombin and also a very energetic antibody for thromboplastin (kmase).

It may be fairly concluded from the available evidence that hirudin has a decided effect upon the prothrombin-antithrombin balance and that it has a neutralizing action on thromboplastin.

There is considerable literature on the experimental use of hirudin and there are some reports upon its therapeutic use by intravenous injection for eclampsia, but no mention of its use as an anticoagulant for transfusing blood.

From the authors' experimental work it has become evident that hirudin affords a convenient alternative for the paraffin method of transfusion under most circumstances (209). The amount of hirudin necessary with our apparatus is so small that its use may not be contra-indicated even in those pathological conditions where there is already an excess of antithrombin or a deficiency of prothrombin in the circulating blood of the recipient.

Kaposi (200) has given 40 mg. of hirudin to a 2,000 gm. rabbit. Cowie (189) has given 35 intravenous injections of hirudin to a rabbit in doses increasing from 10 mg. to 22 mg. in 26 days and maintained this last dosage until the final injection, the total period of treatment covering 54 days. At the end of this time the animal had gained in weight and was in every respect perfectly well. Bodong (186) has given 23 to 73.25

mg. *pro.* kilogram of body weight to rabbits, and states that it has no influence on the circulation or the respiration, and is in no other way harmful to the animal. Von Hertzen and Ohman (198) have confirmed Bodong's observation in a series of 12 experiments and concluded that hirudin has no disturbing effect upon the heart and blood vessels. Abel, Rowntree and Turner (182) have used very large quantities of hirudin in "vividiffusion" experiments on dogs without apparently impairing the health or normal physiological condition of the surviving animals. Dienst (192) reports that he has given 200 mg. in 50 c. c. of salt solution by intravenous injection to a patient with very severe eclampsia with most excellent results; and Engelmann (194, 195) has reported 17 cases of eclampsia treated in this way with doses of 200 to 300 mg.

In making use of hirudin for transfusion we have employed our regular pipets and cannulas, but have simplified the preparation of the pipets. No coating of paraffin is applied to the cylinders but only to the tip and neck of the pipet. This partial coating is done by aspirating a small quantity of the sterile melted paraffin mixture at a temperature of 70° to 80° C. (158° to 176° F.) just within the neck of the cylinder and expelling it again, with the same precautions against blocking the tip with paraffin which have been mentioned above under *second coating.* This use of paraffin, from the tip to the neck, is primarily to insure an air-tight junction of the pipet-tip with the metal bushing, and of the latter with the neck of the cylinder, but it also has an undoubtedly valuable effect in lessening thromboplastin formation during aspiration of the blood, and permits the employment of a minimal quantity of hirudin.

**Coating the Pipets with Hirudin.**—If the commercial preparation of hirudin is employed, one 10-mg. tube is sufficient to coat from 4 to 5 pipets. The label is soaked off the tube of hirudin, and one end of the tube is well scored with a file to insure easy breakage. At the time of operation the tube is immersed in a small tray of alcohol to sterilize its exterior. The solution of hirudin may be previously prepared or it can be made up conveniently as soon as the irrigation apparatus has been set up. Under sterile precautions 4.5 c.cm. of 0.9 per cent. sodium chlorid solution are run off from one of the irrigating tips into a sterile calibrated cylinder. The hirudin tube is then broken in a piece of gauze like a tube of catgut, care being taken that the hirudin is shaken down into the other end before breaking off the end which has been marked by the file. The hirudin can now be dissolved by adding one or two c.cm. of the salt solution from the calibrated cylinder, shaking well, and washing back and forth until all the hirudin is dissolved. This solution, which has a dilution of 1-450, is transferred to one of the paraffin-sealed pipets, by removing the rubber stopper and air-filter, and pouring in the hirudin while holding the pipet in the horizontal position. The rubber stopper is then replaced, and, while still holding the pipet in the horizontal position with the tip pointing upward, the hirudin solution is flowed over the inside of the pipet, rotating and shaking the latter so that the whole interior is completely and thoroughly wet by the liquid. When this is done the neck portion of the pipet is coated in a similar manner by tilting up the pipet, and the liquid is then allowed to run out of the tip, back into the receptacle in which it was mixed, or else directly into the next pipet which is to be coated. It takes from 1 to 1.5 c. c. of the hirudin solution to coat a pipet in this manner, and when so coated, the pipets are ready for immediate use and should be placed in the horizontal position until required.

With the exception of the preparation of the pipets as noted, the operation with hirudin is conducted in precisely the same way as with the paraffin-coated apparatus.

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# THE SURGICAL TREATMENT OF ANEURYSM

# CHAPTER X

## THE SURGICAL TREATMENT OF ANEURYSM

James M. Hitzrot

The treatment of aneurysm is usually divided into medical and surgical treatment. This chapter has nothing to do with the former, except in so far as measures spoken of as purely medical may act as adjuncts for the preparation for strictly surgical methods.

Among the medical methods usually enumerated, rest in the horizontal position may be considered as an important adjunct in the preparatory treatment for a surgical procedure. Rest reduces the pulse rate approximately 10 beats per minute, or 14,400 beats in the 24 hours. Rest in the horizontal position furthermore reduces the general blood-pressure about 10 mm. of Hg.

Hence rest not only decreases the force of the arterial impact against the aneurysmal wall, but likewise decreases the number of these impacts. With the decrease in the force and number of the impacts, a resulting decrease in the size of the sac may be obtained, and thus rest is of value both in internal and in traumatic aneurysm, preparatory to surgical interference.

Bornhaupt, Saigo, Kikuzi, Makins, and others, advise delay from 4 to 6 weeks, in operating on traumatic aneurysm, and during this period, or a large part of it, rest will materially lessen the discomfort of the patient, and will tend to limit the size of the aneurysmal sac.

The purely surgical treatment includes all forms of external measures used directly on the aneurysmal sac, and includes the application of ice (refrigeration), compression, acupuncture, wiring (with or without electrolysis), ligation, the various constricting appliances to produce gradual occlusion of the artery, Halsted's bands, elastic ligatures, Keen's compressor, Stratton's compressor, etc.; the radical operations on the sac itself, aneurysmotomy with intrasaccular ligation, the operations devised by Matas, endo-aneurysmorrhaphy and aneurysmoplasty; and aneurysmectomy with arteriorrhaphy or angioplasty.

### REFRIGERATION

The application of an ice-bag is used to inhibit the congestion about the aneurysmal sac and is chiefly serviceable in traumatic aneurysm and as a palliative measure in inoperable aneurysms.

## COMPRESSION

Compression may be used as a direct pressure on the aneurysm itself, or indirect pressure, i. e. pressure upon the artery above or below the sac or both.

**Direct pressure upon the aneurysmal sac should never be used inasmuch as compression thus produced is likely to cause results more dangerous than the aneurysm itself.**

Indirect pressure is applied as digital pressure, pressure by instruments, by tourniquet, or by posture (flexion).

Digital pressure is made by a number of assistants working in pairs. Care should be taken to shift the pressure of the digits to different areas of the skin. "Ether or morphin should be used when the patient begins to complain of pain" (Stimson). The application of digital pressure should be divided into a number of sittings of 4 hours each, and should be continued from 24 to 36 hours. After 36 hours, the chances for a cure are very slight, and the treatment, if unsuccessful after that time, should be abandoned (Delbet).

The method is difficult to carry out, and gangrene is prone to occur, especially if the digital pressure is unsteady. "Recovery may be expected in fifty per cent. Gangrene occurs in six per cent." (Matas).

Instrumental compression was practiced by many instruments invented for that purpose for application to the abdominal aorta. It is applicable only in a few selected cases and of little value because the time limit of compression of the abdominal aorta is so short.

**Elastic Compression—Reid's Method.**—This method consists in the firm application of an elastic bandage from the periphery of the extremity up to the sac, then a few light turns of the bandage over the sac, and from the sac continued in firm, even turns well up the extremity so as to compress the artery both distally and proximally. The application is quite painful, and requires an anesthetic (Walsham). The bandage should be kept on for 1 to 2 hours (1 to 1½ hours) and then digital compression maintained on the proximal side of the main artery for from 36 to 48 hours.

Delbet states that it leads to gangrene twice as frequently as digital compression. Stimson states that the method failed to cure in 15 per cent. of the cases.

The method has been modified by Gersuny and Petit, who apply the bandage at intermittent intervals of ½ hour each (intermittent elastic compression).

**Compression by Posture (Flexion).**—This method was successfully tried in aneurysms in the groin, the popliteal space, and the elbow.

In applying the method, the flexion must be sufficient to stop pulsation in the vessels distal to the sac. It is painful, and must be continued from 10 to 14 days to accomplish any result. Delbet states that it leads to rupture of the sac more often than any other form of compression.

**As a whole, compression in any of its forms has little to commend it in com-**

**parison with the more clearly defined surgical procedures. The results are less favorable, the dangers greater and the suffering more marked than would seem justifiable with modern progress along surgical lines.**

## LIGATURE

The use of the ligature is the oldest form of treatment and was practiced by Antyllus in the second and third centuries A. D. (see Fig. 1).

The method described by Antyllus has been named aneurysmotomy by Matas.

It consists in a linear incision over the sac along the course of the artery carried far enough to expose the artery at its entrance and exit from the sac. The vein is then retracted and the artery tied close to the sac at its entrance and exit. When these ligatures are tied, a small incision is made into the sac and its contents evacuated.

With the advent of the Esmarch bandage, that is, in modern times, this form of constriction is applied before proceeding to the operation above described. After the ligation of the main vessel, the bandage is released. Should any bleeding occur due to entering collateral vessels, the bandage should be tightened, and the collaterals tied after dissecting them free or by intrasaccular ligature after the method of Annandale, or the obliterative endo-aneurysmorrhaphy of Matas may be practiced.

Mikulicz modified the Antyllian operation by dividing it into two stages. His first stage consisted in the ligation of the artery on the proximal side (Anel or Desault-Hunter type—v. infra). When the circulation in the sac had decreased and the sac had diminished in size, the sac was punctured by a small incision and the clot evacuated (his second stage).

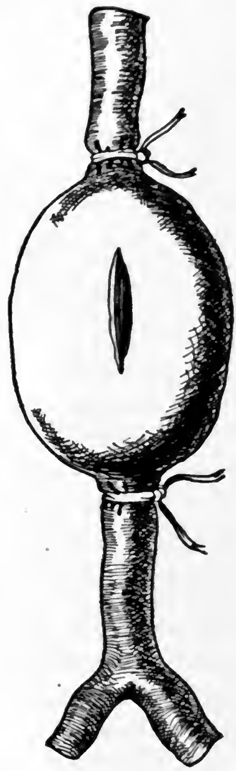


FIG. 1.—METHOD OF ANTYLLUS. Proximal and distal ligation, close to the sac. Incision and evacuation of contents of sac.

This modification of the older method has little to commend it, as pointed out by Matas, due to the occurrence of hemorrhage during the second stage of the operation or hemorrhage following that procedure at a later period.

Philagrius or Purman (1680) further modified the Antyllian operation by the extirpation of the sac after ligation of the vessels (aneurysmectomy).

The steps in this operation to which attention must be paid are preliminary control of the circulation, afferent and efferent, and the identification of the companion vein.

Where possible, the arterial supply above mentioned should be controlled by circular constriction. The vessels are then exposed by dissection and ligated, or the vessels may be controlled by the various clamps described by Crile, Matas, Billroth, etc.

Where circular constriction is impossible (in the neck, for example), the arteries must be exposed by dissection and ligated or clamped, as the case may be.

**This preliminary hemostasis is absolutely essential for the carrying out of the operation and neglect of it may lead to serious if not fatal hemorrhage.**

The identification of the companion vein is often difficult. Koehler has devised the following expedient to render its identification possible. In popliteal aneurysms, for example, he applies a circular rubber bandage below the aneurysm at a sufficient distance to permit of easy access to the sac. From the upper level of this constricting bandage a second rubber bandage is applied in firm circular turns well up to the middle of the thigh, to squeeze out the blood and cut off the circulation beyond it. The lower turns are then released up to the last few upper turns, leaving the region of the sac, and a wide zone about it, completely anemic. If in exposing the sac it is difficult to determine the location or permanency of the vein, the lower bandage is released, and the vein will fill up, thus giving a clew to its location and its permeability.

If the vein is so adherent in the wall of the sac that its dissection is difficult or impossible, Sonnenberg advises leaving behind the piece of the sac to which the vein is adherent.

Matas lays especial stress upon the preservation of the vein and believes that the extirpation of the vein must always be regarded as dangerous to the future vitality of the limb.

Bearing in mind the above cautions, the aneurysmal sac is exposed by free incision and the afferent and efferent vessels exposed. The sac is then dissected free by blunt dissection, care being taken to avoid injury to the veins and nerves which are flattened out on various regions of the sac. If possible the sac should be dissected free intact, and all collateral vessels entering it ligated or clamped before division.

When the sac is freed sufficiently, the main vessels are ligated or clamped and divided and the sac removed.

If any injury to the vein occurs, it should be repaired by suture with very fine silk, if the vein has given evidence of patency. If obliterated, it may be tied.

The upper constricting bandage is then removed, and all bleeding points caught and tied. For success, it is essential that the hemostasis be perfect and absolute, so that a perfectly dry, clean wound is left.

When this is obtained, the wound is closed in layers without drainage and dressed with sterile gauze in such a manner as to avoid any compression of the wound or limb because of the danger of interference with the peripheral circulation.

It is also essential to state that the highest form of aseptic surgical technic is absolutely essential to success.

The dangers incident to the operation are gangrene of a part or all of the limb peripheral to the area of the operation, infection and secondary hemorrhage, and such late effects as edema of the limb, trophic nerve disturbances, pain and limitation of function in the proximal joint, etc.

FIG. 2. — METHOD OF ANEL. Proximal ligation close to the sac.

The postoperative treatment should comprise all methods which will tend to aid in the establishment and maintenance of the collateral circulation.

The limb should be elevated and kept warm. If the extremity remains cold after the second postoperative hour, the limb should be placed in a Bier hot-air apparatus, or in a covered tent and hot air introduced through a pipe, such as is used in giving the hot-air bath to uremic patients.

FIG. 3. — METHOD OF DESAULT AND HUNTER Proximal ligation at some distance from the sac.

When the wound is healed, hot-water baths, especially those containing salt, hot sand baths, static electricity, and gentle massage, should be used to increase the circulation. The proximal joint should be baked and massaged and submitted to gentle passive movements as soon as compatible with the healing of the wound, usually toward the end of the second week.

Active use of the limb, especially the leg in walking, should be prohibited until the circulation is so well established that no marked edema occurs upon standing.

Too early use often leads to irreducible swelling in the limb distal to the zone of operation, and once established, it is not likely to be relieved.

Delbet regards extirpation as the ideal operation, in that the cure is more complete, and gangrene is less apt to occur after extirpation than in the other forms of ligation. Matas, however, does not believe that the ideal has been obtained in extirpation.

**Proximal Ligation.**—Anel (1710) ligated the artery on the proximal side close to the sac without opening the sac. (See Fig. 2.)

Desault, in June, 1785, and Hunter, in December of the same year, ligated the artery on the proximal side at some distance from the sac. Hunter's idea was to place the ligature at some distance from the sac, so that it tied the artery at a point in which the vessel wall was more likely to be normal. Scarpa, in 1819, ligated the artery in Scarpa's triangle for popliteal aneurysm (Scarpa's operation).

From the impetus thus given many more operations for aneurysms were done, and it was discovered that total arrest of the blood stream was unnecessary for a cure. Later it became evident that such failures as occurred were due to the development of a collateral circulation by the way of large branches to the sac. The ligature close to the sac (Anel) is to be preferred in proximal ligation in that it shuts off the circulation at once and thus decreases the size of the sac.

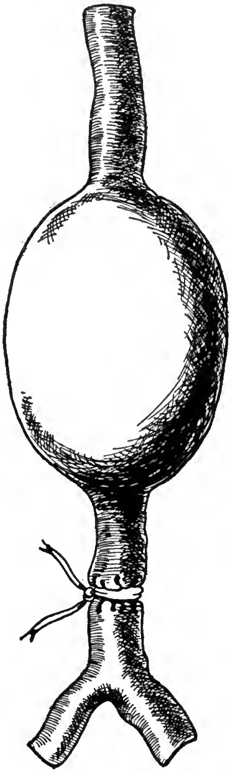


FIG. 4.—BRASDOR'S OPERATION. Distal ligation close to the sac.

**Distal Ligation of the Vessel.**—Distal ligation arose as a result of the treatment for those cases in which proximal ligation was too dangerous or impossible.

The distal ligation close to the sac was suggested by Brasdor about 1790 (Brasdor's operation), but was first practiced by Deschamps in 1798 and Sir Astley Cooper about the same period. The earlier cases were failures. (See Fig. 4.)

In 1825 Wardrop ligated the vessel on the distal side at some distance from the sac, and in Wardrop's cases the ligature was applied to one of the main branches after it had been given off from the parent vessel, i. e. carotid artery in innominate aneurysm. (See Fig. 5.)

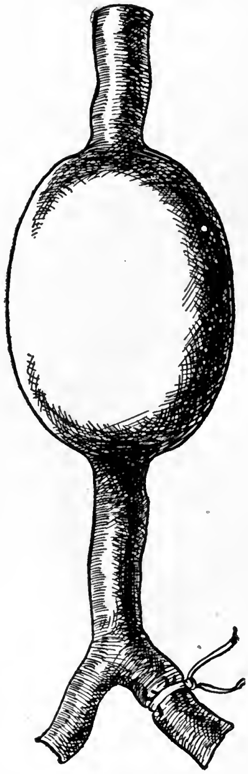


FIG. 5.—WARDROP'S OPERATION. Distal ligation some distance from the sac. Wardrop placed the ligature upon a main branch after it had been given off from the parent trunk.

**Results of Ligation, and Objections to This Form of Treatment.**—"Gangrene, however, remains a serious objection to all methods of ligation" (Matas). The aneurysm may recur after a number of years, six cases collected by Delbet, and eight by Matas. The presence of the sac and its sclerosis, furthermore, may cause pressure on the included nerves with peripheral motor paralysis or peripheral sensory nerve changes, neuralgias, paresthesias, trophic ulcers, etc., which remain until relieved by further operation.

Sub-total, or partial, occlusion of the vessel was suggested by Porta about 1850 for treatment of aneurysm of the large vessels in which total occlusion would be dangerous due to ulceration, gangrene, or secondary hemorrhage.

For this he recommended different forms of partial compression by various instruments, elastic ligatures, or a series of gradually contracting ligatures.

Halsted in 1906 placed the method on a modern surgical basis by producing gradual occlusion of the artery by the use of aluminum bands. He advises the use of bands of 32 to 36 thickness (sheet metal gauge) and has devised a set of instruments for the application of the bands to the vessel.

## NEEDLING

Needling consists in the introduction of a long needle into the aneurysm so that it scratches the intima sufficiently to irrigate it and permit the deposition of a fibrinoplastic exudate upon the injured wall. The needle is left inside the sac for 24 hours and frequently moved from place to place to increase the zone of the irritation.

The method has no practical value because of the uncertainty of its action and the fact that the wall of the sac is usually lined with laminated plastic exudate, which is disturbed rather than increased in the process.

## WIRING

**Moore's Method.**—Moore introduced fine silver wire into the sac with the idea of forming a framework for the fibrin to become deposited upon. Later, iron, steel, and copper wire; catgut (Abbe); horse-hair, fine metal watch springs (Bacelli and Montenovessi) were employed.

The method has certain elements of danger in that the wires, etc., may migrate even into the left ventricle of the heart (Ballance, Parkam, quoted by Matas).

**Wiring with Electrolysis—Moore-Corradi Method.**—Corradi (1879) in addition to introducing the wire as a framework, passed an electric current through the wires, to cause electrolysis of the fluid blood in the sac, and to hasten the deposition of fibrin on the framework formed by the wires. The method is applicable mainly to thoracic and abdominal aneurysm.

Various types of wires are recommended. Silver wire, silver copper wire (Finney and Hunner); gold wire (Stewart), and gold platinum "Clasp" alloy wire (Lusk).

Lusk recommends using a piece of No. 11 wire about 11½ inches long and drawing it out to No. 28 (Brown and Sharpe gauge), which will produce a strand 50 feet long of very resilient wire immune to the solvent action of the electric current.

Lusk furthermore recommends using a gold needle insulated with a covering of porcelain enamel of a caliber just large enough to admit the 28 wire without friction.

Lusk states, "The wire at its introducer extremity should be spirally shaped. To prevent snarling during the introduction of the wire, the spiral extremity, freed from its position of fixation, should first be started through the needle before the binding wire is removed from the coil, after which the binding wire should be removed, and then the loops can be kept from crossing one another by finger pressure over the site of the binding coil, which maintains the orderly arrangements of the loops so that they will unwind without tangling. The grip for holding the coil is to hold it in the middle, ring, and little fingers and the palm of one hand, which leaves the thumb and index finger free for assisting the other hand with the manipulation of the wire. As the wire, thus held, is now introduced, it uncoils from off the hand after the manner of uncoiling a rope. This transmits a twist through the introduced wire with the passage of each loop, which, through the resiliency of the wire, enables the loops to reform within the sac. The technic of passing the wire through the needle should be practiced in the open previous to operation.

The needle should be boiled in distilled water.

The negative electrode should be placed against the back directly over the area which corresponds to the situation of the aneurysm, and should be larger than the aneurysm.

The external portion of the wire should trail over a piece of rubber dam during the passage of the current.

The current should be started at 100 ma. for 15 minutes, and then the current should be gradually lowered to 50, 40, and 30 ma. each for 15 minutes. The positive pole should be attached to the gold wire, and the negative electrode placed upon the back."

The needle should be inserted through a thick portion of the aneurysmal wall. Should hemorrhage occur upon its removal, the wire which was sheathed by the needle should be pulled upon till one of the intrasaccular coils with its attached fibrin is brought in contact with the site of the puncture, when bleeding will stop. Should this fail to stop the hemorrhage, Lusk suggests the passage of a 50 ma. current through the wire for about 3 minutes. (In his experience, the time required to control the hemorrhage never exceeded nine minutes.) The projecting wire is then cut off close to the sac and the skin wound closed.

## ENDO-ANEURYSMORRHAPHY AND ANEURYSMOPLASTY (THE MATAS OPERATIONS)

The operations devised by Matas consist in intrasaccular suture of the opening or openings into the sac to cut off from the sac all vascular communications with it. He divides his operations into three types.

Type 1.—Obliterative endo-aneurysmorrhaphy in which all the openings in the sac are closed by sutures so placed as to completely close the vascular stomata which enter the sac. The method is essentially an intrasaccular ligation of the arteries, which communicate with the sac, and in this first type the parent artery is obliterated by the sutures.

Type 2.—Endo-aneurysmorrhaphy with partial arterioplasty (restorative endo-aneurysmorrhaphy).

This type is suitable for sacculated aneurysms with a s i n g l e vascular opening into the sac. By sutures properly placed, the opening into the sac wall is closed and the continuity of the parent vessel preserved by an arterioplasty done within the sac wall. (Fig. 7.)

Type 3.—Endo-aneurysmorrhaphy with reconstructive arterioplasty (reconstructive endo-aneurysmorrhaphy or aneurysmoplasty). (Fig. 8.)

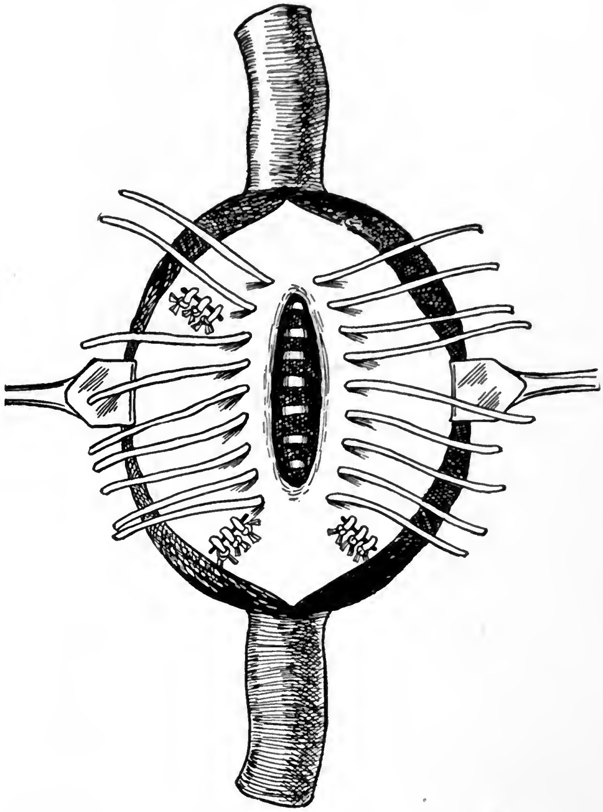


Fig. 6.—Diagram of Obliterative Endo-aneurysmorrhaphy. Note the inclusion of the posterior wall of the artery in the sutures, and also the collaterals closed by suture. (After Matas.)

This variation is applicable solely to fusiform aneurysms in which the sac walls are firm and resistant, and the two openings leading to the main artery lie at the same level and are in close proximity and visible in the bottom of the sac, in a superficial, easily accessible sac.

The essential features of the operation consist in reconstructing a new artery out of the walls of the sac.

A rubber catheter or a biliary hammer of Halsted is inserted into the two arterial openings and fine silk or chromic sutures inserted and so placed as to reconstruct the lumen of the vessel over this guide. Before tying the central sutures the guide is removed, and the sutures are then tied, effectually closing and reconstructing the lumen of the main vessel.

The operations of this type are called for only in cases in which the condition of the sac is favorable for reconstructing the artery, or in cases in which

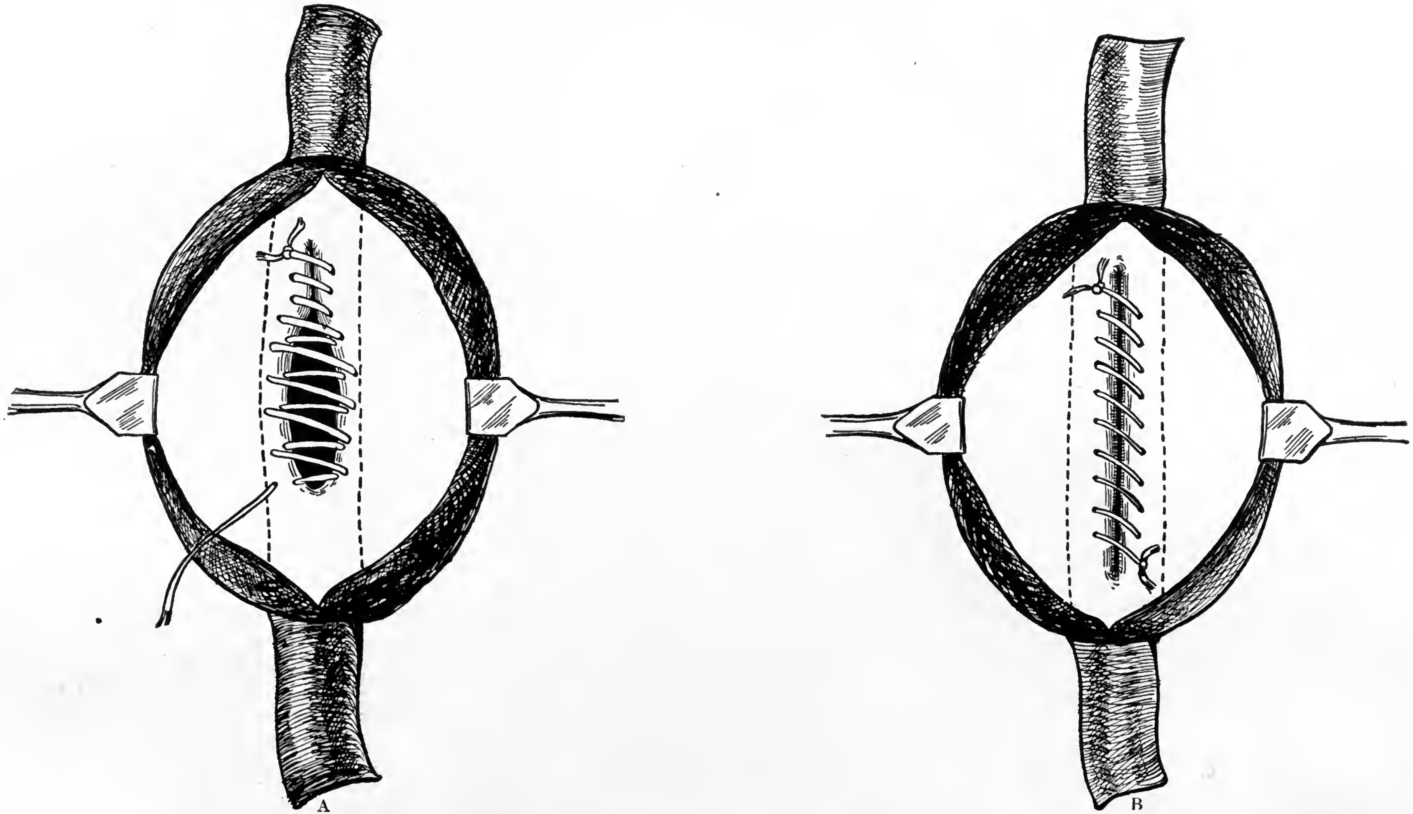
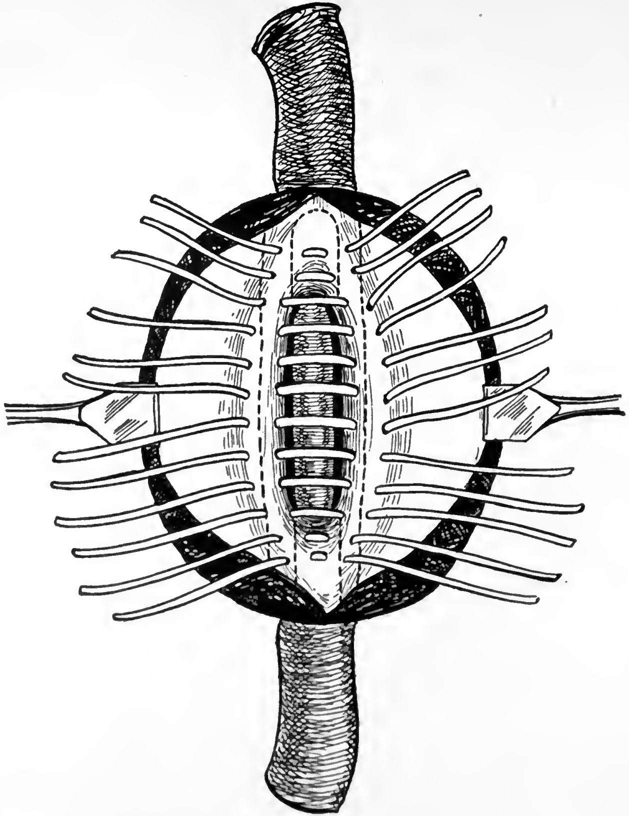



Fig. 7.—Diagram of Restorative Endo-aneurysmorrhaphy. A continuous suture to close the aperture into the sac and to restore the continuity of the artery. (After Matas.)



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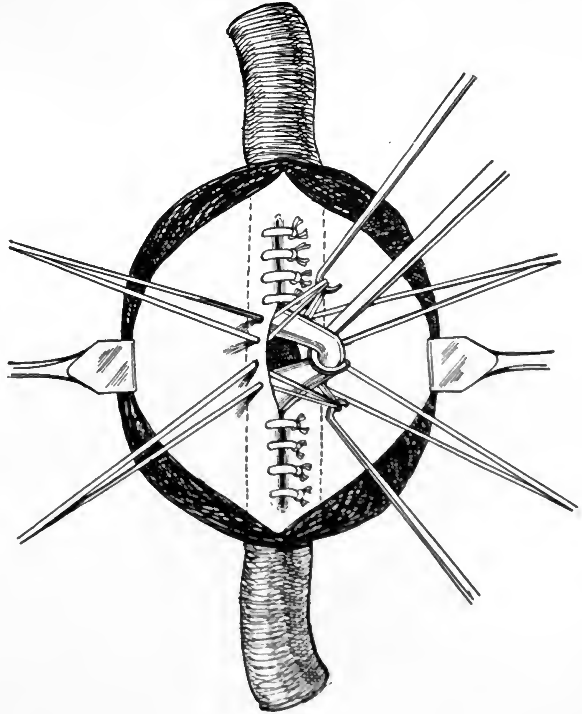

B

FIG. 8.—DIAGRAM OF RECONSTRUCTIVE ENDO-ANEURYSMORRHAPHY. Shows a method of reconstructing the parent vessel from the aneurysmal sac by suture over a guide in fusiform dilatations. A shows the method of placing the guide at the bottom of the sac and the reconstructing sutures. B shows some of the sutures tied and the remainder retracted to allow for the removal of the guide. (After Matas.)

the collateral circulation is insufficient. In the latter condition, although the reconstructed vessel, especially in atheromatous vessels, will function only for a short time, that short period may be sufficient to permit of the establishment of a sufficient collateral circulation. Should a secondary aneurysmal dilatation occur at the side of the reconstruction, an obliterative endo-aneurysmorrhaphy may then be carried out without the previous great danger of gangrene since the collateral circulation will have become established in the interim.

The method is furthermore especially applicable in traumatic aneurysm in which the question of atheromatous change does not enter and in these cases should be as successful as arterioplasty, as carried by the Carrell or other methods and will probably show a no larger number of failures.

The suture material should be fine silk dipped in vaselin, or number 0 or 00 chromic catgut.

The needle best adapted for endo-aneurysmorrhaphy are the half and full curved intestinal needles of the Murphy, Fergusson, or Kirby type, conjunctival needles or the staphylorrhaphy needles of Lane (if the opening is small).

In placing the sutures, a firm bite should be taken upon the sac wall. No attempt should be made to freshen the edges of the sac about to be approximated. As Matas has stated so frequently this preliminary denudation of the margin to be sutured is more apt to cause failure of than to aid in the repair process. The primary layers of sutures should be reinforced if possible by a secondary tier which should be a continuous running suture which grasps and approximates the wall of the sac and draws it over the first tier and reinforces it.

The treatment of the sac after the closure of the arterial stomata by one of the above methods is described by Matas under five different headings.

**1.—Total Obliteration of the Sac by Suture and Inversion of the Skin Flaps.**—The method consists in closing the sac by a continuous stitch which begins at one pole and is whipped across the sac wall to the opposite pole until that portion of the sac wall included in the suture is completely approximated in the midline. A sufficient number of layers of these sutures are applied to bring the closure of the sac wall close to the surface. When this step is completed, any excess of the sac is folded upon itself and stretched together by stitches which pass through the skin and are tied upon a gauze roll, and the superimposed skin closed by a suture which includes the linear approximation of the sac wall (see illustration).

If the dead spaces are carefully obliterated, no drainage is necessary.

**2.—Total Obliteration of the Sac by Suture, Leaving the Sac Buried in the Wound.**—This method is applicable to small aneurysms deep in the tissues in which the skin flaps are not large enough to invert. The closure of the arterial opening and the superimposed layers of stitches are placed as in the first method and the skin and other tissues are closed in layers upon the sac.

**3.—Lining the Wall of the Sac with Skin Flaps or Grafts.**—In this method the sac is not obliterated but the skin is mobilized and the edges tacked down to the bottom of the sac in a manner similar to that used by Neuber in bone cavities. If the flaps are insufficient, the areas left may be covered by skin grafts, either at the time of the operation or at a later date when granulations have formed. Matas suggests using pedunculated flaps as a possible covering for the sac in certain cases, but the method would seem of doubtful utility in view of the disturbed circulatory conditions which exist in the skin about the sac wall. A sloughing flap would, I believe, be more dangerous than open packing of the wound.

The method is applicable to large aneurysms with rigid walls, and especially in popliteal sacs which are adherent to the femur and the ligaments about the knee joint.

**4.—Partial Obliteration of the Sac, Excision of the Superfluous Portions of the Sac and Packing the Space Left by Gauze Saturated with Balsam of Peru.**—The method is adapted to ruptured or infected sacs with irregular diverticulæ which do not permit of obliteration by any of the foregoing methods.

This method was successfully used in a case of the writer's in which there was a traumatic aneurysm of the profunda femoris in a subtrochanteric fracture of the femur. The circulation was controlled by digital pressure of the femoral against the pubis, the sac opened, the clots evacuated, and the ragged lateral tear in the vessel closed by the obliterative suture described under obliterative endo-aneurysmorrhaphy. Since a large part of the sac was formed by the femur and the callus thrown out about the angulated overriding fragments, it was not possible to obliterate any except a very small portion of the sac just adjacent to the suture line in the artery. The wound was packed and healed by granulation without subsequent trouble.

**5.—A Method Used for Intraperitoneal Cases (Iliac Aneurysms).**—The method resembles the third method above described except that the peritoneum is used to obliterate the sac instead of the skin.

The methods devised by Matas are applicable to all forms of aneurysms in which primary hemostasis is possible, and have all the advantages of the Antyllian operation without any of that operation's dangers or disadvantages. As an operative procedure, the technical details are not as difficult as ligation and extirpation, and the results of the Matas operation are better than those derived from any form of ligation.

It is essential to emphasize one detail, namely, the preliminary hemostasis. This may be obtained by elastic constriction on peripheral vessels; by preliminary exposure of the main vessel and hemostasis by temporary clamping of it close to the sac in axillary, subclavian, carotid, and other aneurysms close to the trunk (Matas uses a special clamp but states that the ordinary long, curved elastic intestinal clamps of the Doyen model are equally satisfactory); in gluteal, sciatic, and obturator aneurysms, by a temporary ligation of the common iliac.

For statistical reports the reader is referred to Matas' articles. In the writer's limited experience (3 cases), the method left nothing to be desired, and

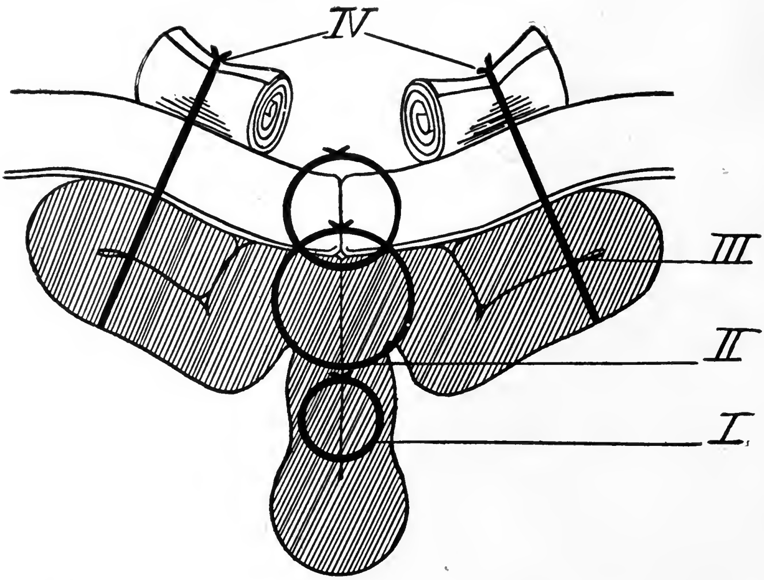


Fig. 9.—Diagram of Method of Obliterating the Sac in Obliterative Endo-aneurysmorrhaphy. I—Sutures obliterating the opening into the sac and the parent vessel. II—Superimposed layer of sutures which reinforce the first tier and reduce the size of the cavity. III—Row of stitches which approximate the skin to the enfolded layers which have been previously placed (I and II). IV—Stitches passed through the sac from without inward to approximate the portion of the sac not obliterated by the previous sutures, and at the same time to approximate the skin to the sac. (After Matas.)

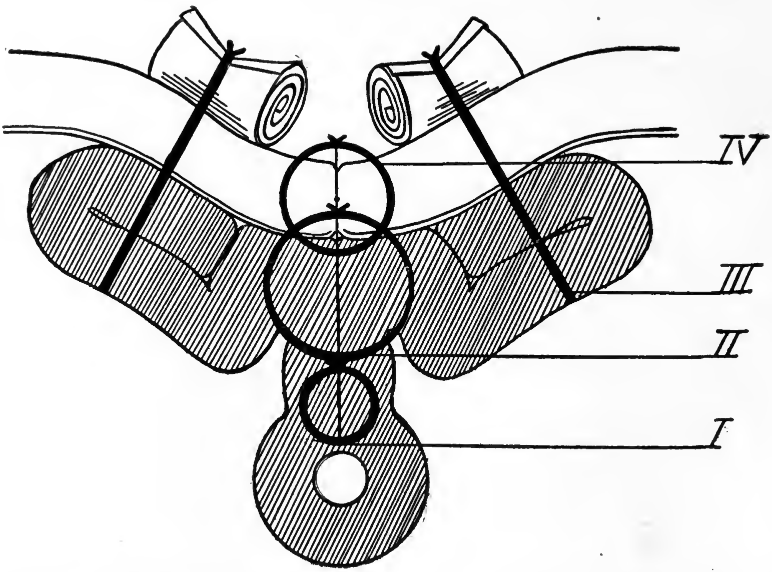


Fig. 10.—Diagram of a Method of Obliterating the Sac in the Restorative and Reconstructive Operations. I—Line of sutures which close the opening into the sac and restore the continuity of the parent vessel. II, III, IV, are similar to those described under method in Figure 9. (After Matas.)

may be said to do all that Matas has claimed for it. The mortality is stated by Matas to be 2.3 per cent., and gangrene occurred in 1.1 per cent., in cases in which the veins were not ligated, and 4.4 per cent. when the vein was ligated.

Relapse occurred only in the reconstructive cases, 28.9 per cent., so that relapse is much more common in the reconstructive type.

Matas states that the method cannot eliminate the dangers of gangrene from thrombosis and embolism, but that the method does not show these complications any more frequently than the method of ligation.

The method furthermore is not applicable to intrathoracic or intra-abdominal aneurysms, and in these, wiring with electrolysis or the Halsted aluminum bands would find their greatest field of usefulness.

## ANEURYSMECTOMY

### IDEAL ANEURYSM OPERATIONS

Under the term ideal aneurysm operations Lexer groups those which remove the sac and at the same time restore the continuity of the vessel, artery or vein or both, by varying forms of suture.

Omi collected 21 cases in which the so-called ideal operations for aneurysm have been done, which include four cases of his own. He summarizes the types of the operations under the following headings:

1. Lateral suture of the artery alone (Heller).
2. Lateral suture of the artery with ligation of the vein (Garré, Meissner, Omi).
3. Lateral suture of the artery and the vein (Körte).
4. Circular suture of the artery alone (Ziembicki, Oppel, Enderlen, Lieblein, Einer Key, Omi, Ribera).
5. Circular suture of the artery and ligation of the vein (Stich).
6. Circular suture of the artery with lateral suture of the vein (Murphy).
7. Circular suture of the artery and vein (Lexer, Auvray).
8. Free transplantation of vessels to repair the deficiency in the artery (Lexer, Omi, 2 cases).
9. Circular suture of the central end of the artery to the peripheral end of the vein and the reverse (Goyanes).
10. Circular suture of the vein and running stitch to close the opening in the artery and vein (Küttner).

Jeger adds to this list:

1. The end-to-side anastomosis of a piece of vein on the proximal and distal sides of the involved vessels (artery or vein) so that the circulation might pass by this method to the periphery until the collateral circulation was established (Jeger and Israel).
2. The implantation of a small artery cut longitudinally, folded crosswise on its long axis, sutured crosswise at the cut end so that the lumen of the trans-

plant is equal to that of the larger vessel and the transplant thus formed may be then sutured by a circular end-to-end suture to fill in the gap in the larger vessel (Jeger and H. Joseph).

Tscherniachowski has collected all the cases in which the above procedures for the treatment of aneurysms have been carried out up to July, 1913, and gives a fairly successful list of such undertakings.

The literature complete to that date is appended to his article.

His collected cases number 47. The operative procedures are enumerated as:

1. Lateral suture of an artery, 16 cases [Marchant, Peugniez, Le Fort, Garré, Swiatecki, Ziembicki (2 cases), Morestin, Sencert, Tichow (2 cases), Heller, Bramann (2 cases), Meissner, Jaboulay].

The result in the 16 cases (Jaboulay's case was added after the publication of Tscherniachowski's paper) was a cure in 13 cases, death in 2 cases, and result not stated in 1.

2. Lateral suture of a vein, 7 cases (Lissianski, Spisharny, Veauiu, Du Verger, Pollard, Neck, Palla, Aubert).

One case (Neck) was an aneurysmal dilatation of the femoral vein and the artery was not involved. The artery in each of the 6 other cases was ligated and the involved area excised with the sac. A cure resulted in all.

3. Lateral suture of an artery and a vein, 9 cases (Körte, Wiesinger, Potherat, d'Antona, Abalos, Auvray, Doyen, Zeidler, Küttner).

A cure resulted in 8 of these cases. In 1 case (d'Antona) infection of the wound occurred and amputation of the extremity was done.

4. Circular suture of an artery, 8 cases (Dauriac, Stich, Goibet, Lieblein, Key, Omi, Oppel, Gellert).

In this series 1 case died (Dauriac's), 7 cases were cured. In 1 of the cured cases there was weakness in the infected limb (Stich's). Necrosis of the terminal phalanx of the thumb occurred in 1 case (Oppel's).

5. Circular suture of an artery and vein, 4 cases (Murphy, Lexer, Enderlen, Tscherniachowski).

All the above series were cured.

6. Transplantation of vessels, 3 cases (Goyanes, Lexer, Pirovano).

In this group there were 2 deaths and 1 recovery (Goyanes).

The regional situation in which the above operations were undertaken are: Axillary artery in 4 cases; brachial in 5 cases; radial in 1 case; external iliac in 1 case; superficial femoral in 23 cases; popliteal in 13 cases (1 case in Tscherniachowski's collection, Neck's case, was a venous varix).

In the cases treated by the above methods death occurred once in the external iliac (100 per cent.); once in the 23 superficial femoral cases (4.3 per cent.); twice in the 13 popliteal cases (15.38 per cent.); once in the 4 axillary cases (25 per cent.).

Gangrene occurred in one of the axillary cases, amputation was necessary in one of the popliteal cases, and there was considerable disability in the limb in one of the superficial femoral cases.

The above forms of aneurysmectomy with the various types of arteriorrhaphy, phleborrhaphy, and vessel transplantation are limited in their application and in the major number of the above cases were done on readily accessible vessels. The mortality in the cases of popliteal aneurysms submitted to the ideal operation (15.38 per cent.) does not compare very favorably with the low mortality of the Matas operations (1.6 per cent.).

In the other regions there is very grave question as to the essential value of the proceeding. The chief objection to the performance of any of the above types of operation lies in the enormous disturbance to the collateral circulation necessary to the performance of the given operation.

In carefully selected cases, in superficial, easily accessible, healthy vessels, there will probably be a definite field for this type of radical surgical treatment of aneurysm.

### THE TREATMENT OF ARTERIOVENOUS ANEURYSMS

All the various forms of the treatment of aneurysm have been used for this special class of aneurysms.

Compression and ligation have been particularly unsuccessful (Stimson, Matas).

Rest, both general and local, together with some form of proximal compression, has been strongly advocated by Makins, Kikuzi, Saigo, etc., as a preliminary to operation. A few cases may, by this means, undergo spontaneous cure. If the aneurysmal sac, however, shows signs of increasing in size operation is indicated.

The ideal operations previously discussed will probably find their greatest field of usefulness in this form of vascular tumor, especially in the recent cases (see Ideal Operations).

In the older cases and in the recent ones in which the dissection necessitated by an ideal operation would in the given case disturb the collateral circulation more than would seem wise, the Matas operations or the intrasaccular suture of Annandale are preferable, while in selected cases in the smaller peripheral arteries ligation and excision of the sac are the simplest and safest operative procedures.

## THE TREATMENT OF SPECIAL ANEURYSMS

### THORACIC ANEURYSMS

With the advent of the X-ray, the diagnosis of thoracic aneurysms has been rendered easier, and the type and size of the sac can be more readily determined than was previously possible.

Whether the ability to recognize the location and the character of the sac (whether saccular or not) will lead to a greater use of surgical treatment in thoracic aneurysm is one of the problems of vascular surgery.

For aneurysm in the above location, wiring with electrolysis (Moore-Corradi) has many advocates. Ransohoff, Stewart, Hunner, Matas, Finney, Hare, Lusk, and others are ardent advocates of the method; while Freeman, Jacobson, Rowlands, and others do not believe the benefits obtained are commensurate with the dangers of the operation.

Finney and Lusk in their recent publications have given the essential features of this form of surgical procedure. The facts herein stated, and those in the general statement on wiring, are obtained from these publications.

The essential details are a rigid asepsis, appropriate wire (see Lusk's description as given in the general statement of treatment in this article), a constant current, rheostat, ammeter, etc., the use of morphin, and local infiltration anesthesia.

The method is applicable only to aneurysm with a definite sac, i. e., sacculated aneurysm, and to this form only in the ascending, the transverse, and to a lesser extent in the descending portion of the thoracic aorta. It is not applicable to aneurysms of the fusiform variety.

The character of the needle varies with different observers. Finney uses a hollow needle not too large in caliber, insulated to within a short distance of the point by the best quality of French lacquer. Lusk recommends the gold porcelain-covered needle, described above.

The wire receiving the most use is that advised by Hunner (75 parts of copper to 1,000 of silver). Lusk from his experiments concluded that the gold platinum alloy "Clasp" wire (gold 62.9 per cent., silver 17.9 per cent., platinum 13.4 per cent., copper 5.8 per cent.) was the most desirable.

The amount of wire to be inserted is usually stated as ten feet. Freeman believes that the greater the amount of wire inserted the better, but Finney states that his observations have not borne out the above statement, but that wire in excess of 10 feet has prevented the contraction of the clot which resulted from the electrolysis.

The needle should be well insulated to prevent an electric burn along the track of the needle.

The strength of the current should not exceed 75 ma. (Finney) and the current should be used for at least 1 hour. In his later cases Finney continued the current for nearly 2 hours. Lusk suggests the use of a current of 100 ma. for 15 minutes, then 50 ma., 40 ma., and 30 ma., each for 15 minutes, and states that he found the current used in these strengths and for the above periods of time as the most favorable for the production of the fibrin.

The passage of the wire through the needle should be so carried out that the coils come in contact with as much of the sac wall as possible. After the current has been used the needle is withdrawn and the wire cut off close to the sac, and the projecting end of the wire buried beneath the entire thickness of the skin so that it does not lie immediately under the skin wound.

To prevent hemorrhage along the track of the needle Lusk recommends the procedure described under wiring in the general statement of that method in this article, and it would seem that his procedure would be more serviceable and less dangerous than the pressure recommended by Finney.

The after-treatment should consist in thorough medical treatment, especially rest and the avoidance of any strain likely to increase cardiac tension, and the use of potassium iodid in 5 to 15 gr. doses thrice daily.

**Result of the Operation.**—Esher collected and tabulated 38 cases up to 1910. Bernheim added 21 cases to that number, including 18 unreported cases of Finney's, a total of 59 up to 1912 which have been submitted to wiring.

Of Finney's personal cases eight were abdominal and will be discussed under abdominal aneurysm. Twelve were thoracic and, inasmuch as this surgeon's experience has been so large, a study of the results obtained by him would seem more profitable than a compilation of all the reported cases with their results if any practical information is to be gained with regard to the utility of the foregoing method.

Of Finney's 12 thoracic cases submitted to wiring, 5 were submitted to second operations, i. e., 17 wirings were done. No cases were reported cured, but one case was living 3 years after the operation.

Eight cases were reported as improved. In one case the improvement has lasted thirteen months and the patient is still well. The improvement in 4 cases varied from 4 to 9 months. In the remainder the length of improvement is mentioned only up to the time of discharge from the hospital, 13 days to 6 weeks, and is too short for any definite idea as to the relative merit of the wiring.

Three cases were not improved in any way and 1 case died within a few days after the wiring as a result of a bronchopneumonia. In that case the wire was covered by a laminated clot.

The chief relief was obtained in the decrease of pain. In 8 it was absent after the wiring; in 3 cases it was markedly diminished; and in 1 there was no change. The pulsations diminished in 7 cases and the tumor decreased in size in 5 cases.

The complications which may ensue are:

1. An electrolytic burn along the course of the needle.

This may occur if the needle is not properly insulated. The slough which results may permit hemorrhage along the track of the needle or the sac may actually rupture as result of the area of weakness thus produced.

2. Charring of the sac by the use of too strong an electric current (Halsted's case). Secondary hemorrhage occurred as a result of the subsequent necrosis about the charred area.

3. Embolism as a result of pieces of the fibrin becoming dislodged and swept into the peripheral circulation.

Embolism occurred in the brachial in a case quoted by Finney in which gangrene of the forearm and hand occurred, necessitating amputation.

Salinger reports a case of cerebral embolism on the third day after wiring an aortic aneurysm with recovery of the patient.

4. The passage of the wire into the heart. Parkam reports a case in which this occurred without fatal results.

5. Infection about the needle wound or in the extravasated blood.

6. Finney states that the newly formed clot may shunt the blood against a portion of the aneurysmal wall, cause it to bulge at the point of impact of the arterial stream and even to give way and result in fatal hemorrhage from this cause.

## The Use of the Ligature in the Treatment of Thoracic Aneurysms

Temporary ligation of the thoracic aorta has been unsuccessfully tried in 2 cases, Tormi and Villar, quoted by Boinet.

Ligation of the aorta below the arch was done by Guinard through a posterior thoracostomy. Death supervened due to complete arrest of the urinary secretion. According to Matas this is the pertinent reason why ligation of the aorta above the renal arteries always proves fatal.

Ligation of the peripheral arteries distal to the sac (Wardrop) in the treatment of the aneurysm of the arch of the aorta.

The procedures advised for this method may be divided into various groups as follows: ligation of the common carotids, right and left; simultaneous ligation of the right common carotid and subclavian arteries; ligation of the right common carotid followed after a suitable interval by ligation of the right subclavian; ligation of the left common carotid and left subclavian, either simultaneously or at two sittings; simultaneous ligation of the left common carotid and the left axillary artery.

(This method has been applied not only to aneurysm of the arch of the aorta but to cases involving the branches of the aorta and no attempt has been made here to separate the groups in the statements from Jacobsthal and Guinard inasmuch as it is difficult to distinguish some of the forms.)

Jacobsthal reports 44 cases in which one or more of the above operative procedures were applied with 23 recoveries. Only 3 cases survived for 3 years.

Guinard reports 15 personal cases. He recommends simultaneous ligation of the right common carotid and subclavian and insists upon the ligation of the carotid as the first step in the operation.

In Guinard's experience the results are better in those cases in which the aneurysmal sac is farthest from the heart. He furthermore states that from his experience distal ligation will give some benefit in all the cases in the region under discussion.

Boinet and Matas believe that the use of distal ligation should be reserved as an operation of necessity for aortic aneurysm and should only be employed when medical measures have failed and the increase in the size of the aneurysm produces pressure symptoms which promise to result fatally.

Kümmell reports a case of aneurysm of the descending aorta in which he sutured the opening in the vessel after temporary control of the circulation. He exposed the artery through a posterior thoracotomy wound such as is used to expose the esophagus. His case died from secondary hemorrhage which he thinks could have been prevented by not packing the wound and by reinforcing the suture line by a fascial transplant.

### ANEURYSMS OF THE ABDOMINAL AORTA

**The Ligation of the Abdominal Aorta.**—The abdominal aorta was first ligated by Sir Astley Cooper in 1817. According to Matas it has been done 15 times since then and in all of these cases it has resulted fatally.

Keen (1899) ligated the abdominal aorta close to the pillars of the diaphragm. His case survived 48 days and died as a result of ulceration and rupture of the aorta at the site of the ligature. In his remarks on his case Keen considers it remarkable that there was so little change in the urinary secretion in his patient. The early establishment of collateral circulation after ligation of the aorta he considers as due to the previous establishment of the collateral circulation caused by the existence of the aneurysm. As a result of the collateral circulation thus established, the human subject can survive ligation of the abdominal aorta without gangrene of the limbs or paralysis of a permanent nature from changes in the cord. But he states further that "death will result from the cutting through of the ligature and secondary hemorrhage in all cases in which this method is applied."

It is needless to state that the condemnation of Keen is a sufficient contradiction against the performance of ligation for aneurysm of the abdominal aorta.

**Temporary Compression of the Abdominal Aorta.**—1. BY A TOURNIQUET.—Temporary compression of the abdominal aorta by means of a tourniquet was devised by Murray in 1864 and used by him successfully.

Barwell reported 5 successful cases up to 1889. Death usually occurs from injury to the intestines underlying the tourniquet and as stated under the paragraphs on compression in general the method has little to commend it at this time.

2. BY THE USE OF INSTRUMENTS APPLIED TO THE ARTERY THROUGH A LAPAROTOMY WOUND.—Keen as a result of his experience with ligation devised a clamp so constructed as to cause a conical constriction of the artery.

By means of this instrument applied to the abdominal aorta through a laparotomy wound the circulation may be partially or completely arrested for any length of time according to the effect of this occlusion upon the patient and the aneurysm. When the occlusion has been satisfactory, the clamp should be removed.

Keen reports the results of animal experimentation with the clamp and from them concludes that the clamp might have a field of usefulness in the treatment of abdominal aneurysm.

Stratton has devised an instrument so constructed that a band of tape can be gradually drawn tight about the aorta, thus gradually constricting it, and recommends its use in abdominal aneurysm. Like Keen's compressor the instrument is left in situ during the period of compression and is removed when it has served its purpose.

The idea in both is to compress the artery gradually on the proximal side so that a collateral circulation may develop before the blood stream is completely arrested.

3. BY METAL BANDS APPLIED TO THE ARTERY.—The Halsted aluminum bands are also devised for the gradual occlusion of the artery in abdominal aneurysm. Experimentally these have proved most satisfactory and their application to the human should be followed by similarly successful results.

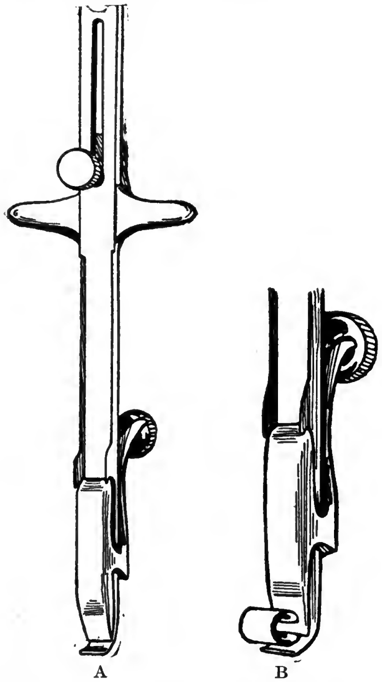

FIG. 11.—HALSTED ALUMINUM BANDS. A shows clamp for the application of the aluminum band of Halsted. B shows band on the jaw of the instrument in the process of being curled about the vessel. Further compression of the band to the desired degree of obliteration of the vessel is done by the finger. (After Halsted.)

Intrasaccular suture (Matas' operation) has been done by Lozano, Munro, Crile, and Gibbon. All of these were failures due to hemorrhage. Matas states that the operation is distinctly contra-indicated in aneurysms above the renal artery and all cases where free access to the sac and complete preliminary control of the circulation are impossible.

The result of any operation upon abdominal aneurysms will depend upon the strain thrown upon the heart. Katzenstein and Oppergeld have shown that ligation of the abdominal aorta below the inferior mesenteric artery is accompanied by such an enormous rise of blood-pressure on the proximal side of the ligature that except in absolutely healthy hearts acute cardiac dilatation occurs and death may result from this cause.

As stated by Keen, the ligature will cut through in all cases and death will result from hemorrhage.

Wiring of abdominal aneurysms occurred 8 times in Finney's series. The technic is similar to that described under thoracic aneurysm. Two cases were improved slightly without any definite change in the aneurysm; 1 was not improved; and 5 cases died. The cause of death is not given in 3, but occurred within a short time after the operation. In 1 case death was due to the rupture of the sac, in the other death occurred as a result of infection about a previously placed Halsted metal band.

Halsted, Nassetti, Matas and Allen have suggested the application of various methods which have a proven experimental basis for the treatment of thoracic and abdominal aneurysms.

Nassetti suggests the use of free fascial transplants so applied as to constrict the lumen of the vessel either above or below the sac.

Halsted has used strips of aorta either as a circular cuff or in his later experiments as a spiral strip so applied as to constrict the lumen of the artery and hence the force and quantity of the blood stream beyond the constriction.

Matas and Allen in some experimental efforts upon plication of the thoracic aorta by lateral parietal suture in dogs believe from their results that this method of narrowing the lumen of the vessel is a safer and more certain way of constricting the lumen of the vessel than can be obtained by metal bands and believe that it may find a field of usefulness in the reduction of the fusiform, cylindrical or saccular aneurysms, either by strengthening the wall of the sac by this plication applied to the sac itself or by plication of the artery above or below the sac to reduce the vis a tergo of the blood stream to the sac. They further suggest that the use of free fascial flaps (Nassetti) or the strips of the aorta (Halsted) to narrow the lumen of the vessel immediately above the vessel should find a greater field of usefulness in producing a partial occlusion of the artery above or below the sac and a reduction in the size of the aneurysm by this method pending the development of a collateral circulation. When the latter has developed further occluding methods might be carried out with a more reasonable assurance of success.

One is forced to conclude that the treatment of abdominal aneurysm as yet has not reached its solution. Whether the operation of the future will comprise the newer methods of fascial or arterial strip occlusion (Nassetti, Halsted), or the plication method of Matas and Allen, is as yet undetermined. The success obtained by their use in animals suggests a possibility that they may solve the problem of the surgical treatment of abdominal aneurysms in man.

### ANEURYSMS OF THE RENAL ARTERIES

Keen collected 12 cases of aneurysm of the renal artery and reported 1 of his own in 1900.

The treatment advised by Oestreich and emphasized by Keen is extirpation of the kidney with the aneurysm.

Three cases were submitted to operation and all recovered.

### INNOMINATE ANEURYSMS

The treatment of innominate aneurysm is practically limited to the use of distal ligation and wiring with electrolysis. Acupuncture, wiring, and the proximal ligation have been discarded for reasons which have been discussed under the general treatment.

The method of wiring with electrolysis has been sufficiently discussed under thoracic aneurysm and does not differ from that given for use in innominate aneurysm.

The method of election in the treatment of aneurysms in the innominate artery is distal ligation (Wardrop) of one or more of the branches of this vessel, i. e., simultaneous ligation of the right common carotid and the right subclavian. The right common carotid should be tied first, then the right subclavian. Jacobsthal states that only 2 of the cases of the 120 known to him which have been treated by distal ligature have lived for more than 3 years and regards the prognosis as very unfavorable. Imbert and Pons give the results as collected by them as apparent cures, 22 per cent.; failures to influence the growth of the aneurysm, 30 per cent.

The complications to be dreaded most are cerebral softening due to the ligation of the common carotid, and secondary hemorrhage.

The Halsted band may have a field of usefulness in preventing such cerebral complications by its application to the carotid, with gradual occlusion of that vessel, which might be made permanent after a suitable interval. Partial occlusion by the fascial strip (Nassetti) or the spiral arterial strip of Halsted may find a field of future usefulness.

Infection of the wound (21 wound infections in 51 operations), while a common occurrence in Burns' statistics, did not apparently affect the outcome.

## COMMON CAROTID ANEURYSMS

The operative treatment of common carotid aneurysm is limited to proximal or distal ligation of the artery, the Antyllian operation, extirpation of the sac, the Matas operations, and the use of the Halsted metal bands, or in special cases by some form of clamp so constructed as to cause gradual occlusion of the vessel.

The proximal ligation (Anel) or the application of a metal band or clamp to the proximal side of the aneurysm is limited to those cases in which there is sufficient space between the aneurysm and the origin of the common carotid from the innominate or the aorta as the case may be.

The use of the double ligature with evacuation of the clot (Antyllus), extirpation of the sac and the Matas operation, are subject to the same limitations as the above, inasmuch as proximal control of the circulation to the sac is essential to their successful outcome.

Distal ligation (Brasdor) or the distal application of the Halsted bands is especially adapted for application to those aneurysms of the carotid which are intrathoracic and which fuse with the innominate or the aorta.

The essential difficulty encountered in any of the above forms of treatment for carotid aneurysms lies in the dangers incident to the cerebral anemia which follows the arrest of the circulation on the occluded side.

For the purpose of preventing these cerebral complications, the band of

Halsted has a wide field of usefulness. The principal essential features of its application in common carotid aneurysm are the use of local infiltration anesthesia; the exposure of the common carotid at the site of election by this method of anesthesia; the application of a Halsted metal band to the common carotid distal to the sac, and the closure of the band just tight enough to obliterate the lumen of the vessel. After the band is tightened the onset of cerebral symptoms will occur promptly if the collateral circulation is defective; should such symptoms arise, the band is cut and removed and with its removal the cerebral symptoms will subside with the return of the circulation to the anemic area.

Smoler devised a specially constructed clamp to produce gradual occlusion of the carotid artery to prevent cerebral complications. He reports 3 successful cases in which he used his clamp without these complications.

After the question of cerebral disturbance has been settled, the subsequent treatment of the sac will depend upon 3 factors, i. e., the absence of pulsation, of pressure symptoms, and changes in the size of the tumor.

In those cases in which the pulsation, etc., disappear, following the application of the band, nothing further need be done.

In cases in which pressure symptoms remain the sac may be exposed and the vessel ligated on the proximal side and the contents of the sac evacuated; or the vessel ligated and the sac extirpated; or if the proximal circulation can be controlled the sac may be treated by the Matas obliterative endo-aneurysmorrhaphy. The treatment of the sac must of necessity depend upon the symptoms which its pressure causes or the structures necessarily injured in its treatment. All of these factors must be weighed carefully and the result of the decision thus arrived at carried out according to one of the above described methods.

The dangers in the past have been due to the disturbance in the brain following the ligation of the common carotid. Delbet states that cerebral complications occur in 20 per cent. of the cases. Jordan says that they occurred in 25 per cent., and of these, 10 per cent. died. Smoler had it happen in 2 of his cases in which elastic ligatures were used, while it was absent in the 3 cases in which gradual occlusion was produced by his clamp. Halsted states he has applied the metal band to the carotid "many times" without accident.

In 3 personal cases in which the common carotid was tied for pulsating exophthalmos, evanescent cerebral symptoms occurred in 1 case and disappeared with a return of the bruit over the head.

### INTERNAL CAROTID ANEURYSMS

These may be intracranial or extracranial. For the treatment of the former, see pulsating exophthalmos.

The same general conditions spoken of under innominate and common carotid aneurysms apply in the treatment of internal carotid aneurysms, namely the dangers of cerebral complications and the efficiency of the collateral circulation should always be tested preliminary to a ligation of this artery.

For this purpose the Halsted metal band or some form of specially constructed clamp should be used. The temporary occluding agent should be applied preferably to the common carotid artery, due to the ease with which the vessel may be approached. In those cases in which the aneurysm is placed low down upon the internal carotid, ligation or compression of this vessel may be practiced on the distal side.

Matas advises extirpation or preferably obliterative endo-aneurysmorrhaphy for those cases in which ligation does not cure the condition. To reach the sac he advises the use of the incision necessary for the removal of retropharyngeal tumors with temporary resection of the lower jaw. He furthermore advises obliterative endo-aneurysmorrhaphy with packing of the sac as more advisable and safer than any attempt at obliterating the sac.

Aneurysm of the internal carotid is not common. Herzen records it as occurring only twice in his cases, once with aneurysm of the external carotid. Monod and Van Verts in their collected cases mention 1 case (Mullen and Stanton) in which restorative endo-aneurysmorrhaphy was attempted and failed because of secondary hemorrhage and death occurred due to that cause. Matas does not mention it in his paper on the statistics of endo-aneurysmorrhaphy in 1908, but in "Keen's Surgery" quotes Bobbio as stating that there were 18 cases of aneurysm of the vessel up to 1906 with ligation of the common carotid in 11 cases with 6 recoveries.

**Aneurysm of the External Carotid and Its Branches.**—Aneurysms of the trunk of the vessel are rare, while aneurysms of the branches are quite common. Herzen mentions external carotid aneurysm in 2 cases (1 in combination with internal carotid aneurysm). Monod and Van Verts do not mention it in their collected cases. Delbet (1895) collected 11 cases of aneurysm of the external carotid.

Aneurysms of the branches of the external carotid are quite common.

The treatment of aneurysms of the external carotid or its branches depends upon the location of the aneurysm. If the sac is close to the origin of that artery near its bifurcation from the common carotid, Matas advises temporary clamping of the common carotid with obliterative endo-aneurysmorrhaphy of the vessel and that method of obliteration of the sac which best suits the aneurysm in question.

The small aneurysms either on the trunk or on its branches should be ligated and extirpated unless the relation of the important structures to the sac are such that extirpation would be dangerous. In the latter instance they may be treated by intrasaccular ligation or suture and the sac obliterated.

Dawbarn suggests the obliteration of the external carotid by paraffin injections for aneurysms of the branches of that artery which are difficult of access.

## SUBCLAVIAN ANEURYSMS

The treatment of aneurysms of this vessel comprises every conceivable remedy suggested for the treatment of aneurysm.

Souchon found that medical measures alone were successful in 11 out of 35 cases. Elliot emphasizes the fact that in slowly growing aneurysms of small size such treatment is indicated and cites a case of his own treated by rest and diet in which the aneurysm perceptibly decreased in size and the patient improved. To the above suggestion one might add the use of potassium iodid in from 5 to 15 grain doses 3 times a day over a long period.

The other non-operative methods may be dismissed without further consideration as useless.

**The Operative Treatment.**—Matas divides the operative treatment proposed as curative for subclavian aneurysms into 6 groups:

1. Incision into the sac, digital plugging of the orifices, and ligation of the poles of the sac (Syme, 1860).
2. Disarticulation of the shoulder joint.
3. Ligation.
4. Extirpation.
5. Aneurysmorrhaphy.
6. Gradual occlusion by the Halsted metal bands.

Of these, only the last 4 are worthy of consideration.

Jacobsthal summarizes the forms of ligation and divides them into distal ligations in which the axillary, carotid, axillary and carotid, or third portion of the subclavian were tied in various combinations. Proximal ligations in which the subclavian was tied in all 3 of its divisions, or the subclavian with the carotid, alone or in conjunction with the vertebral; or the innominate alone or in combination with carotid, subclavian, vertebral, and internal mammary in various combinations. Proximal and distal ligations in which the subclavian and the axillary were tied:

Jacobsthal, in his collected cases since 1890, 25 in number, states that the mortality was 16 per cent., gangrene of the arm occurred 3 times, and of the hand, 4 times.

Matas, in his statistics on arteriovenous aneurysms of the subclavian vessels, found that gangrene occurred in 13.5 per cent. after the ligation of both artery and vein, and in 1.7 per cent. after ligation of the third division of the subclavian.

Aneurysms of the subclavian are most frequently found in the first and third divisions of that vessel. According to their relation to the scalenus anticus they are called extrascalenic or intrascalenic (Savariaud). The second portion of the artery is usually involved by extension of the aneurysm from one or other of its divisions.

In the extrascalenic aneurysms, the method of election, if ligation is pursued, is proximal ligation or proximal and distal ligation with extirpation of the sac where it is possible.

In the intrascalenic, proximal ligation is more dangerous than distal ligation and this latter procedure should be attempted first.

In those cases in which it is possible to obtain preliminary hemostasis the Matas obliterative endo-aneurysmorrhaphy is more advisable than any form of ligation. Elliot states that the great advantages of the obliterative operation of Matas are that it is almost always permanent, cures the aneurysm and that the dangers of secondary hemorrhage are very slight, once in 63 cases of obliterative aneurysmorrhaphy; that gangrene of the extremities is rare, 3 to 5 per cent., and that the mortality of the operation was 3 per cent. Relapse occurred in 1½ per cent. Gangrene occurred in 6½ per cent., and the mortality was 7 per cent. in ligation alone, with 74 per cent. of cures. Excision of the sac gave 90 per cent. of cures, with 1½ per cent. of relapses, and a mortality of 3 per cent.; gangrene occurred in 4 per cent. The inference from the above statistics of Monod, Van Verts, and Matas, according to Elliot, is that the Matas operation and the treatment of the aneurysm by excision are about of equal merit and superior to ligation.

Monod and Van Verts, however, do not believe that the Matas operation is suitable for subclavian aneurysms.

Elliot believes that the most satisfactory treatment of aneurysm of the third portion of the subclavian is the ligation of the first portion of that artery together with its branches with the possible exception of the vertebral.

If recurrence takes place, then distal ligation as close to the sac as possible may be done. Should the aneurysm recur after this procedure, extirpation may then be done after the ligation of the other vessels to the sac.

Elliot further advises a preliminary resection of the clavicle and, if necessary, of the manubrium.

Halsted has applied his metal band to the subclavian twice without accident and a thorough trial of this method may prove it to be the method of election for aneurysm of the subclavian.

The result of any treatment for subclavian aneurysm may be followed by some sensory, motor, or trophic disturbances in the extremity. Furthermore, after ligation, etc., aneurysm of the aorta is prone to develop.

## AXILLARY ANEURYSMS

The treatment of aneurysms in this region comprises ligation, proximal and distal, the Antyllian operation, extirpation of the sac, the Matas operation, the use of the Halsted band, and one or other of the so-called "ideal" operations.

The objections to the use of the ligature are, its failure to cure, the liability to relapse, and the dangers of gangrene.

Extirpation of the sac is preferable to ligation but is apt to be followed by injury to the brachial plexus and the axillary veins.

For that reason the Matas operation, the Halsted band, or some one of the forms of the ideal operations is to be preferred.

The selection of the type of the above 3 forms of operative treatment must of necessity depend upon the conditions to be met at the operation and the equipment and experience of the operator.

The treatment of aneurysms of branches of the axillary down the arm and into the hand resolves itself into extirpation or some form of the ideal operation. Excision is easily carried out in most cases and if the anatomical relation to nearby nerves is given sufficient consideration, it will result in a cure without any neurological complications.

In suitably selected cases some reconstructive operation upon the artery or vein or both (ideal operation) may find a field of further usefulness.

## ANEURYSMS OF THE ILIAC ARTERIES

These may, according to Matas, be divided into (a) aneurysms of the external iliac tract, including the common iliac artery, the external iliac, the iliofemoral, and the common femoral to the origin of the profunda artery; (b) aneurysms of the internal iliac (hypogastric) and its branches.

**Aneurysms of the External Iliac Tract.**—Halsted ("The Effect of Ligation of the Common Iliac Artery, etc.," Johns Hopkins Bull., xxxiii, 191) has collected the cases of ligation of the common iliac arteries and divides them into 2 periods: up to 1880, and from 1880 to 1912. For the older group, the reader is referred to the original article.

Of the cases collected from 1880 to 1912, 30 in number, 14 died; gangrene occurred in 12; and in 11 that recovered without gangrene function in the limb was distinctly interfered with. In the 11 cases of recovery recurrence of the aneurysm occurred in one case and Halsted believes that this would have happened more frequently had the cases been observed long enough. Extirpation of the sac has rarely been resorted to except in aneurysm of the external iliac, and gangrene occurred in 20 per cent. in this group (Matas).

Endo-aneurysmorrhaphy in Matas' opinion would meet the indications admirably for those aneurysms in which the circulation could be controlled and he advises compression of the abdominal aorta to bring about this temporary hemostasis. In 2 cases (Frazier, Mitchell) severe hemorrhage occurred from collaterals to the sac in spite of preliminary hemostasis. Matas states that the statistics are not yet sufficient to draw conclusions as to the value of this procedure.

The obliteration of femoral aneurysms giving off the deep epigastric, circumflex iliac, and profunda arteries will be followed by more or less serious impairment in the circulation of the foot and leg due to disturbance of the collateral circulation. Obliteration of an aneurysm of the iliac artery above the origin of these vessels should not produce as great a disturbance in peripheral circulation.

Halsted reports the cure of an iliofemoral aneurysm by the application of one of his bands to that vessel and the result of his operation would indicate that that method is worthy of a more extended trial.

More recent methods for partial occlusion (Halsted, Nassetti, Matas and Allen), proximal or distal, have not yet been tried clinically. Their success experimentally would suggest a definite field of clinical usefulness.

From the above meager résumé, it would seem that one of the methods of partial occlusion should be used as the first stage in the treatment of iliac aneurysm and this preliminary step followed by some further secondary operation to meet the conditions which remain after the occlusion. The character of the secondary operation must of necessity be selected in each case.

**Internal Iliac Aneurysms.**—Any of the branches of this vessel may become aneurysmal.

Those branches most frequently involved are the gluteal and sciatic arteries. These may be intra- or extrapelvic. The former are so infrequent as to need little consideration. In 1 case of the writer's of intrapelvic aneurysm, which from its location suggested its origin from the sciatic, operation was refused and the patient developed sciatic nerve paralysis and subsequently died of hemorrhage while under medical treatment for that condition.

The extrapelvic variety of aneurysms of this vessel, while not common, is of sufficient surgical interest to deserve mention. The majority are due to traumatism and are chiefly outside the pelvis, although some may project through the sciatic notch into the pelvis.

Frischberg collected 19 cases of gluteal aneurysm submitted to radical surgical procedures. In 2 of his collected cases proximal ligation (Anel) was done with 1 death; the internal iliac was tied in 5 cases with two deaths; the common iliac was ligated in 1 case which resulted fatally; in 11 cases treated by the Antyllian method there were 2 deaths.

Rupp collected 45 cases of gluteal aneurysm and reports a successful extirpation of gluteal aneurysm by Lexer.

Bryan collected 24 cases of sciatic aneurysm and reports a case of his own successfully treated by extirpation.

Of the methods used he mentions injection of chlorid of iron in 4 cases; medical treatment in 1 case; compression in 2 cases; clamping of sciatic in 1 case; galvanopuncture in 1 case; ligation of common iliac in 2 cases; ligation of internal iliac in 5 cases; ligation of hypogastric in 4 cases; ligation of sciatic in 5 cases.

He considers it feasible, at this stage of modern surgical development, to attempt any of the finer surgical procedures of obliteration such as suture, Halsted's occlusion methods, the Matas operation, or the wiring methods (Moore-Corradi) for this important terminal artery, but believes that ligation and extirpation of the sac should be the method of election for the treatment of aneurysms of this artery.

Ligation of the common iliac is contra-indicated, owing to the dangers incident to that operation. Temporary ligation or clamping of the internal iliac might be used for those cases in which the aneurysm projects into the notch until the sciatic artery could be properly secured on its proximal side when the internal iliac could be freed from the temporary compression.

The method of election in the treatment for aneurysm of the sciatic and gluteal arteries would then be extirpation of the sac with or without temporary occlusion of the internal iliac artery.

The incision best adapted for the purpose of extirpation is a long curved incision from the great trochanter parallel to the gluteal fold across the buttock. The tendon of the gluteus maximus should be cut together with the gluteus medius and these muscles so displaced as to expose the aneurysmal swelling. After all structures, especially the sciatic nerve, are dissected free, ligation and extirpation are done in the ordinary manner. Drainage is indicated. Infection occurred in Bryan's case but it seemingly did not interfere with a successful outcome.

## FEMORAL ANEURYSMS

These are aneurysms of that portion of the femoral artery from the origin of the profunda to the popliteal end of Hunter's canal.

Herzen quotes deep femoral aneurysms as occurring 9 times and superficial femoral aneurysms as occurring 26 times in the traumatic aneurysms treated by the Russian surgeons.

Of the older methods, compression in its various forms and ligation were frequently practiced (Matas, Bolton).

Extirpation, aneurysmorrhaphy, or some form of the ideal operation would seemingly be the method of election for aneurysm in this region.

Aneurysm of the profunda femoris is rare. A case of the writer's due to subtrochanteric fracture with successful obliterative endo-aneurysmorrhaphy is quoted in that portion of this article devoted to the Matas operation (v. supra).

Superficial femoral aneurysm, due to the ease with which the circulation can be controlled, readily lends itself to the more radical forms of surgical treatment. In those cases in which the collateral circulation is sufficient to avoid the dangers of gangrene, extirpation is undoubtedly the method of choice.

When the vitality of the limb is threatened by occlusion of the vessel, restorative or reconstructive endo-aneurysmorrhaphy or some one of the forms of the ideal operations could be used in properly selected cases.

## POPLITEAL ANEURYSMS

Aneurysms in this region are the most frequent of all the forms of peripheral aneurysms.

For this reason there are more methods of treatment than need any serious consideration. One may divide the therapeutic procedures into ancient and modern methods:

The ancient methods comprise compression, acupuncture, wiring, ligation, proximal and distal, and amputation of the leg. It does not lie within the province of this article to discuss the demerits of the above forms of treatment. Those interested in the subject will find the data in Delbet and Matas.

The modern treatment is of chief interest. Of the radical methods, extirpation and the Antyllian operation are old in years but still have modern advocates. The Matas operations, the methods of gradual occlusion, and the ideal operations are of more recent development.

Herzen, Delbet, Monod and Van Verts believe that extirpation is as successful as any of the other forms of treatment. Aseptic ablation of the sac is the ideal operation in their estimation. Herzen believes that infection is an important factor in the production of the late results of this operation (i. e., inflammatory edema, vascular thrombosis, peripheral nerve disturbances, etc.).

Matas regards the various forms of his operation selected to meet the given conditions as the ideal operation for aneurysms of this region. He quotes 62 cases treated by his method with 1 death; 2 cases of gangrene of the limb; and 3 relapses cured by a secondary intrasaccular operation. In 18 of his collected cases the artery was reconstructed so that the continuity of the blood stream was uninterrupted.

Halsted states that he applied the metal band in 1 case of popliteal aneurysm but gives no details. Any form of partial occlusion would it seems to me have a very limited field of usefulness in this locality and should be limited to those cases in which any more complete operation would undoubtedly cause gangrene. Under such conditions, partial occlusion might be used pending the development of collateral circulation or even to reduce the size of the aneurysm before proceeding to more radical methods.

The value of the so-called "ideal operation" so selected as to fit the individual case of popliteal aneurysm is as yet undetermined, but it would seem that the field of usefulness of these more or less intricate procedures is very definitely limited. The first limitation is covered by general experience on the part of the ordinary surgeon in the technic of vascular surgery. That is easily surmountable by a process of education. The second and more important limitation is included in the detail of the operation. This detail is necessarily arduous and time-consuming and it yet remains to be proven whether the end justifies the means.

Selected cases, especially of small aneurysms easily ablated or of small arteriovenous sacs, in the hands of adepts in vascular surgery, will, I believe, be the restricted field of this form of surgical treatment in popliteal aneurysm. (See Ideal Aneurysm Operations under the general discussion for further details.)

In 2 personal experiences with popliteal aneurysm the obliterative operation of Matas was easily performed and the result was most satisfactory. One case was observed for 5 years without any sign of recurrence. The only disability in either case was a limitation of about 10 per cent. in flexion in the knee involved in the operation.

It would seem from the above that the operation of election in the treatment of popliteal aneurysm would be the Matas operation in one of its forms. That form of endo-aneurysmorrhaphy must be chosen which will meet the conditions of collateral circulation prevailing in the case in question (see general discussion on the Matas Operation).

Should conditions arise during the operation or afterward which render success more likely by means of some other form of operative procedure, extirpation, the Antyllian method, and the ideal operations must be matters of selective second choice.

In the vessels peripheral to the popliteal space, Herzen mentions aneurysm of the posterior tibial in 5 cases, anterior tibial in 4 cases, anterior and posterior together in 3 cases, peroneal in 1 case. All were the result of warfare injuries. The essential method of treatment is aseptic extirpation of the sac.

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[1] The appended references do not pretend to comprise a complete list of the voluminous literature on the subject of aneurysms, but include such portions as were of great value in the preparation of this article.

The writer desires to acknowledge his indebtedness to the masterly publications of Matas on the subject. If the critical reader should find the text very similar to that in some of the Matas publications, the author freely acknowledges his indebtedness to that writer and pleads the sin of too close reading and an inability to state the desired facts in any other similar terms.

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# CHAPTER XI

## LIGATIONS OF ARTERIES IN CONTINUITY[1]

WALTON MARTIN

### GENERAL CONSIDERATIONS

The ligation of an intact artery is spoken of as ligation in continuity, and the term is used in contradistinction to the tying of a severed vessel. The arteries are exposed and ligated in continuity for a number of conditions: (1) in the treatment of aneurysms, the ligature being placed near or at a distance from the sac, either distally or proximally (see chapter on Aneurysms); (2) as a preliminary measure in certain operative procedures, thus the lingual arteries may be exposed and ligated to control the hemorrhage in removal of the tongue; (3) to check hemorrhage in some branch not accessible; (4) to modify glandular activity, for example the superior and inferior thyroid vessels are ligated in certain cases of hyperthyroidism; (5) for wounds of the larger arteries.

**Instruments.**—The instruments required are: scalpels, thumb and mouse-tooth forceps, retractors, scissors, grooved directors, artery forceps, aneurysm needles, and ligatures.

**Ligatures.**—The materials ordinarily used are silk, kangaroo tendon, chromic catgut for the larger vessels and plain catgut for the smaller vessels. In ligating the larger vessels the material used should be slowly absorbable, sufficiently pliable to tie easily and strong enough to stand considerable tension. It is also desirable that the surfaces of the ligature material used should offer sufficient friction to prevent the first loop of the knot from slipping.

*Kangaroo tendon* is very strong, slowly absorbable and flat on cross-section rather than round, so that wider surfaces of the arterial walls are brought in contact. It, however, has a smoother surface than the other ligatures and therefore there is more tendency for the first loop of the knot to slip. This objection is met by using the stay knot.

*Chromic catgut* is slowly absorbable but it is not as strong as kangaroo

[1] The anatomical terms employed in this chapter are those given by the Basle Anatomical Nomenclature. These terms have been adopted in the recent editions of the Standard Anatomies.

tendon, the surface is less smooth and the loops of the knot have less tendency to slip. *Silk* is strong and very pliable, and the knots have even less tendency to slip, but it is not as well tolerated by the tissues, and it is nonabsorbable. Soft floss silk should be used, as the ordinary plaited or twisted silk in the heavier ligatures makes a very hard knot.

**The Knot.**—The pressure in the larger vessels makes it difficult to keep the first loop of a square knot or even of a surgeon's knot from slipping and loosening and thus failing to occlude the lumen of the vessel completely; this fact has been frequently observed and is borne out by the experimental work of Ballance and Edmunds (2). They suggested the use of the so-called *stay knot,* and this is the best knot for the

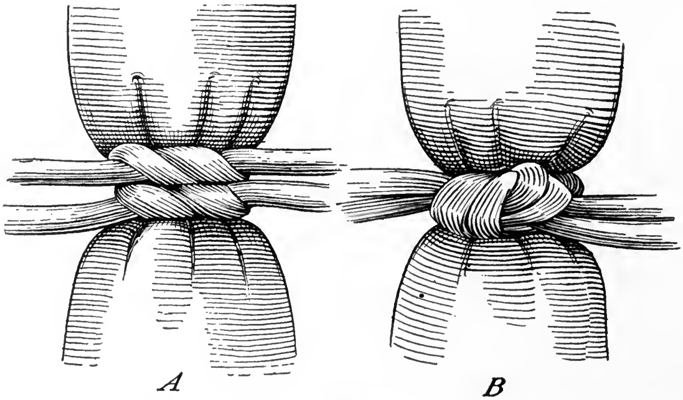


Fig. 1.—The Stay Knot. A, First loop; B, second loop. (Ballance and Edmunds.)

purpose. Two or more ligatures are passed around the vessel side by side, and the first loop of a square knot tied, care being taken that the twists of the loops pass in the same direction. The free ends of the ligatures are then tightened, sufficient force being applied at the same time to occlude the vessel. The friction of the ligatures lying side by side is sufficient to keep the first loop of the knot from slipping. The two ligatures are then treated as a single ligature in tying the second loop of a square knot (Fig. 1).

**The Force to Be Applied and the Question Whether or Not It Is Necessary to Rupture the Vessel Wall.**—It has been asserted that sufficient force should be applied to occlude the vessel but not to rupture the wall. The vessel wall is thus thrown into transverse folds, the folds lying in contact with one another so that the vessel is completely plugged (Fig. 2). Rupture of the arterial coats of the larger vessels is said to be accompanied by the danger of secondary hemorrhage. This view was supported by the experimental work of Ballance and Edmunds (2) on the larger vessels of sheep and horses. Their treatise appeared in 1891. In 1894 Forgue and Bothézat (12), however, disagreed with these conclusions and, from their experimental work, condemned the ligation without rupturing the coats. They advised that the ligature be tied with sufficient force to rupture the inner and middle coats. Monod and Van Verts (18) in their monograph on the surgery of arteries have adopted this view (1909).

The amount of force necessary to rupture the arterial coats differs greatly in the living subject and in the cadaver, due to the difference in the intra-arterial tension, and is dependent on the size and pressure in the different vessels. If the stay knot is used, the force necessary to rupture is said in some cases to exceed ten pounds, which Lister said was the maximum force which could be applied under the conditions of ligation in continuity. Therefore, in using a stay knot in ligating the larger vessels one need not fear erring on the side of excess.

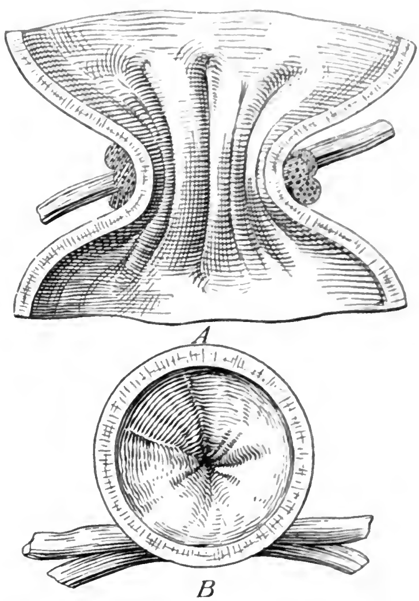


Fig. 2.—A, Infolding of Vessel Walls by the Ligature Without Rupturing Them; B, Occlusion of the Lumen by the Infolding of the Vessel Wall. (Ballance and Edmunds.)

In several of the cases of ligature of the innominate artery reported since 1891 (7) there is reference to the fact that an effort was made to draw the ligature sufficiently tight to occlude the vessel but not to rupture the coats. As the ligature is tightened there is a distinct give, when the constricting force becomes sufficient to rupture the inner coats. From vessels the size of the femoral (8 mm., 0.32 in.) downward, it is certainly of no consequence if the coats are ruptured, and I believe even in the larger vessels there is more danger of not occluding the lumen than of causing secondary hemorrhage from rupture of the coats by the ligature.

**Results.**—Most of the deaths after ligature of the vessels done before the nature of infection was understood resulted from secondary hemorrhage due to infection. Statistics taken from cases reported since the introducing of antiseptic and aseptic measures show an extraordinary change in mortality. The ligation of any excepting the largest vessels nowadays creates no comment, and the cases are not as a rule reported excepting incidentally.

The frequence of gangrene of the extremities following the ligature of the main vessels of the extremities seems, however, to have slightly increased during the same period, judging from the cases collected and classified by Wolff (29). This may be due to the fact that ligature of the vessels of the extremities is often not reported unless something unusual, such as gangrene, occurs.

**Recognition of the Artery.**—The arteries during life are pinkish white and can be seen and felt to pulsate synchronously with the heart. The nerves are round, pure white cords. The veins, often larger than the arteries, are dark blue, flatten readily under the finger and become swollen when pressure is applied to the cardiac angle of the wound.

**Opening the Sheath of the Vessel and Passing the Aneurysm Needle.** — The vessels and nerves are usually surrounded by a connective tissue sheath, and it is necessary to incise this sheath to pass the ligature about the artery: for example, the common carotid, the internal jugular and the vagus nerve are

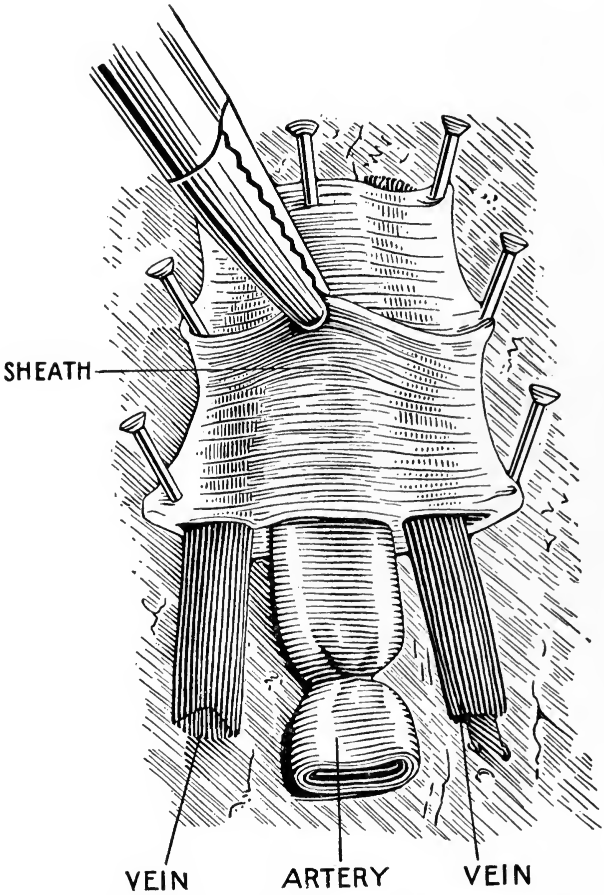


Fig. 3.—Pinching up the Sheath of the Vessels in a Transverse Fold. (Farabeuf.)

contained in a connective tissue sheath, which it is necessary to open in order to pass a ligature around the carotid. The connective tissue of the sheath invests the vessel closely. The sheath may be opened by dividing the structure with a knife, care being taken that the cut simply passes through the sheath; or it may be pinched up by thumb forceps so that a fold is lifted up transversely to the axis of the vessel and over the artery. The fold is then incised. The incision should be about 10 mm. (2/5 in.). A button-hole is thus formed in the sheath, and if necessary this may be readily enlarged (Fig. 3).

After the sheath is opened the aneurysm needle is passed. The rule is to pass the needle away from the point of danger; thus the ligature is passed from without inward in ligating the common carotid, care being taken that the instrument is kept in contact with the artery, so that a vein or nerve lying in the sheath may not be included in the ligature.

## INNOMINATE ARTERY

**Anatomy.**—The innominate artery is 3 to 4 cm. (1½ in.) long and about 14 to 15 mm. (½ in.) in diameter. It rises from the arch of the aorta at the junction of the ascending and horizontal portion in front and to the right of the left common carotid. It passes upward and to the right, and

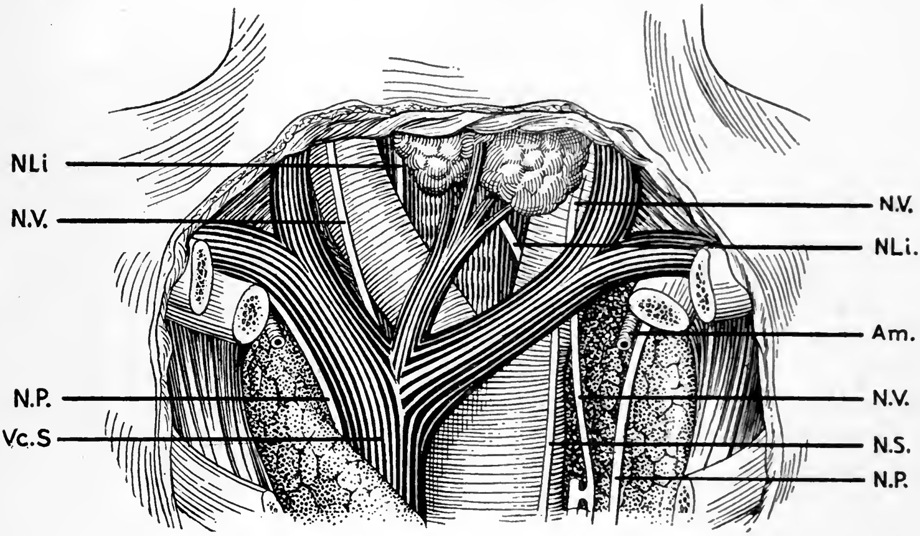


FIG. 4.—ANTERIOR MEDIASTINUM. NLi., Recurrent nerve; N.V., vagus nerve; N.P., phrenic nerve; Am., internal mammary artery (section). (After Zuckerkandl.)

opposite the sternoclavicular joint divides into the two terminal branches, the right common carotid and the right subclavian. It is thus placed entirely within the thorax. The posterior surface of the sternum is separated from the vessel by the inferior insertion of the right sternohyoid and sternothyroid muscles, the remains of the thymus gland and the left innominate vein. It is also crossed by the cardiac filaments of the vagus and usually by the two right inferior thyroid veins. The innominate trunk crosses the trachea obliquely, and between it and the trachea are cardiac filaments of the sympathetic and recurrent laryngeal nerves. On its outer side it lies in contact with the pleura, which separates it from the right lung, and is in relation with the right innominate vein and the vagus.

The projection of the course of the vessel on the sternum corresponds to a line passing at the level of the lower border of the sternal extremity of the first costal cartilage in the mid line (Fig. 4) upward and outward to the level of a line passing through the middle of the right sternoclavicular articulation.

**Operation.**—The patient is placed in the dorsal position with the neck extended and the shoulders slightly raised.

FIRST METHOD.—The incision, about 7.5 cm. (3 in.), commences just above the clavicle and passes to the interval between the insertions of the sternal portion of the sternocleidomastoid muscle, where it is joined by a second incision of about the same length along the mesial border of the sternomastoid muscle. An angular incision is thus made with the apex of the angle downward. The skin, superficial fascia and platysma, sternomastoid, sternohyoid and sternothyroid are divided in the line of the horizontal portion of the skin incision. The triangular flap thus formed is retracted. A deep layer of fascia containing the inferior thyroid veins is carefully divided by blunt dissection, and the veins are retracted, or, if this is difficult, they are divided between two ligatures. The sheath of the common carotid then comes in view. The sheath is opened, the jugular and vagus are retracted and the carotid followed downward until the origin of the right subclavian is seen. The upper portion of the innominate artery is then exposed by blunt dissection and the right innominate vein retracted with the vagus outward and the left innominate pushed downward, and an aneurysm needle passed from without inward and the ligature tied.

SECOND METHOD.—The upper portion of the sternum and the right sternoclavicular joint are resected to gain a better exposure of the vessel. The incision in this case extends along the anterior border of the sternocleidomastoid muscle from the level of the cricoid to 5 cm. (2 in.) below the superior edge of the sternum. This is joined by a transverse incision passing horizontally inward from the middle of the clavicle. After the sternal muscles are divided, the right sternoclavicular joint and about 2.5 cm. (1 in.) of the right upper portion of the sternum are removed by means of trephine and bone forceps. A flat retractor is passed beneath the bone to protect the vessels during this part of the operation. The rest of the dissection is carried out as in the first method.

THIRD METHOD.—The manubrium sterni is split in the middle line, then divided transversely just above the second rib. The two halves can be separated for 5 cm. (2 in.). The vessel is then exposed and ligated as above (Curtis, 7).

**Results.**—In 1905 Sheen (25) published a table made up of 36 reported cases of ligation of the innominate artery. The first of these reports dates back to 1818 (Mott). The mortality based on these statistics is 78 per cent. Statistics based on the cases reported since 1871, that is omitting the cases reported before the antiseptic period, and adding the case reported by Burns (4), 1908, and 2 reported by the Japanese army surgeon, Saigo (22), show a mortality of 47 per cent., 19 cases with 9 deaths.

## COMMON CAROTID ARTERY

**Anatomy.**—The right carotid artery arises from the innominate artery, the left from the arch of the aorta. They pass upward in the neck to divide, about 1 cm. (2/5 in.) above the superior border of the thyroid cartilage, into the external and internal carotid. The level of the bifurcation varies, and from 4 cm. (1.6 in.) above to 4 cm. (1.6 in.) below the level indicated above as normal is said to be the extreme limit of this variation (Livini).

From their difference in origin the left carotid is necessarily longer than the right. A line drawn from the hollow between the angle of the jaw and the mastoid process to the sternoclavicular joint corresponds to the course of the common carotid in the neck. The relations of the right and left common carotid in the neck are the same. The artery lies on the prevertebral aponeurosis which covers the longus colli and the longus capitis. These muscles separate the vessel from the transverse processes of the cervical vertebra, a little mesial to their anterior tubercles. The sympathetic nerve lies behind the carotids, and its superior and middle branches pass behind the vessel before they enter the thorax. At the level of the anterior tubercle of the sixth cervical vertebra (tubercle of Chassaignac) the inferior thyroid artery crosses behind it. On its inner side are the trachea, the esophagus, and the recurrent nerve, and higher up the larynx and pharynx. The esophagus, owing to its curve to the left, lies in closer relation to the left carotid than to the right. On its outer side is the internal jugular vein; when the vein is distended it partly covers the vessel anteriorly, and as the vessels pass upward the vein has a tendency to lie in front of the artery, a position which it definitely occupies in the neighborhood of its termination. The vagus nerve usually lies between the vein and the artery posteriorly. The artery is covered in front by the skin, the platysma, and the sternocleidomastoid, with the aponeurosis derived from the cervical fascia. When the head is in the position which is usual at operation, with the face turned to one side, the vessel at the root of the neck lies beneath the interval between the sternal and clavicular attachments. In the middle of the neck the artery is covered only by the anterior border of the muscle. Near its termination the vessel lies a little anterior to the muscle, covered by the fascia, platysma and skin. The deep cervical lymph glands which lie beneath the sternocleidomastoid are in relation with the internal jugular vein rather than with the artery (Fig. 5). The descending branch of the hypoglossal passes down the surface of the vessel and the nerve and the loop which it forms with the cervical nerves lies on or within the carotid sheath. The superior and middle thyroid veins also cross the artery to empty into the jugular, and a small artery, the sternocleidomastoid branch of the occipital, crosses the upper part of the vessel. The posterior border of the lateral lobe of the thyroid gland also lies in front of the vessel.

The carotid artery and the vagus nerve are contained in a thin-walled but distinct connective tissue sheath.

**Operation.**—The artery is usually ligated (1) above the omohyoid; (2) immediately below the omohyoid. The site of election is immediately above the omohyoid.

(1) LIGATION ABOVE THE OMOHYOID.—The patient is placed in the dorsal position with the shoulders slightly elevated and the face turned to the

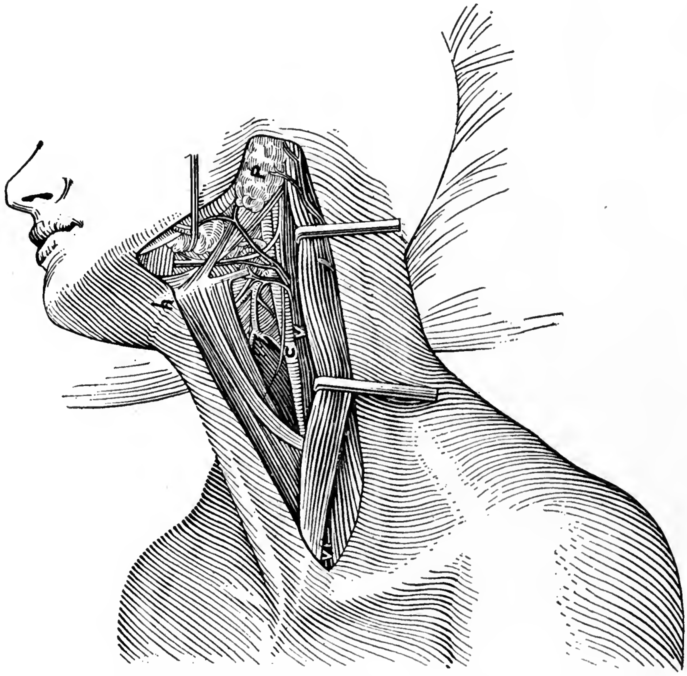

**Fig. 5.—The Sternocleidomastoid Drawn Backward with the External Jugular Vein with Its Confluent Veins, Facial, Lingual, Pharyngeal, etc.** V, v, Internal jugular; c, common carotid; t, thyroid; p, p, parotid; h, hyoid. (Farabeuf.)

opposite side. The incision is made along the anterior border of the sterno-cleidomastoid muscle. Its length should be about 8 cm. (3 1/8 in.). The center of the incision corresponds to the cricoid cartilage.

The skin, superficial fascia and platysma are divided in the line of the incision. The anterior edge of the sternocleidomastoid is exposed, and the fascia enclosing the muscle divided. The muscle is retracted outward, exposing the middle layer of the cervical fascia, enclosing the omohyoid. The fascia is divided in the direction of the fibers of the muscle, and the muscle is retracted downward and inward. The anterior and middle thyroid veins then come in view; they are divided between ligatures or retracted. The sheath of the vessels now appears at the bottom of the wound. A portion of the sheath is pinched up by forceps, making a fold transverse to the course of the vessels and incised. The opening in the sheath is made well to the inner side to avoid the vein. When the vein is distended it completely overlaps the artery. The exact position of the artery can be determined by the pulsation of the vessel. The opening in the sheath is enlarged sufficiently to identify the arterial wall, and the edge of the sheath grasped by thumb forceps and held up while an aneurysm needle is gently inserted from without inward, hugging the artery as it is passed about it, so that the vein or the vagus nerve may not be injured. The needle is then threaded and withdrawn and the knot tied.

The thyroid veins sometimes form a plexus which lies in front of the artery.

(2) LIGATION BELOW THE OMOHYOID.—The incision is made along the anterior border of the sternocleidomastoid muscle from the level of the cricoid downward for about 8 cm. (3 1/8 in.). The skin, superficial fascia, and platysma are divided, and the edge of the sternocleidomastoid exposed by dividing the fascia; the muscle is then retracted outward. The small sternocleidomastoid artery usually crosses the upper part of the incision and is divided. The tendon of the omohyoid enclosed in the middle layer of the fascia of the neck, crossing the artery obliquely, is identified, the fascia covering it divided, and the tendon retracted upward and inward. Care is taken not to divide the descending branch of the hypoglossal nerve lying in the sheath. The sheath is opened and the aneurysm needle passed, threaded, and withdrawn as in the operation described above.

**Results.**—Hemiplegia follows in certain cases of ligature of the common carotid. The accident usually occurs from the end of the first to the end of the third day. In the great majority of cases it terminates fatally. It is said to be due to the extension of the thrombus from the site of the ligature along the internal carotid to the cerebral arteries; an attenuated infection is probably a factor in its production. Insufficient arterial communication

| Ligature | Number of Cases | Number of Deaths | Percentage |
|---|---|---|---|
| For nervous affections—epilepsy, elephantiasis of the face (vascular system sound) | 40 | 1 | 2.5 |
| For traumatic pulsating exophthalmos | 76 | 4 | 5.2 |
| For idiopathic exophthalmos | 27 | 6 | 22.2 |
| For aneurysm (not including exophthalmos) | 276 | 102 | 36.7 |
| For removal of tumors | 115 | 49 | 42.6 |
| For hemorrhage | 322 | 163 | 50.6 |

between the cerebral arteries of the two sides is also a factor (De Fourmestraux, 8).

The mortality rate according to statistics of Siegrist (26) (1900) taken from 997 cases is 38 per cent.

The table on page 407 taken from Siegrist is of interest.

## EXTERNAL CAROTID ARTERY

**Anatomy.**—The upper portion of the line drawn from the hollow between the angle of the jaw and the mastoid process to the sternoclavicular joint corresponds to the external carotid. The bifurcation of the common carotid into the internal and external carotid usually takes place a little above the upper border of the thyroid cartilage; it terminates by dividing into the superficial temporal and internal maxillary, usually about 4 cm. (1.6 in.) above the angle of the mandible, that is to say a little above the middle of the posterior border of the ascending ramus (Livini). It is generally about 7 cm. (2.8 in.) long, but varies, according to the position of the bifurcation and its place of origin, between 3 cm. (1 2/5 in.) and 11 cm. (4 2/5 in.) (Livini). It is smaller than the internal carotid, its diameter being about 6 mm. (¼ in.). At its origin it is placed a little within and anterior to the internal carotid. The first portion of the vessel is relatively superficial. It is covered by the skin, superficial fascia, and platysma, and the sternocleidomastoid or (in the position assumed at operation with the face turned to one side) the cervical fascia which divides to enclose this muscle. Under this fascia is a layer of cellular tissue containing a varying amount of fat and a number of lymph glands. The hypoglossal nerve crosses the artery from 5 to 20 mm. from its origin; and the large vein (the common facial) formed by the junction of the facial and the anterior division of the temporomaxillary passes over the vessel close to the bifurcation. This large venous trunk often completely covers the artery. The vessel lies in this part of the course on the internal carotid, which it gradually crosses obliquely. It lies at first a little anterior and internal to the carotid. The glossopharyngeal nerve passes between the external and internal carotid, and the superior laryngeal passes to the inner side of the vessels.

The external carotid then passes upward in contact with the pharynx, and under the posterior belly of the digastric and stylohyoid, and finally enters the substance of the parotid. The artery is held in intimate relation with the gland by the branch which it gives off in this part of its course. The other structures passing through the parotid, the external jugular vein, the auriculotemporal nerve, the facial nerve, and most of the parotid lymph glands are situated external to the artery (Figs. 6, 7, 8).

**Operation.**—The patient is placed in the dorsal position with the head slightly extended and the face turned to the opposite side. The skin and superficial tissues are divided in the line extending from the angle of the jaw to the cricoid cartilage; the platysma and the cervical fascia covering the sternocleidomastoid are cut through, and the edge of this muscle is exposed and retracted. The cellular tissue and lymph glands are pushed to one

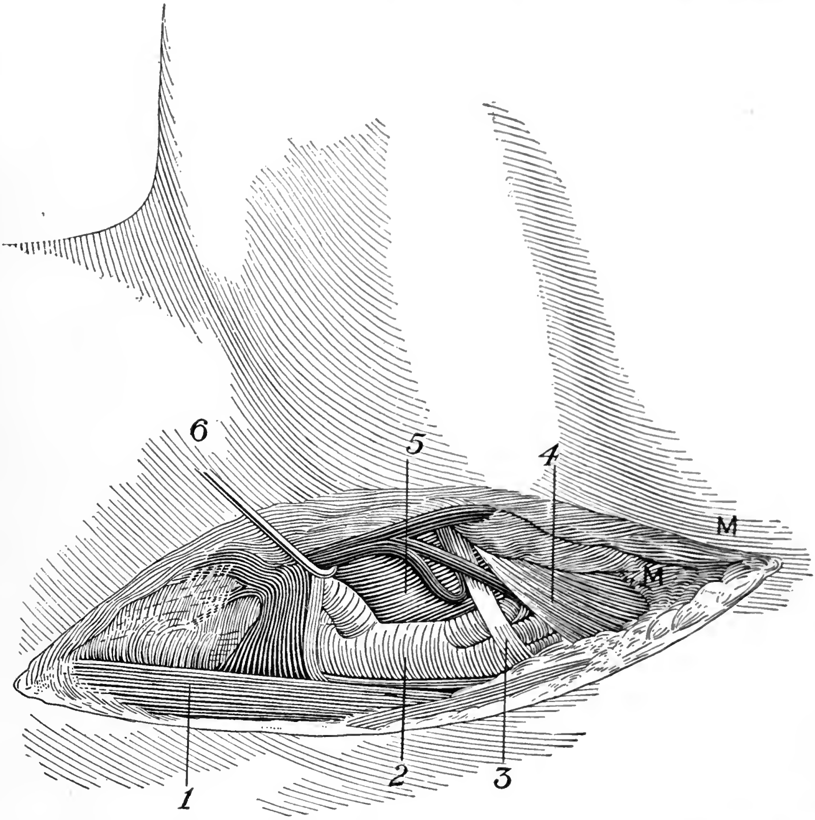


FIG. 6.—LIGATURE OF THE LEFT EXTERNAL CAROTID. M, Angle of jaw; 1, anterior border of the sternocleidomastoid; 2, the artery with the descending branch of the hypoglossal; 3, hypoglossal; 4, posterior belly of the digastric; 5, tip of greater cornua of hyoid bone; 6, thyrofacial lingual trunk drawn downward and inward to show the place of election for ligating between the origin of the superior thyroid and the lingual. (Farabeuf.)

side by blunt dissection, and the tendons of the digastric and stylohyoid muscles with the hypoglossal nerve identified. The artery is, at this point, often partly covered by the facial vein as it joins the internal jugular; but by blunt dissection the vein can be pushed to one side, or, if it is too much in the way, it may be divided between ligatures. The internal jugular is carefully retracted outward and the artery exposed for a distance sufficient to see one or more of the branches springing from the vessel anteriorly. The aneurysm needle is then passed from without inward around the vessel, great care being taken that the needle be kept in contact with the arterial wall so that the superior laryngeal nerve may not be caught in the ligature. The needle is threaded, withdrawn, and the ligature tied.

The internal carotid has been mistaken for the external. If the vessel

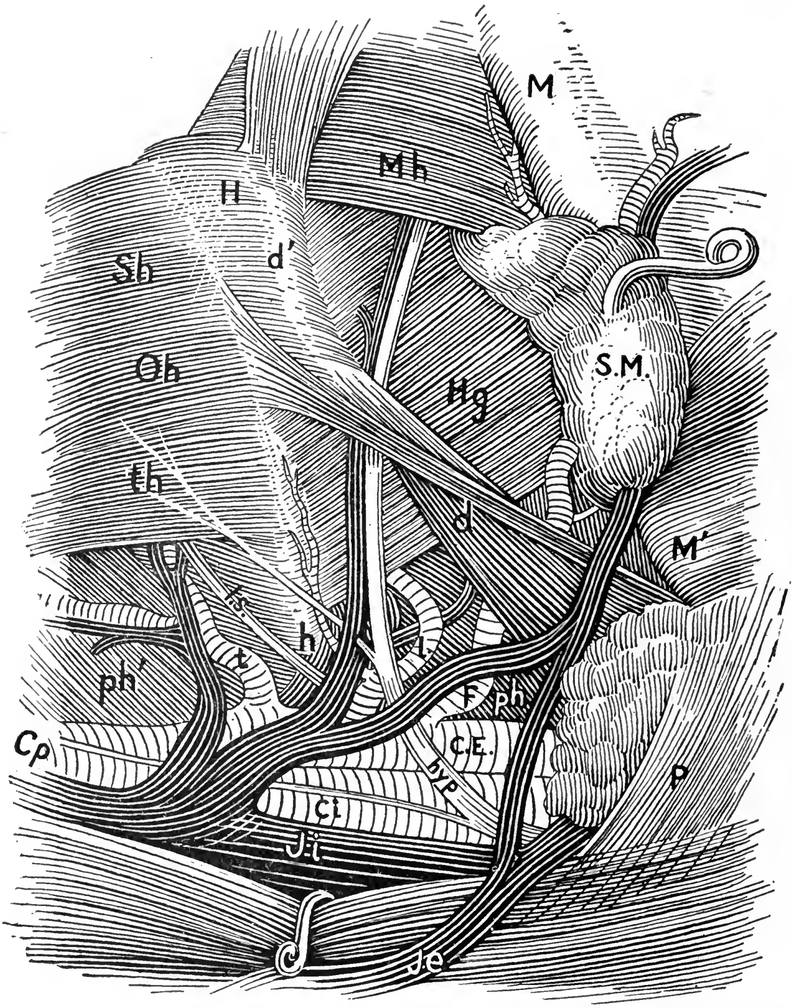


FIG. 7.—RELATIONS OF THE INTERNAL AND EXTERNAL CAROTIDS. (Subject in same position as at operation.) M, Lower border of mandible; M′, angle of mandible; H, hyoid bone; h, extremity of the greater horn of the hyoid; Sh, sternohyoid; Oh, omohyoid; th, thyrohyoid; ph′, inferior constrictor of pharynx; ph, middle constrictor; d, posterior belly of the digastric perforation of the stylohyoid; d′, pulley of digastric; Hg, hyoglossus; Mh, mylohyoid; P, parotid gland covered with aponeurosis of sternomastoid; sm, submaxillary gland lifted up; Je, external jugular; Ji, internal jugular, exposed by the retraction of the sternomastoid; hyp, loop of the hypoglossal; l.s., superior laryngeal nerve; Cp, common carotid; Ci, internal carotid; C.E., external carotid; t, superior thyroid; l, lingual; F, facial. (Farabeuf.)

is sufficiently exposed to show the branches, this mistake cannot occur, for the internal does not give off branches in the neck except very exceptionally a pharyngeal or occipital branch. **The anastomosis between the branches of the right and left external carotid is very free, so that the ligation of the** vessel on one side often has not a marked effect on the hemorrhage from the regions supplied by these vessels.

## INTERNAL CAROTID ARTERY

**Anatomy.**—The linear guide is the same as that for the external carotid, that is, the upper portion of a line drawn from the hollow between the jaw and the mastoid process and the sternoclavicular joint. The cervical portion of the internal carotid at its origin lies a little lateral to the external carotid, but as it passes upward it is directed mesially, thus passing behind the external carotid and crossing it very obliquely from without inward. The first portion of the artery is covered only by the skin, superficial fascia and platysma and sternocleidomastoid. On its inner side is the pharynx and in front of the vessel is the external carotid. Posteriorly it lies on the transverse processes of the cervical vertebræ, covered by the longus capitis muscles. The internal jugular lies in contact with its external wall. As it passes upward, it lies behind the posterior bellies of the digastric and stylohyoid muscles, and is deeply placed behind the stylopharyngeus and the deep surface of the parotid gland. It is crossed by the occipital and posterior auricular arteries. The vagus and the upper ganglion of the sympathetic lie behind the artery. The hypoglossal crosses the vessel, and the glossopharyngeal and pharyngeal branches of the pneumogastric pass between the external and internal carotid, and the superior laryngeal lies to the inner side of the vessel. The spinal accessory nerve at its exit from the skull lies close to the artery, but usually passes backward and downward beneath the jugular vein. The internal carotid is slightly larger than the external—6 mm. (1/4 in.) (Figs. 7 and 8).

**Operation.**—The patient is placed in the dorsal position with the head slightly elevated and the face turned a little to one side. The incision is made along the anterior border of the sternocleidomastoid from the angle of the jaw downward for about 8 cm. (3 1/8 in.), having its middle point opposite the hyoid bone. The skin, superficial fascia and platysma are divided, and the edge of the sternocleidomastoid exposed by incision of the fascia. The muscle is retracted outward. The cellular tissue with the lymph glands is divided by blunt dissection and pushed to one side. The hypoglossal nerve passing almost transversely across the wound is identified above, and the large venous trunk (the common facial) a little lower down. This venous trunk is freed by blunt dissection and retracted inward. The external and internal carotid and the bifurcation of the common carotid are exposed and the internal carotid identified by the absence of branches (Figs. 7 and 8). The aneurysm needle is passed from without inward, hugging the vessel closely.

**Results.**—In a certain percentage of cases hemiplegia follows the ligation of this vessel as of the common carotid. In the great majority of cases this complication is fatal. It is due to a thrombus starting from the point of


FIG. 8.—DISSECTION OF NECK, LEFT SIDE. M, Mastoid; St. cl. m., sternocleidomastoid; Sp, splenius; C, complexus; Dig, digastric; Je, external jugular; Ji, internal jugular; H, hyoid; 1, superior thyroid; 2, lingual; XII, hypoglossal; 3, facial; Gl. s. m., submaxillary gland; 4, occipital; 5, auricular art.; 6, internal maxillary.

ligation and extending to the cerebral arteries. It is said to occur in 15 per cent. of the cases.

For ligation of the superior thyroid, lingual, facial, occipital and superficial temporal arteries, see special chapters in this work dealing with surgery of the respective regions.

## SUPRA-ORBITAL ARTERY

**Anatomy.**—The vessel passes out of the orbit through the supra-orbital notch or foramen at the junction of the inner and middle thirds of the supra-orbital margin. The notch is usually palpable. The first part of the vessel passes upward on the forehead in a sagittal direction.

**Operation.**—The incision is made transversely along the supra-orbital margin, following the line of the shaved eyebrow. The skin, cellular tissue, and the orbicularis oculi muscle are divided and the vessel exposed and ligated.

## SUBCLAVIAN ARTERY

**Anatomy.**—The left subclavian arises from the arch of the aorta behind the origin of the left carotid. It is, therefore, very deeply placed within the thorax. The right subclavian arises from the innominate branch, so that the left subclavian is longer than the right. The artery passes over the apex of the lung lying in contact with the pleura, then passes behind the scalenus anticus muscle, and ends beneath the clavicle, passing on into the axillary artery. It is divided into three portions by the scalenus anticus muscle.

The thoracic portion of the left subclavian lies behind the left carotid on the vertebral column, which is here covered by the lower portion of the longus colli muscle. The recurrent nerve, the trachea and the esophagus lie to its inner side and on its outer side are the pleura and lung. The thoracic duct passes along its inner side and then over and behind the vessel to enter the junction of the internal jugular and the subclavian veins. It is crossed by the phrenic and branches of the sympathetic nerve. The vagus descends vertically in front of the thoracic portion. The cervical portion of the left subclavian is crossed by the innominate vein and the sternohyoid, sternothyroid and sternocleidomastoid muscles. The first portion of the right subclavian is less deeply placed. In front of the artery are the skin, superficial fascia, platysma clavicle and the lower insertions of the sternocleidomastoid, sternohyoid and sternothyroid, and beneath these muscles the junction of the internal jugular and the subclavian veins. The artery is also crossed by the vertebral and the anterior and external jugular veins which empty into the subclavian.

The phrenic, branches of the sympathetic, and the vagus pass over the vessel, and the recurrent nerve passes behind it. The vessel passes over the pleura, which separates it from the dome of the lung. It lies on the transverse process of the seventh cervical vertebra and is separated from it by the inferior ganglion of the sympathetic and the muscular slip passing from the transverse process to the dome of the pleura (28). The artery then passes between the scalenus anticus and medius, lying in a groove on the first rib.

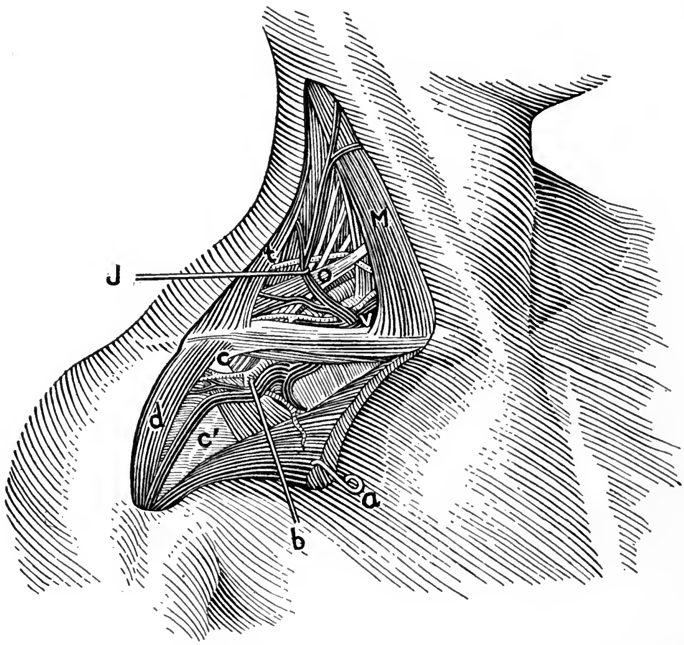


Fig. 9.—Course and Relation of the Subclavian and Axillary Arteries. M, Sternocleido muscle; t, trapezius; o, omohyoid; the retractor has drawn the external jugular to one side; v, the subclavian vein; d, deltoid; a, retractor pulling downward the clavicular portion of the pectoralis major; c, coracoid process; b, retractor pulling down the cephalic vein, making the thyrocervical trunk visible. (Farabeuf.)

It is separated in this part of its course from the subclavian vein by the scalenus anticus muscle, and has the cords of the brachial plexus above it.

The third portion of the subclavian is covered by the skin, superficial fascia, platysma, descending branches of the cervical plexus, and beneath this by a layer of fatty tissue in which are imbedded lymph glands. The inferior belly of the omohyoid lies above and in front of the artery, and the external jugular vein, as it arches around the outer margin of the sternocleidomastoid, crosses over it. This portion of the artery lies on the first intercostal space. The subclavian vein and the suprascapular artery pass between it and the clavicle, and the scalenus medius is behind it. The linear guide of the cervical course of the artery is represented by a curved line from the sternoclavicular joint to the mid point of the clavicle, and the convexity of the curve extends upward about 2.5 cm. (1 in.) above the clavicle. This is the course of the vessel with the shoulder depressed.

The artery gives off a number of branches which usually spring close together from the first part of the artery: namely the vertebral, the thyrocervical trunk, the internal mammary, and the costocervical trunk. The vertebral is the first branch given off. The thyrocervical trunk arises usually close to the scalenus anticus (Figs. 9, 10).

The vessel can be ligated mesially to the scalenus anticus, that is in its first portion, either (1) on the peripheral side of the thyrocervical trunk, or (2) on the cardiac side of the vertebral. (3) The left subclavian may be ligated close to its origin within the mediastinum.

**Operation.**—(1) LIGATURE OF THE FIRST PORTION OF THE SUBCLAVIAN (RIGHT OR LEFT) ON THE PERIPHERAL SIDE OF THE THYROCERVICAL TRUNK. —The patient is placed in the dorsal position with the head slightly extended and turned to the opposite side. The incision, about 8 cm. (3⅛ in.) long, is made along the lateral border of the sternocleidomastoid. This is met by an incision over the clavicle for about the same distance, the two incisions forming an acute angle. The skin, superficial fascia, platysma and clavicular attachment of the sternocleidomastoid are divided. The flap thus formed is retracted inward. The inferior belly of the omohyoid is exposed, the fascia covering it divided, and the muscle retracted upward or divided. The scalenus anticus muscle is identified, and its inner border followed downward until the pulsation of the subclavian is felt. The internal jugular vein is retracted inward, and the subclavian vein downward. This exposes the first portion of the subclavian. The phrenic and the cardiac branches of the sympathetic and the vagus are identified, and an aneurysm needle passed about the vessel, threaded, and withdrawn, care being taken to avoid including the nerves in the ligature. The ligature passes between the phrenic and sympathetic. The vessel is then tied with the stay knot, the divided muscles are sutured, and the wound closed.

(2) LIGATURE OF THE SUBCLAVIAN ON THE CARDIAC SIDE OF THE VERTEBRAL.—This is a much more difficult operation. The incision, about 10 cm. (4 in.) long, is made over the clavicle. It is slightly curved, the convexity of the curve being upward, and it passes over the sternoclavicular joint and extends about 1 cm. (2/5 in.) within the sternal border. The clavicular portion of the sternocleidomastoid is severed, and the clavicle divided about 6 cm. (2 2/5 in.) from its sternal end, and this inner portion subperiosteally resected. The costoclavicular ligament is divided, and the posterior fibers of the sternoclavicular ligament, thus exposing the joint. The sternal portion of the resected clavicle is turned over to the inner side. An incision is then made in the cervical fascia at its junction with the superior border of the retroclavicular periosteum, and the lower border of the wound retracted. This exposes the internal jugular and the subclavian veins. The internal jugular

is freed along its mesial border and retracted outward. The vagus nerve is identified by blunt dissection. It passes downward vertically, close to the mesial margin of the internal jugular vein. To the inner side of the vagus nerve is the carotid artery. To its outer side and beneath it is the subclavian artery. The artery is exposed and the ligature passed about it. On the right side the ligature passes almost in contact with the loop of the recurrent nerve. The clavicle is turned back and sutured. The muscles are sutured and the wound closed.

(3) LIGATURE OF THE LEFT SUBCLAVIAN WITHIN THE MEDIASTINUM. —Position as in No. 1.—The incision, about 10 cm. (4 in.) long, is made over the clavicle and over the upper border of the sternum to the mid line and then descends vertically to the level of the second costal cartilage. The pectoralis major is dissected away from the clavicle and sternum. The inner half of the clavicle is resected subperiosteally. It is disarticulated from the sternum and first rib. The finger is then gently introduced behind the sternum in the mid line, and the dome of the pleura and the elastic mass formed by the summit of the lung gently pushed outward. The sternum is then divided vertically in the mid line and horizontally at the level of the first costal cartilage, its posterior surface is carefully freed, and the first costal cartilage is divided at its junction with the rib. The left half of the manubrium and the first costal cartilage are then removed in one piece. The innominate vein is thus exposed. It occupies the entire operative field. Its direction is nearly horizontal. Two or three small veins enter its inferior border. They are divided between ligatures and the vein gently retracted upward. By blunt dissection in a vertical direction the vagus is exposed. It descends almost vertically in front of the artery crossing it with a very slight obliquity. The finger introduced into the wound palpates the trachea. In the angle between the trachea and esophagus is the subclavian, very deeply placed. Below is the aortic arch and anteriorly is the left common carotid. The ligature is placed about 5 cm. (2 in.) from the aortic arch. The pectoralis is sutured to the sternocleidomastoid and the wound closed.

Instead of removing the bone a temporary cleidosternocostal resection may be made. The sternum is divided horizontally and vertically and the clavicle is divided. The sternum is turned downward and outward. The flap hinges on the junction of the cartilage and rib (Duval, 11).

**Results.**—Writing in 1897, B. F. Curtis (6) in reporting a case in which the first portion of the subclavian had been successfully tied in continuity, referred to the statistics of Souchon which gave 16 cases with 16 deaths. The results of cases since then are very different, Saveriaud (23) in 1906, Monod and Van Verts (18) in 1909, and Rubritius (21) in 1911 have arranged tables from the cases reported since Dr. Curtis. Adding a case reported by Schwartz (24) in 1911, there have been 21 cases reported with 3 deaths: that is, the mortality in the reported cases since 1897 is 14.3 per cent.

**LIGATION OF THE THIRD OR SECOND PORTION OF THE SUBCLAVIAN ARTERY**

The patient is placed in the dorsal position with the face turned slightly to the opposite side and the shoulder depressed; a narrow sand bag is placed under the spine, not under the shoulder.

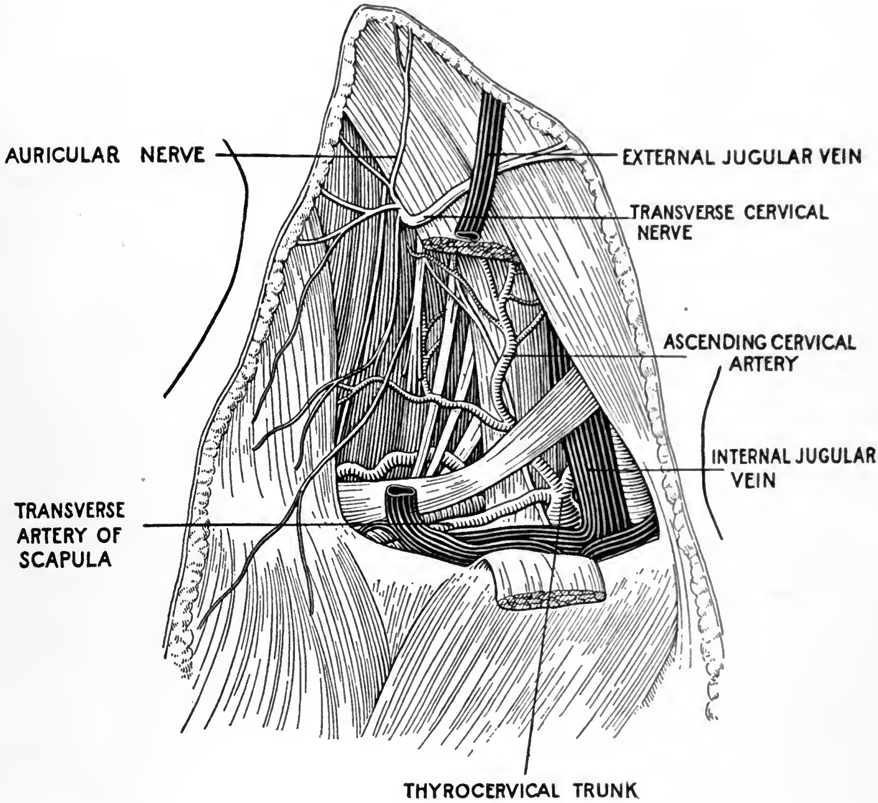


FIG. 10.—SUPERIOR CLAVICULAR REGION. (Poirier-Charpy.)

**Operation.**—The incision is made parallel to the clavicle and about 1 cm. (2/5 in.) above it. It should be about 8 cm. (3 1/8 in.) long, and the middle of the incision should be over the middle of the clavicle. The skin, superficial fascia, and platysma are divided and usually a few of the sensory filaments of the cervical plexus.

The external jugular vein, as it passes around the lateral border of the sternocleidomastoid, is divided between ligatures and the sternocleidomastoid retracted inward or severed close to its clavicular attachment. The cellular and fatty tissue are divided by blunt dissection and the inferior belly of the omohyoid exposed. This muscle or the fascia at its lower border is divided and retracted upward. The scalenus anticus muscle is identified. The subclavian artery passes outward from beneath this muscle; the cords of the brachial plexus lie above and behind it. The transverse artery of the scapula crosses the subclavian and is divided or retracted. The subclavian vein is retracted downward and the ligature is passed about the artery and tied. In ligating the second portion the phrenic nerve is identified as it crosses the scalenus anticus obliquely. It is freed by blunt dissection and retracted inward. The scalenus anticus is then divided and the second portion of the artery exposed. On the right side the costocervical trunk is usually given off from the back part of the vessel. If the aneurysm needle is passed gently and kept in contact with the arterial wall, this branch is not injured. The muscles are replaced and sutured and the skin incision closed.

**Results.**—The results of the ligature of the third portion of the subclavian are very good. In the recent cases in which the artery was ligated for aneurysm Monod and Van Verts (1909) (18, 23) give 10 cases of the ligature of the third portion with no deaths. These statistics are taken from cases reported since 1884. I can add a personal case operated on in 1912, in which the third portion of the subclavian and the common carotid were ligated successfully for innominate aneurysm.

## VERTEBRAL ARTERY

**Anatomy.**—The vertebral artery arises from the first part of the subclavian and passes upward and slightly outward to enter the foramen in the transverse process of the sixth cervical vertebra.

The vessel, between its origin and its entrance into the foramen in the transverse process, occupies the deepest portion of the supraclavicular region. In front of it are the vertebral vein, passing over the vessel to enter the subclavian vein, the anterior portion of the subclavian loop of the sympathetic nerve (ansa Vieussenii), and the inferior thyroid artery which, as it passes upward perpendicularly, crosses it. On the left side the thoracic duct crosses the subclavian below the vertebral artery.

The vessel lies for a short distance at its origin in contact with the pleura covering the dome of the lung (cupulopleura) (28). On approaching the foramen in the transverse process of the sixth cervical vertebra, it passes between the longus colli and the scalenus anticus muscle. The artery passes upward through the foramina in the transverse processes of the sixth, fifth, fourth, third, and second cervical vertebræ. On reaching the axis it passes very obliquely upward and outward to reach the foramen in the transverse process of the atlas; it then passes around the groove in the lateral process of the atlas and perforates the posterior atlo-occipital ligament.

The vessel is usually ligated in the portion between its origin and its entrance into the foramen in the transverse process of the sixth cervical vertebra.

**Operation.**—The patient is placed in the dorsal position with the face turned to the opposite side and the shoulder slightly elevated. An incision is made, 8 cm. (3 1/8 in.) long, parallel to the clavicle and just above it, starting external to the posterior border of the sternocleidomastoid muscle. The skin and platysma are divided, and the posterior border of the sternocleidomastoid and the external jugular vein identified and retracted inward. If this does not give enough room, the muscle is divided just above the clavicle. The deep cellular tissue is separated by blunt dissection, and the carotid tubercle and the interval between the scalenus anticus and the longus colli identified.

In this interval the vertebral artery, usually covered by the accompanying vein, is exposed. After separating the vein by blunt dissection, a ligature is passed about the vessel. In passing the ligature care must be taken not to injure the pleura. In ligating the vessel some of the filaments of the sympathetic are likely to be included in the ligature; this produces contraction of the corresponding pupil.

**Results.**—The vessel has been ligated a number of times by Alexander and Baracz for the cure of epilepsy, in many instances on both sides, without any untoward cerebral complications. Mikulicz (17) successfully ligated the vessel for aneurysm.

For ligation of the *inferior thyroid* see page 309, Vol. III.

## INTERNAL MAMMARY ARTERY

**Anatomy.**—The internal mammary artery arises from the anterior surface of the subclavian about 3 to 4 mm. external to the vertebra. It passes downward, forward and a little inward in contact with the pleura of the dome of the lung and behind the subclavian vein. At this level it is crossed by the phrenic nerve. It then passes downward in contact with the posterior surface of the first costal cartilage and, becoming nearly vertical, crosses the posterior surfaces of the upper costal cartilages. At the level of the sixth interspace it divides into its terminal branches; as far as the third rib it is in relation posteriorly with the parietal pleura; from the third costal cartilage downward the transverse muscle of the thorax (triangularis sterni) intervenes between the pleura and the artery. It is accompanied by two veins and a chain of lymphatic glands. At the first interspace the artery is about 10 mm. (2/5 in.) from the border of the sternum; at the level of the sixth it is about 20 mm. (4/5 in.) from this border. The interval between the artery and the border of the sternum gradually increases from above downward (Fig. 11).

**Operation.**—The patient is placed in the dorsal position. A vertical incision is made over the third intercostal space extending from the third rib to the lower border of the fourth rib and about 10 mm. (2/5 in.) from the margin of the sternum. The skin, subcutaneous tissue and fibers of the pectoralis major are divided, and the intercostal space with its muscles exposed. The aponeurosis of the external intercostal muscle and finally the internal intercostal muscle (about 5 to 8 mm. thick at this point) are divided. The artery with its two veins is separated by blunt dissection from the fatty and cellular bed in which it lies. After gently separating the veins, a ligature is passed

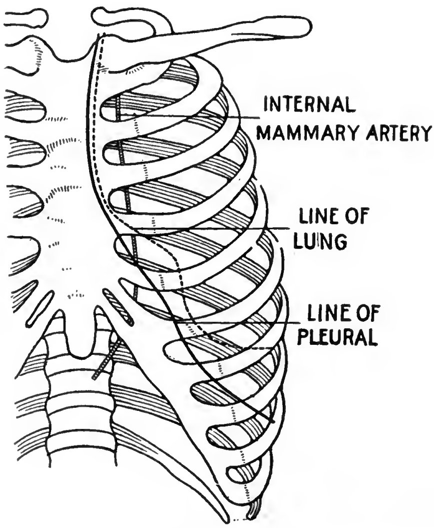


Fig. 11.—Line of Left Pleura, Lung and Internal Mammary Artery. (Précis de Technique Opératoire.)

about the artery. Great care is necessary in passing the aneurysm needle to prevent injury of the pleura. The transverse muscle of the sternum, which intervenes between the pleura and the artery, is often poorly developed, or even partially absent.

## AXILLARY ARTERY

**Anatomy.**—The axillary artery extends from the outer border of the first rib to the lower margin of the teres major. It is divided into three portions by the pectoralis minor. The first portion extends from the clavicle to the upper border of the pectoralis minor (Fig. 12). In front of the vessel are the skin, superficial fascia, pectoralis major, and beneath this muscle a layer of cellular tissue and fat in which pass the thoraco-acromial artery and vein, the nerve to the pectoralis major, the terminal part of the cephalic vein, the subclavian muscle and the strong fascia which extends from the upper border to the pectoralis minor—the upper portion of the claviculocoraco-axillary aponeurosis. The vessel lies on the first two digitations of the serratus anterior, and behind lie the fat and cellular tissue which fill the scapulothoracic junction. The second portion is covered by the pectoralis minor, and has to its outer side the coracoid insertion of the coracobrachialis and biceps. Behind it lies the subscapular muscle, covering the head of the humerus. The third portion of the artery is slightly overlapped by the coracobrachialis, which separates it from the pectoralis major. Covered by the skin and aponeurosis on its inner side, it passes downward in the groove in the coracobrachialis lying on the latissimus dorsi. In the first portion the vein lies to the inner side of the artery. When the vein is distended, it overlaps the artery. This portion of the vessel is crossed by the cephalic and acromial veins and by the outer one of the brachial veins. The terminal portions of the brachial plexus are placed behind and to the outer side. The nerve to the pectoralis minor passes behind the artery.

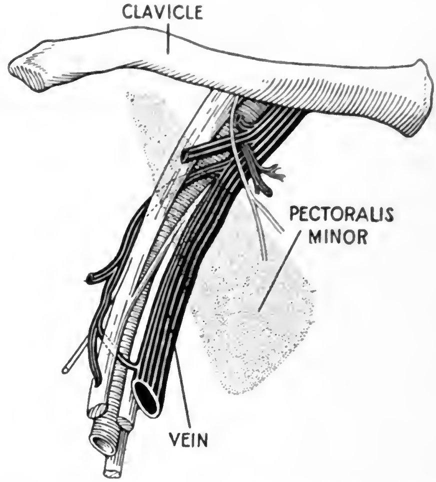

Fig. 12.—Neurovascular Bundle in Axilla. (Poirier.)

In the second portion the vein is in less close relation to the artery. One cord of the brachial plexus lies behind the artery, one to its outer side, and one to the inner side, intervening between the artery and vein. The branches of the brachial plexus are disposed about the third portion of the artery. The radial (musculospiral) and the circumflex are behind; between the artery and the vein is the ulnar; on the outer side is the median. These relations are given with the arm in position for ligature, that is, abducted (Fig. 12).

With the arm abducted at right angles to the body, a line drawn from the middle of the clavicle to the junction of the anterior and middle thirds of the outer axillary wall at the outlet of the axillary space represents the line of the vessel.

**Operation.**—The patient is placed in the dorsal position with the arm abducted at right angles to the trunk and the extended forearm midway between pronation and supination. The operator stands between the extended arm and the axilla.

Ligation of the First Portion.—An incision is made parallel to the fibers of the pectoralis major downward and outward from the clavicle to a finger's breadth below the coracoid process. The fibers of the pectoralis major are separated and retracted, or the fibers of the muscle are divided. The claviculocoraco-axillary aponeurosis is exposed, and the thoraco-acromial vessels identified, piercing the fascia just above the pectoralis major. The fascia is then divided, the artery is gently separated from the vein, and a ligature passed about it. The distended vein generally overlaps the artery. The cephalic vein and the cords of the brachial plexus must be carefully avoided. The vessel is deep in this situation and the ligation difficult.

LIGATION OF THE SECOND PORTION.—The incision is carried downward and outward from below the clavicle to $2\frac{1}{2}$ cm. (1 in.) below the coracoid process. The fibers of the pectoralis major are divided, and the narrow portion of the pectoralis minor exposed, its lower border freed from its fascia and the finger gently inserted beneath the muscle, and the muscle divided. The artery, the vein and the cords of the plexus are immediately beneath the muscle. The vein is gently retracted downward, and a ligature passed about the artery. The severed pectoralis minor and the separated fibers of the pectoralis major are sutured, and the wound closed.

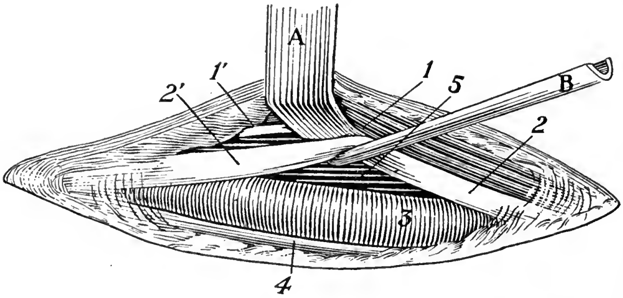


FIG. 13.—LIGATION OF THE AXILLARY ARTERY. The retractor (A) has pulled upward the coracobrachialis (1) with the musculocutaneous nerve (1′). The director (b) elevates the second landmark, the median nerve (2′). The lesser internal cutaneous nerve (4) has remained in place, generally not noticed like the other nerves and the large vein. The small collateral vein (5) can be seen in the depths of the wound.

LIGATION OF THE THIRD PORTION.—The incision is made over the inner border of the coracobrachialis, over the line of pulsation of the artery which can usually be easily felt. It should be about 8 to 10 cm. (3-4 in.) long. The center of the incision is above the anterior axillary fold. The skin and superficial fascia are divided and the thin fascia of the upper arm laid bare. The coracobrachialis is identified, the fascia carefully divided, and the lower margin of the wound retracted. The median nerve now appears, imbedded in loose cellular tissue; it is freed and retracted upward. The artery is thus exposed and a ligature passed about it (Fig. 13).

**Results.**—Recent reports of the results of the ligature of the axillary artery are favorable. According to Delbet (9) gangrene after ligature of the axillary is extremely rare. V. Bergmann has seen only good results after ligature for wounds of the artery. Koch (9) has collected 45 cases of ligature without any trouble with the circulation in the arm.

## BRACHIAL ARTERY

**Anatomy.**—The vessel commences at the lower margin of the teres major and, passing down the inner and interior aspect of the arm, terminates about 1 cm. below the bend of the elbow, where it divides into the radial and ulnar arteries. At first the artery lies internal to the humerus; but as it passes down the arm it gradually acquires a more anterior position, and at the bend of the elbow it lies midway between the two epicondyles. The artery is superficial throughout its entire course, being covered in front by the integument, the superficial and deep fasciæ; the bicipital fascia separates it at the elbow from the median basilic vein; the median nerve crosses it at its middle. Behind, it is separated from the long head of the triceps by the radial nerve (musculospiral nerve) and superior profunda artery. It then lies upon the inner head of the triceps, next upon the insertion of the coracobrachialis, and lastly on the brachialis. On its outer side it is in relation with the commencement of the median nerve, the coracobrachialis and biceps, which overlap the artery to a considerable extent. On its inner side, the upper half is in relation with the medial cutaneous nerve of the forearm and the ulnar nerve. The basilic vein lies on the inner side of the artery, but is separated from it in the lower part of the arm by the deep fascia. It is accompanied by two venæ comites, which lie in close contact with the artery, being connected at intervals by short transverse communicating branches.

At the bend of the elbow the brachial artery lies in a triangular-shaped space, the cubital fossa, the base of which corresponds to a line drawn between the two epicondyles of the humerus, the sides to the inner edge of the brachioradialis muscle and the outer edge of the pronator teres, the floor being formed by the brachialis and supinator. The contents of this space are: the brachial artery and its two veins; the radial and ulnar arteries; the median and radial nerves (musculospiral nerves); and the tendon of the biceps. The brachial artery lies along the middle line of this space and divides opposite the neck of the radius into the radial and ulnar arteries. The artery is covered in front by skin, superficial and bicipital fascia, and is crossed by the median basilic vein. Behind, it lies upon the brachialis, which separates it from the elbow joint. The median nerve lies on the inner side of the artery, close to it above, but separated from it below by the slip of the pronator teres, which arises from the coronoid process of the ulna. The tendon of the biceps lies to the outer side of the space, and the radial nerve (musculospiral nerve) still more externally, situated upon the supinator and partly concealed by the brachioradialis.

If the thumb be pressed into the deepest part of the axilla, just behind the tendon of the pectoralis major, the pulsation of the axillary artery can be felt. Between this point and the middle of the crease of the elbow a straight line is drawn. This line should correspond to the inner border of the coracobrachialis and biceps, which can always be felt and usually seen. The pulsations of the brachial artery can often be felt along this line (Fig. 17).

The brachial artery can be ligated at any point in its course. For convenience of description, ligature of its upper and middle third and in the cubital fossa will be described.

**Operation.**—UPPER THIRD.—The patient should be in the dorsal position, with the arm at a right angle to the body and the hand held by an assistant in a position half way between pronation and supination. An incision of 8 cm. in length is made, beginning at the lower border of the pectoralis major and along the linear guide to the vessel. This incision is carried down to the deep fascia, which is divided with great care to prevent possible injury to the internal cutaneous nerve or basilic vein, which sometimes runs on the surface of the artery as high as the axilla. After division of the fascia, care should be taken not to injure the ulnar or medial cutaneous nerve of the forearm, which lie to the inner side of the artery, or the median nerve, which lies usually to the outer side, or the venæ comites, which are on either side of the vessel. After the artery has been isolated from these structures, the needle should be passed around the artery from the inner to the outer side (Fig. 14).

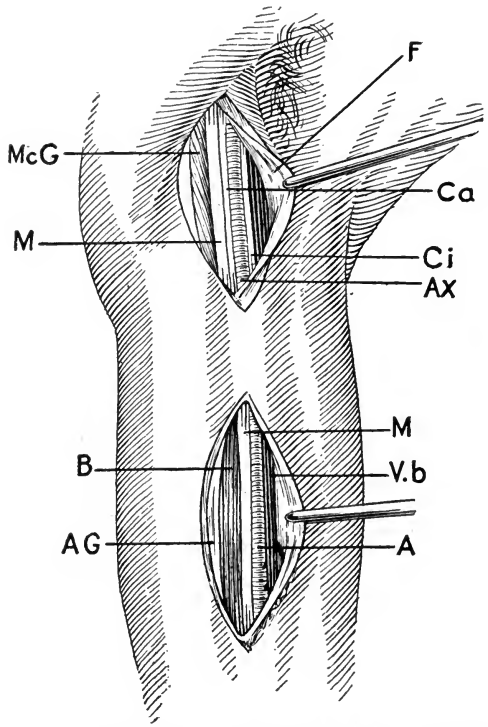


Fig. 14.—Exposure of the Axillary and Brachial Arteries. McG, Coracobrachialis muscle; F, inner side of fascia of upper arm; M, median nerve; Ci, medial nerve of upper arm (lesser internal cutaneous); Ca, medial nerve of forearm (internal cutaneous); Ax, axillary artery; B, biceps; F, fascia brachii; M, median nerve; A, brachial artery; V.b, brachial vein. (Zuckerkandl.)

Middle Third.—An incision of 8 cm. in length is made opposite the most prominent part of the biceps and along the linear guide to the vessel. The fascial lata is divided with care to prevent injury to the median nerve, which lies in front of the artery in this situation, as it passes from its outer to its inner side. After retraction of the nerve and isolation of the artery from its venæ comites the needle is passed around the artery from within outward (Fig. 14).

In the Cubital Fossa.—The forearm is held in a position of forced supination in order to define the tendon of the biceps. An incision of 8 cm. in length is made along the inner border of the tendon of the biceps, care being taken not to divide unnecessarily the median basilic vein, which can be retracted. The bicipital fascia is then exposed and divided. The artery is seen lying between two venæ comites, with the median nerve to its inner side and the tendon of the biceps to its outer side. After the artery has been isolated from its veins, the needle should be passed from within outward (Figs. 15, 16).

## RADIAL ARTERY

The radial artery can be ligated at any point between its origin at the bifurcation of the brachial, just below the bend of the elbow, and the point where it passes forward between the two heads of the first dorsal interosseous muscle to become, by anastomosis with the deep branch of the ulnar, the deep volar arch.

**Anatomy.**—The linear projection of the radial artery on the surface is represented by a line drawn midway between the apices of the bony epicondyles

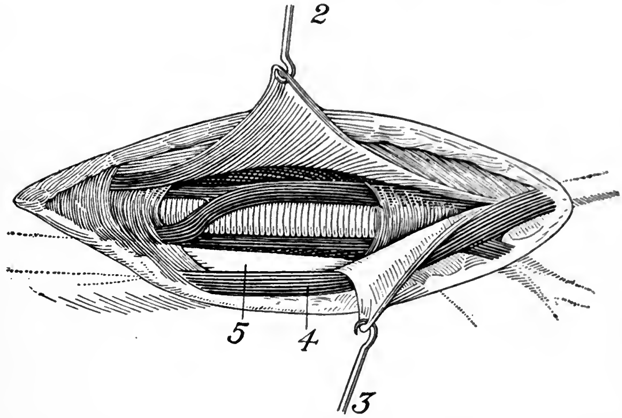


Fig. 15.—Ligature of the Left Brachial at the Bend of the Elbow. 2, External lip; 3, internal lip of the fascial expansion of the biceps retracted; 4, origin of the basilic vein; 5, median nerve. (Farabeuf.)

of the humerus and the inner aspect of the extremity of the styloid process of the radius (Figs. 16 and 17).

It extends from the bend of the elbow, where it lies opposite the neck of the radius, to the anterior aspect of the extremity of the styloid process. It lies to the inner side of the shaft of the bone above and in front of it below. It is overlapped in the upper part of its course by the fleshy part of the brachioradialis muscle. Throughout the rest of its course it is superficial, being covered only by skin and by superficial and deep fasciæ. In its course downward it lies upon the tendon of the biceps, the supinator, the pronator teres, the radial origin of the flexor longus pollicis, the pronator quadratus and the lower extremity of the radius. In the upper third of its course it lies between the brachioradialis and the pronator teres. In its lower two-thirds, between the tendons of the brachioradialis and flexor carpi radialis. The radial nerve lies close to the outer side of the artery in the middle third of its course, and some filaments of the musculocutaneous nerve, after piercing the deep fascia, accompany the lower part of the artery as it winds around the wrist. The vessel is accompanied by venæ comites throughout its whole course, At the wrist, as it winds round the outer side of the carpus from the styloid process to the first interosseous space, it lies upon the external lateral ligament and then upon the scaphoid bone and trapezium, being covered by the extensor tendons of the thumb, subcutaneous veins, some filaments of the radial nerve and the skin. It is accompanied by two veins and a filament of the musculocutaneous nerve.

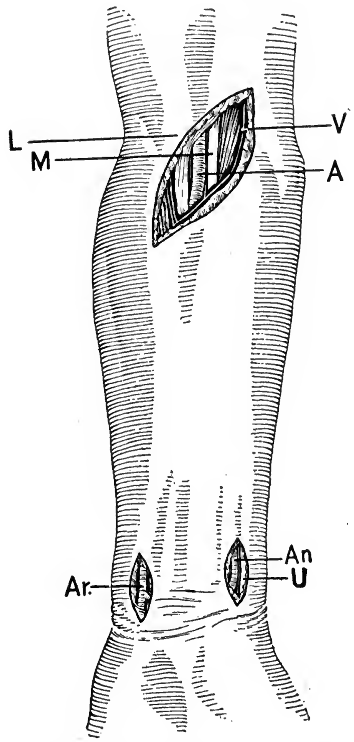


Fig. 16.—Exposure of the Brachial Artery in the Cubital Fossa and of the Radial and Ulnar Arteries. L, Oblique incision of the bicipital fascia; A, brachial artery with the venæ comites; M, median nerve; V, median basilic vein; Ar, radial artery; An, ulnar artery; U, the inner edge of the flexor carpi ulnaris. (Zuckerkandl.)

At this situation the surface outline of the space in which the vessel lies is a triangle, bounded internally by the tendon of the extensor longus pollicis, externally by that of the extensor brevis pollicis and the base corresponding to the apex of the styloid process of the radius. If the thumb be forcibly extended, the outlines of the space will be well marked.

In the hand it passes from the upper end of the first interosseous space, between the heads of the first dorsal interosseous muscle, transversely across the palm to the base of the metacarpal bone of the little finger, where it anastomoses with the communicating branch of the ulnar, forming the deep volar arch. It lies upon the carpal extremities of the metacarpal bones and the interosseous muscles, being covered by the adductor pollicis, the flexor tendons of the fingers, the lumbricales, opponens and flexor brevis minimi digiti. Alongside of it is the deep branch of the ulnar nerve (Fig. 18).

**Operation.**—UPPER THIRD.—With the forearm supinated, an incision 8 cm. in length is made along the linear guide to the vessel, beginning opposite the inferior angle of the cubital fossa. Upon division of the fascia, the brachioradialis muscle herniates into the wound. Its internal border should be found and the muscle retracted laterally, exposing the artery accompanied by its two veins with the nerve to the radial side. The artery is then isolated and the needle passed from without inward.

The vessel has been found lying over the fascia instead of beneath it. It has also been observed on the surface of the brachioradialis instead of under its inner border.

LOWER THIRD.—The vessel is superficial, covered only by the skin and superficial and deep fasciæ, and can be readily recognized by its pulsation.

With the arm placed as in the preceding operation, an incision 6 cm. (2.4 in.) in length is made along the course of the vessel. Upon division of the skin and fasciæ the artery is seen, accompanied by its two veins, lying between the tendons of the brachioradialis (supinator longus) and the flexor carpi radialis. The artery is isolated and the needle passed from without inward, great care being taken not to injure the nerve which lies just to the outer side of the artery.

AT THE WRIST.—An assistant should hold the hand with its ulnar border on the table and move the thumb so as to make the extensor tendons stand out and define the triangular space through which the vessel passes.

An incision 3 cm. (1.18 in.) in length is made half way between the two extensors of the thumb and parallel with them, beginning at the tip of the styloid process of the radius and continued downward. Upon division of the skin, the dorsal vein of the thumb is exposed, and is either retracted or ligated. The deep fascia is divided in the line of the skin incision, keeping always between the tendons. With the tendons retracted, the cellular tissue beneath is held up between two forceps and incised, exposing the artery accompanied by its two veins, passing through this space in a downward and backward direction. The vessel is isolated and tied by passing the needle in either direction.

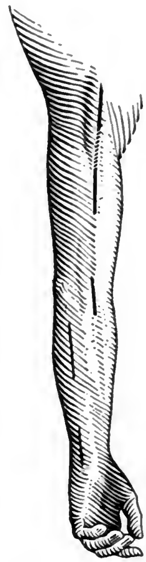

FIG. 17.—LINES OF INCISION FOR LIGATURE OF BRACHIAL ARTERY. (Farabeuf.)

IN THE HAND.—The linear projection of the deep volar arch on the surface is a curved line with its convexity downward, drawn parallel to and a finger's breadth above the linear projection of the superficial volar arch, which is represented by a continuation across the palm of a line drawn along the palmar border of the thumb when it is held in a position of forced extension.

An incision 5 cm. (2 in.) in length is made vertically downward in the mid line, ending just below the line of the superficial volar arch. The palmar aponeurosis is divided in the line of the skin incision and retracted with the skin edges, exposing the superficial volar arch crossing the lower part of the wound. In the upper angle of the wound are seen the flexor tendons, with the digital branches of the median nerve between them. A division with the handle of the knife is made between the tendons, great care being taken not to injure the branches of the median to the three innermost lumbricales, which are given off at about this point. Blunt retractors are introduced and the division enlarged by means of them, exposing the deep volar arch accompanied by the deep branch of the ulnar nerve. The needle should be passed from below upward, particular care being taken not to injure the branches of the ulnar supplying the volar interossei.

## ULNAR ARTERY

**Anatomy.**—The linear projection on the surface of the lower two-thirds of the ulnar artery is represented by a line drawn from the apex of the median epicondyle of the humerus to the radial side of the pisiform bone (Fig. 17). To project the upper third of the artery upon the surface, the junction of the

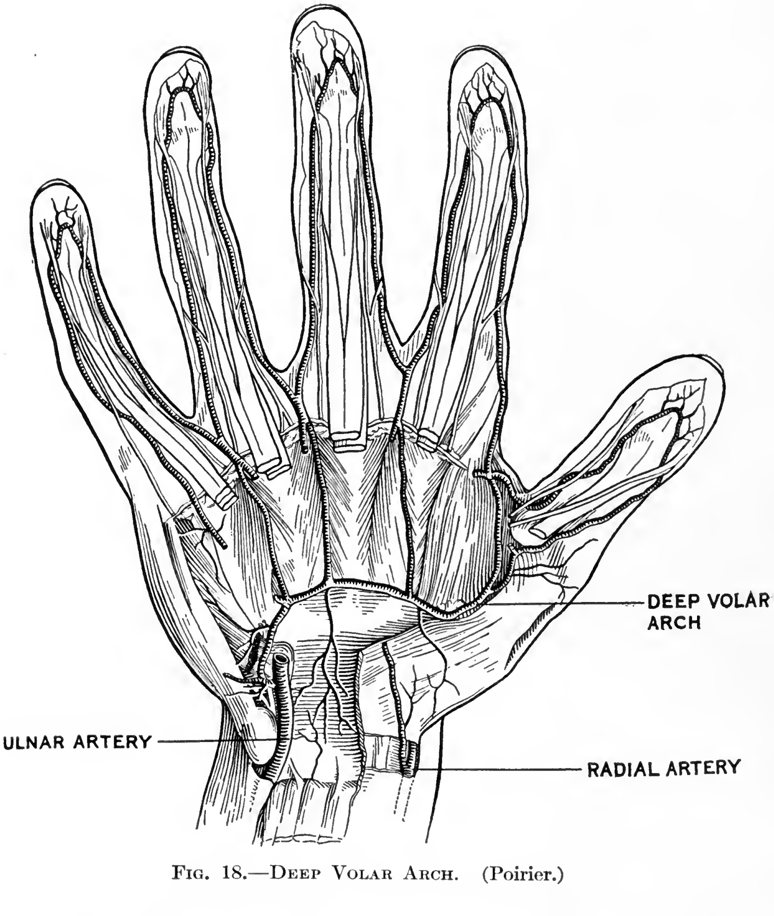


FIG. 18.—DEEP VOLAR ARCH. (Poirier.)

upper and middle thirds of this line is connected with the center of the hollow in front of the elbow joint. The projection of the superficial volar arch upon the surface is represented by a continuation across the palm of a line drawn along the palmar border of the thumb, when it is held in a position of forced extension.

The ulnar artery commences a little below the bend of the elbow, and crosses obliquely the inner side of the forearm to the commencement of its lower half; it then runs along its ulnar border to the wrist, crosses the transverse carpal ligament on the radial side of the pisiform bone, and immediately beyond this bone divides into two branches which enter into the formation of the superficial and deep volar arches. In its upper half it is deeply seated, being covered by all the superficial flexor muscles, excepting the flexor carpi ulnaris; the median nerve is in relation with the inner side of the artery for about an inch and then crosses the vessel, being separated from it by the deep head of the pronator teres; it lies upon the brachialis and flexor profundus digitorum. In the lower half of the forearm, it lies upon the flexor profundus, being covered by the integument and the superficial and deep fasciæ, and is placed between the flexor carpi ulnaris and flexor sublimis digitorum. It is accompanied by two venæ comites. The ulnar nerve lies on its inner side for the lower two-thirds of its course, and a small branch from the nerve descends on the lower part of the vessel to the palm of the hand.

At the wrist it is covered by the skin and fascia and lies upon the transverse carpal ligament. On its inner side is the pisiform bone. The ulnar nerve lies to the inner side and somewhat behind the artery; here the nerve and artery are crossed by a band of fibers which extends from the pisiform bone to the transverse carpal ligament.

In the hand the artery, by anastomosis with a branch from the radial volar artery of the index finger or the superficial volar ramus, branches of the radial artery, forms the superficial volar arch.

**Operation.**—JUNCTURE OF UPPER AND MIDDLE THIRDS.—The forearm should be supinated. An incision 8 cm. (3.15 in.) in length is made along the linear guide to the vessel, beginning 8 cm. (3.15 in.) below the medial epicondyle of the humerus. This incision is carried down through the deep fascia, which is retracted with the skin edges, exposing the superficial muscle layer. The line of division between the flexor carpi ulnaris and flexor sublimis digitorum is sought for, and these muscles are separated from one another along this line. The artery is now seen lying upon the flexor profundus digitorum, accompanied by its two veins, with the ulnar nerve to its inner side. The artery should be freed and the needle passed from within outward.

LOWER THIRD.—The position of the patient and the forearm should be as in the preceding operation. The hand should be forcibly extended so as to make the tendon of the flexor carpi ulnaris tense. An incision 8 cm. (3.15 in.) in length is made along the radial border of this tendon and carried down through the deep fascia, permitting the tendon to be retracted in an inward direction. The artery is found beneath the tendon, accompanied by its two veins, and with the ulnar nerve lying to its inner side. The artery should be freed from its veins and the needle passed from within outward.

AT THE WRIST.—With the hand resting on its dorsal surface, a curved incision with its convexity outward, 5 cm. (2 in.) in length, is made along the radial side of the pisiform bone. Keeping close to the pisiform bone, this incision is deepened through fascia and fatty tissue, until the vessel is reached. After the artery has been isolated from its two companion veins, to avoid injury to the ulnar nerve, which lies close to the inner side of the artery, the needle should be passed from within outward (Fig. 16).

IN THE HAND.—The operation for tying the superficial volar arch is the same as that for ligation of the deep volar arch, as the superficial arch is exposed in the course of this operation.

## ABDOMINAL AORTA

**Anatomy.**—The abdominal aorta extends from the opening in the diaphragm to the body of the fourth lumbar vertebra, where it divides into its

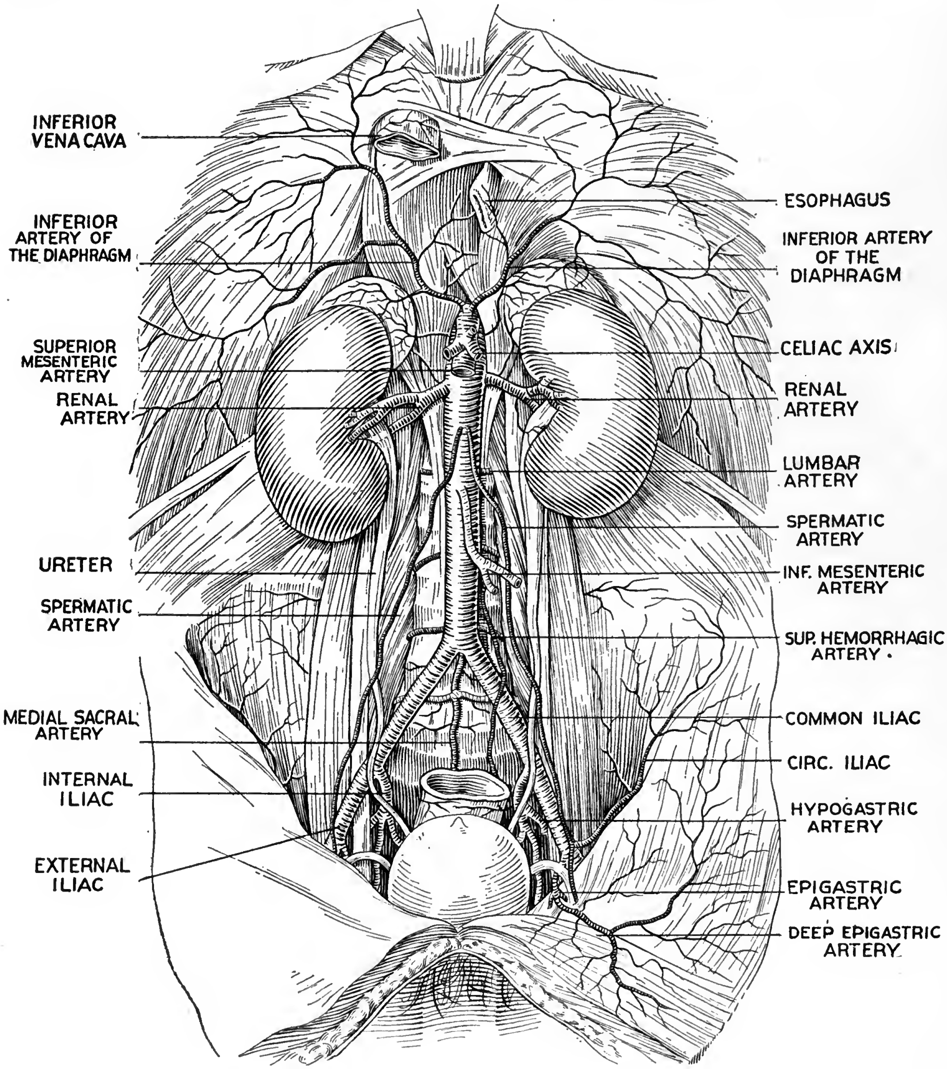


FIG. 19.—ABDOMINAL AORTA AND COMMON ILIAC ARTERIES.

terminal branches. The point of bifurcation of the vessel is approximately indicated by the intersection of a horizontal line passing through the upper limits of the iliac crests and the median line of the abdomen. It gives off large visceral branches to the gastro-intestinal tract, to the kidneys and to the genital organs. Its lowermost visceral branch is the inferior mesenteric. It has usually been ligated below this branch in the last two inches of its course. It lies on the vertebral column, the lumbar veins and the recepticulum chyli; at its right lies the inferior vena cava. In front are the peritoneum, the sympathetic and the intestines (Fig. 19).

**Operation.**—The patient is placed in the Trendelenburg position. A vertical incision about 10 cm. (4 in.) long is made through the abdominal wall just to the left of the navel, and beginning about 3 fingers' breadth above it. The intestines are pushed upward and kept in place by abdominal pads. The peritoneum is divided over the vessels, which can be readily seen and felt, and a ligature passed about it. The peritoneum and celiotomy wound are then sutured.

EXTRAPERITONEAL LIGATION.—The vessel may be ligated extraperitoneally. The patient is placed in the dorsal position. The incision extends from the tenth rib downward and forward to within one inch of the anterior superior spine of the ilium; the abdominal wall is divided. The patient is then turned to one side, the peritoneum is gently separated with the fingers and pushed with the intestines inward. The ureter is raised with the peritoneum; the aorta comes in view on retracting the upper margin of the wound, and a ligature is passed about it.

**Results.**—The abdominal aorta has been ligated 15 times; it has been ligated 12 times for aneurysm and 3 times for hemorrhage. The operation has been done 10 times through the peritoneum and 5 times extraperitoneally. Death has resulted in every instance, in from one hour to 48 days. In no instance have there been signs of gangrene of the lower extremities. The fatal issue has been attributed 7 times to infection; twice to hemorrhage due to the ligature; 4 times to hemorrhage independent of the ligatures. In the other cases reported the cause of death is not indicated.

According to animal experimentation the gravity of the operation depends upon the site of the ligature; yet in Keen's patient, who survived 48 days, the ligature applied for aneurysm was passed about the vessel just below the diaphragm. It has been suggested that in this instance a collateral circulation had already been established (Monod and Van Verts, 18).

## COMMON ILIAC ARTERY

**Anatomy.**—The common iliac artery extends from the bifurcation of the aorta at the lower border of the fourth lumbar vertebra to the line of the sacro-iliac junction. It measures about 5-7 cm. (2-3 in.) in length, the right being a little longer than the left. The vessels pass downward and outward, diverging from one another at an angle of 65° in man and 75° in woman. The artery lies on the lateral portion of the fifth lumbar vertebra and on the inner border of the psoas.

The relations of the veins to the arteries vary on the two sides. On the right the vein lies behind the artery and is intimately attached to it. On

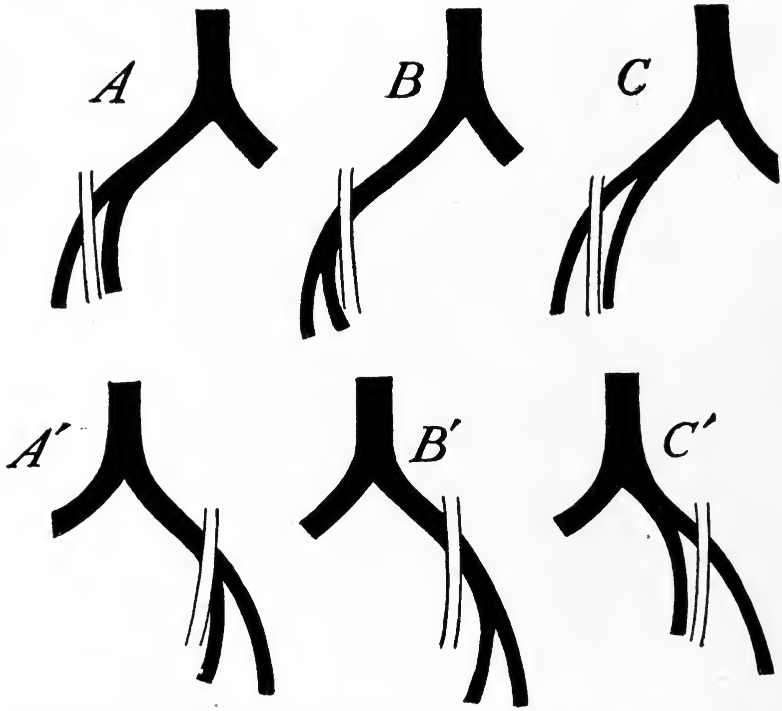


Fig. 20.—Scheme of the Different Types of Relation of the Ureter and Iliac Vessels. A, A′, Normal type; B, B′, low bifurcation of common iliac; C, C′, high bifurcation. (Proust and Maurer.)

the left the vein lies at first to the inner side of the artery and in contact with it, and then passes beneath the right common iliac to form the inferior vena cava. The lymphatic ganglia of the iliac chain are ordinarily placed on either side of the artery. The ureter normally crosses the left common iliac artery nearly perpendicularly. On the right side the ureter usually crosses below the bifurcation, passing over the external iliac; exceptionally the ureter passes over the common iliac on the right side (Fig. 20). The vessels are covered by peritoneum and the subperitoneal cellular tissue.

**Operation.**—(1) TRANSPERITONEAL.—The patient is placed in the Trendelenburg position. An incision about 10 cm. (4 in.) in length is made along the outer border of the rectus muscle, and the abdominal cavity opened. The intestines and omentum are pushed upward and held back by suitable gauze pads. The vessel is identified by touch and sight. A small opening is made in the peritoneum over the artery and the aneurysm needle threaded with the ligatures passed about the vessel. The needle is passed from without inward on the right, and from within outward on the left. The ureter is carefully avoided in making the peritoneal incision, and the ligature is passed in close contact with the artery to avoid injuring the veins. The needle is withdrawn

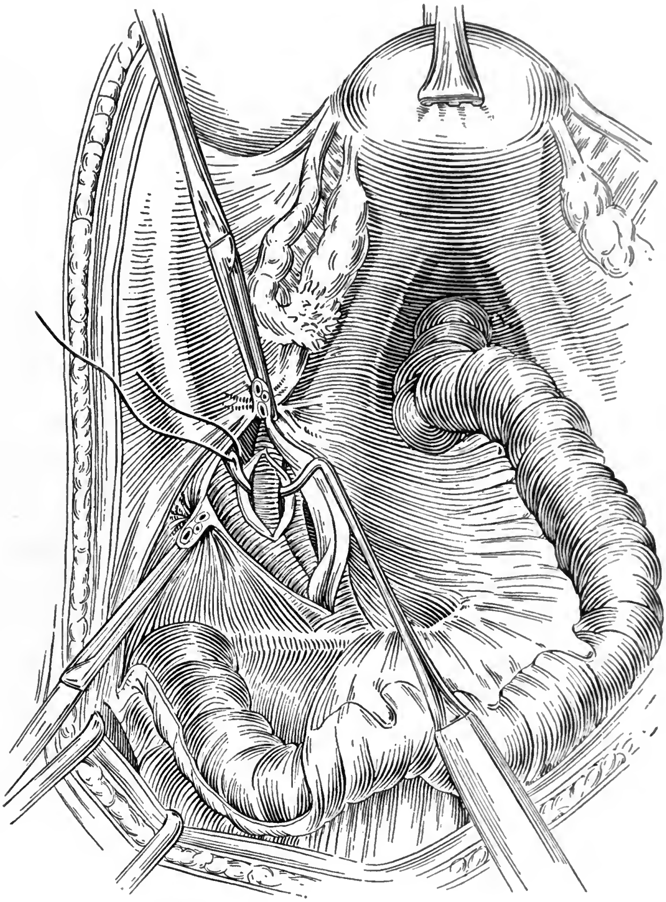

Fig. 21.—Ligature of Left Internal Iliac. The utero-ovarian vessels are divided. The ureter is seen in the upper part of the internal lip of the incision. (Proust and Maurer.)

and the ligature tied, the peritoneum sutured, and the abdominal incision closed by the usual layers of sutures.

(2) Extraperitoneal.—The patient is placed in the Trendelenburg position. The incision begins near the apex of the cartilage of the last rib, passes downward and outward to a finger's breadth above the crest of the ilium, and then runs parallel to the crest just below the anterior superior spine. The muscles of the abdominal wall are cut through down to the peritoneum. The peritoneum is then gently separated by blunt dissection from the tissues be-

neath until the arteries are felt. The peritoneum and abdominal muscles are then retracted inward. The arteries can now be easily seen. The ureter is lifted up with the peritoneum. The aneurysm needle armed with a ligature is passed from without inward on the right, and from within outward on the left. The needle is made to hug the vessel and is passed very gently to avoid injuring the veins. The ligature is tied, the peritoneum allowed to fall back in place, the muscle sutured in layers, and the skin incision closed.

**Results.**—The mortality, taken from the statistics of Kümmell from the operations done before the antiseptic period, is high, about 75 per cent. In the recent figures of Delbet (9) the proportion of deaths is 22 per cent. Gillette (13) gives the mortality in 21 cases done since 1880 as 47 per cent. Gangrene of the extremity is said to follow in 53 per cent. of the cases reported (Wolff, 29), but Delbet gives its occurrence as 22 per cent., and according to Gillette (13) it has occurred in 33⅓ per cent. of the cases he has tabulated.

## INTERNAL ILIAC ARTERY

**Anatomy.**—The common iliac artery bifurcates at the lower border of the fifth lumbar vertebra, near the sacrovertebral angle at 3 to 5 cm. (1 1/10 to 2 in.) from the middle line. The internal iliac extends from this point downward toward the great sacrosciatic foramen, near the upper border of which it divides. The commencement of the artery crosses the upper end of the external iliac veins, and the internal iliac veins lie behind and to its inner side. The artery is covered by the peritoneum. On the left side the peritoneum covering the artery is exposed if the sigmoid is lifted upward. In the female the infundibulopelvic ligament containing the ovarian vessels crosses the artery. The ureter is adherent to the peritoneum and is lifted up with the peritoneum when this is divided. On the right side the ureter usually passes down to the outside of the artery. Occasionally when the bifurcation of the common iliac is lower, the ureter passes downward below the internal iliac after crossing the common iliac (Fig. 20). On the left side the ureter usually crosses the iliac vessels at their bifurcation; occasionally it crosses the common iliac internal to this point; and less commonly still, when the bifurcation is high, the ureter crosses the external iliac and passes downward to the outside of the internal iliac.

**Operation.**—The patient is placed in the Trendelenburg posture. The abdomen is opened in the middle line, beginning at the level of the navel and passing downward for about 10 cm. (4 in.). The intestines are pushed upward and held in place by suitable gauze pads. The common iliac is identified and followed down to its bifurcation. The ureter is easily recognized and the peritoneum is carefully incised, avoiding this structure. An aneurysm needle is gently passed about the artery at a point about 2 cm. (4/5 in.)

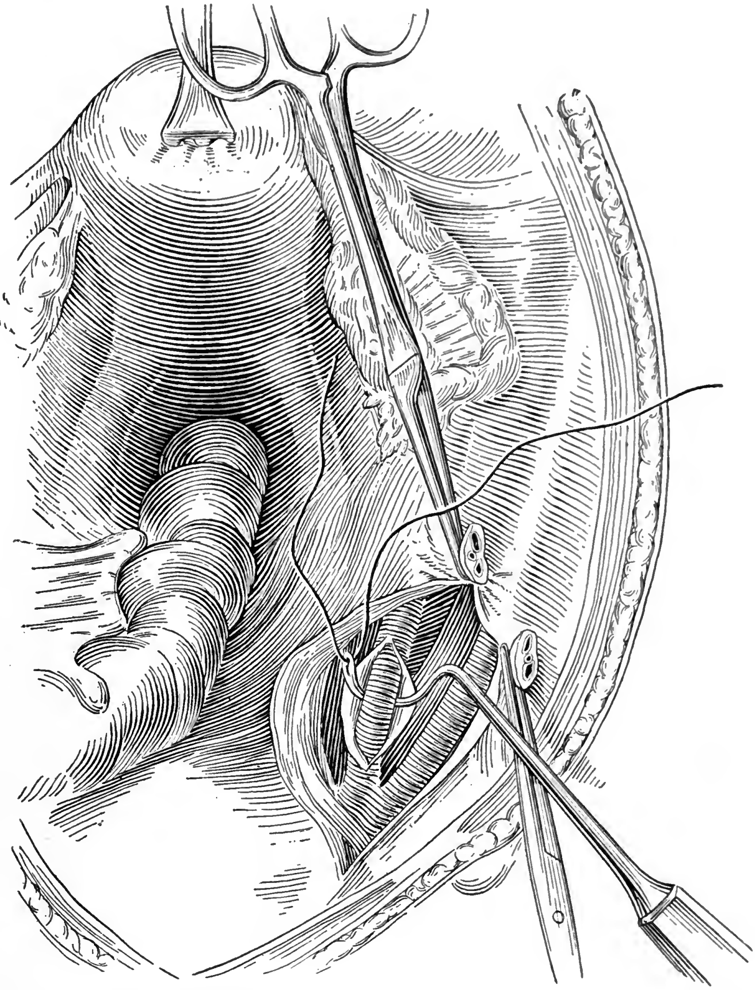

FIG. 22.—LIGATURE OF THE RIGHT INTERNAL ILIAC. The ureter with the peritoneum retracted to one side, exposing the internal iliac. (Proust and Maurer.)

from its origin. The needle is kept in close contact with the artery, which at this point is intimately related to the iliac veins (Figs. 21, 22).

**Results.**—The vessel has usually been ligated to control the hemorrhage in pelvic operations. Transperitoneal aseptic ligating is accompanied by a low mortality rate. Proust and Maurer (20) report 8 cases with 1 death, in which the vessel was ligated in the course of abdominal hysterectomy for cancer.

## GLUTEAL ARTERY

**Anatomy.**—The gluteal artery passes out of the pelvis between the piriformis and the upper border of the sacrosciatic notch. It is accompanied by two large veins, one lying in front, the other—usually the larger—lying behind the artery. The superior gluteal nerve passes out of the pelvis with the artery, but in front and to the outer side of the vessel. The gluteus maximus covers the artery (Fig. 23). The artery lies at the junction of the upper and

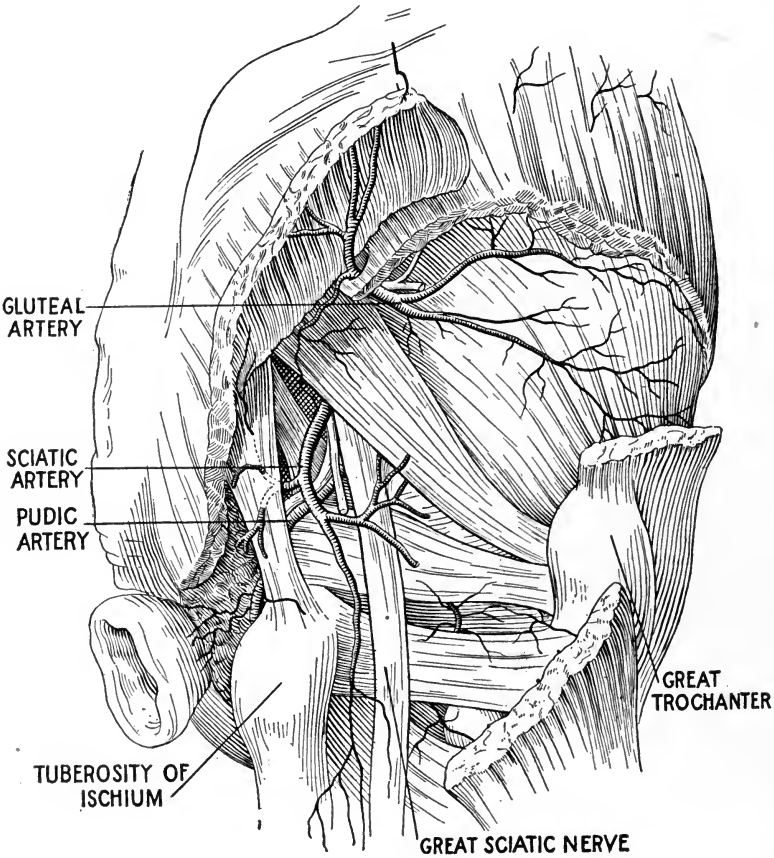


Fig. 23.—The Gluteal and Sciatic Arteries. (Poirier.)

middle third of a line drawn from the posterior superior spinous process of the ilium to the great trochanter with the thigh rotated inward.

**Operation.**—The patient is placed face down with the thighs extended and rotated in. An incision is made along the line extending from the posterior-superior spinous process of the ilium to the great trochanter. This incision lies in the direction of the fibers of the gluteus maximus. The fibers of this muscle are separated, and the gluteus medius covered by its fascia exposed. This fascia is divided and the lower margin of the gluteus medius freed by blunt dissection or retracted upward. The upper margin of the great sacrosciatic notch can then be easily felt, and between this margin and the piriformis the artery is exposed and ligated, the accompanying veins and nerve being carefully avoided.

## SCIATIC ARTERY

**Anatomy.**—The sciatic artery passes out of the pelvis below the piriformis muscle, and passes downward between the great trochanter and the tuberosity of the ischium. As it passes out of the pelvis it lies to the inner side of the sciatic nerves and passes over the internal pudic vessels and nerve (Fig. 22).

**Operation.**—The patient is placed prone. An incision is made parallel to the line drawn from the posterior superior spinous process of the ilium to the great trochanter with the thigh rotated inward, and two fingers' breadth below it. The fibers of the gluteus maximus are separated and the lower edge of the piriformis exposed. The sciatic nerves are gently retracted outward. The vein which lies to the outer side of the artery is pushed to one side and a ligature passed about the artery.

## INTERNAL PUDIC ARTERY

**Anatomy.**—The internal pudic artery leaves the pelvis by the great sacrosciatic notch in the space between the border of the piriformis and the superior border of the lesser sacrosciatic ligament. It then passes over the ischial spine and through the small sacrosciatic foramen, to continue above the outer wall of the ischiorectal fossa, being placed about 2 cm. (4/5 in.) above the lower margin of the tuberosity of the ischium. As it crosses the spine of the ischium, the sciatic nerve is in front and to its outer side.

The internal pudic nerve, which accompanies the artery, is behind it, passing over the summit of the ischial spine and over the commencement of the lesser sacrosciatic ligament. The vessel then runs along the outer wall of the ischiorectal fossa. It is covered, in this part of its course, by a layer derived from the obturator fascia (Fig. 23).

**Operation.**—The vessel may be ligated (1) as it emerges from the sacrosciatic foramen or (2) in the perineum.

(1) The incision is made parallel to the line drawn from the posterior superior spine of the ilium to the trochanter major and two fingers' breadth below it. The gluteus maximus is separated and retracted, and the lower border of the piriformis defined. The gluteal artery is retracted upward and the pudic artery, as it passes over the spine of the ischium, is exposed and ligated.

(2) The patient is placed in the lithotomy position. A longitudinal incision, along the mesial border of the tuber ischii and about 10 cm. (3.94 in.) long, is made through the skin and the cellular tissue. Anteriorly, the transverse muscle of the perineum is avoided and retracted forward; posteriorly, the posterior border of the gluteus maximus is exposed. The fascia covering the internal surface of the obturator is divided, the deeply placed internal pudic artery and nerve exposed, and the ligature passed about the artery.

## EXTERNAL ILIAC ARTERY

**Anatomy.**—The course of the external iliac artery corresponds to the lower two-thirds of a line, drawn from a point 1 cm. below and to the left of the navel to a second point halfway between the anterior superior spine of the ilium and the symphysis pubis. The length of the vessel varies according to the point of bifurcation of the common iliac, averaging 10 cm. In its course downward the artery rests against the inner border of the psoas. It is covered by the peritoneum and is crossed on the right side by the lower part of the ilium and on the left by the sigmoid flexure. The external iliac vein lies at first behind the artery and a little to its inner side; but as the vessels reach the inguinal region, they are on the same level, and the vein lies to its inner side. Near its termination the artery is crossed by the circumflex iliac vein and three or four lymph glands lie along its outer and inner sides. The spermatic (or ovarian vessels) and the genital branch of the genitocrural intersect it near the inguinal ligament. On the right side the ureter usually crosses the external iliac just below the bifurcation, except when the latter is very low; on the left side, it generally crosses at the bifurcation, only intersecting the external iliac when the division of the common iliac into its two branches is very high (Fig. 20).

**Operation.**—(1) EXTRAPERITONEAL METHOD.—The patient is placed in the Trendelenburg posture. An incision is made parallel to and above the middle third of Poupart's ligament. The skin, superficial fascia and the aponeurosis of the external oblique are divided. The lower margins of the internal oblique and transversalis are separated and retracted upward, and the transversalis fascia divided by blunt dissection. The peritoneum and the subserous tissue are then gently displaced upward and held by retractors. This exposes the vessels. The sheath is opened and an aneurysm needle with the ligature passed from within outward.

(2) TRANSPERITONEAL METHOD.—The usual incision for exposing the appendix is made midway between the anterior superior spine of the ilium and the semilunar line. The aponeurosis of the external oblique is divided, the internal oblique and the transversalis are separated, and the peritoneum opened. A small gauze pad is inserted into the wound, pushing the coils of intestine away from the peritoneum covering the external iliac artery. The wound margins are retracted and the peritoneum covering the vessel pinched up and divided. With an aneurysm needle a ligature is carried about the vessel from within outward.

**Results.**—The mortality following ligature of the external iliac has been much reduced in recent years. Monod and Van Vert (18) collected 7 cases with no death. Kermission in the period from 1874 to 1883 gives a mortality of 12.5 per cent.

The frequency of gangrene following ligature of the external iliac has been variously stated. Wolff (29) gives it as occurring in 5.26 per cent. of the patients in which the artery was ligated for aneurysm.

## DEEP EPIGASTRIC ARTERY

**Anatomy.**—The deep epigastric is given off from the external iliac just as that vessel passes beneath the inguinal ligament, and continues upward and inward to a point situated 2 cm. (.79 in.) external to the navel. At its origin it passes mesial to the internal abdominal ring. It lies between the fascia transversalis and the peritoneum and enters the rectus sheath at the semicircular fold of Douglas. A line drawn from the navel to the mid point of the inguinal ligament corresponds to the course of the artery.

**Operation.**—An incision is made parallel to the inguinal ligament and about 3 cm. (1.18 in.) above it. The aponeurosis of the external oblique is divided and the lower fibers of the internal oblique and transversalis are separated and retracted upward. The transversalis fascia is then divided, exposing the vessel with its two accompanying veins. The ligature is passed about the artery and tied. The vessel may also be tied somewhat high up, as it passes beneath the margin of the rectus abdominalis.

The incision, parallel to the inguinal ligament and about 5 cm. (1.97 in.) above it, is made through the sheath of the rectus and the aponeurosis of the lateral abdominal muscle just external to the rectus. Separation of the transversalis fascia exposes the artery with its veins as it passes beneath the rectus.

## DEEP CIRCUMFLEX ILIAC ARTERY

**Anatomy.**—The vessel passes upward and outward from its origin, outside of the external iliac, behind the inguinal ligament. It lies on the iliacus muscle in a fibrous compartment formed by the junction of the transversalis and iliac fasciæ.

**Operation.**—The incision is made over the outer third of Poupart's ligament and just above it. The skin, subcutaneous tissue and the aponeurosis of the external oblique are divided. The internal oblique and transversalis are separated and retracted upward. The fascia transversalis is opened, and the peritoneum gently displaced upward, thus exposing the iliacus muscle covered by its fascia. On opening the iliac fascia the artery is exposed and ligated.

## FEMORAL ARTERY

**Anatomy.**—The course of the vessel is indicated by a line extending from a point midway between the anterior superior spine of the ilium and the symphysis pubis, downward to the adductor tubercle of the femur; the thigh being flexed, everted and slightly adducted. The upper 4 cm. of this line corresponds to the common femoral; the upper two-thirds to the common and the superficial femoral. As it passes through Scarpa's space, the vessel is covered by the skin, subcutaneous tissue, the iliac portion of the fascia lata and, in the upper part, by the femoral sheath. It then enters a canal made by the fibrous membrane which passes over the artery from the abductor to the extensor muscles and is covered by the sartorius muscle. The femoral vein lies at first to the inner side of the artery, becomes more posterior at the level of the apex of Scarpa's triangle, and as it passes down through Hunter's canal, is situated distinctly behind the artery. In Hunter's canal the internal saphenous nerve accompanies the artery, lying along its anterior surface, and the internal cutaneous crosses its upper part.

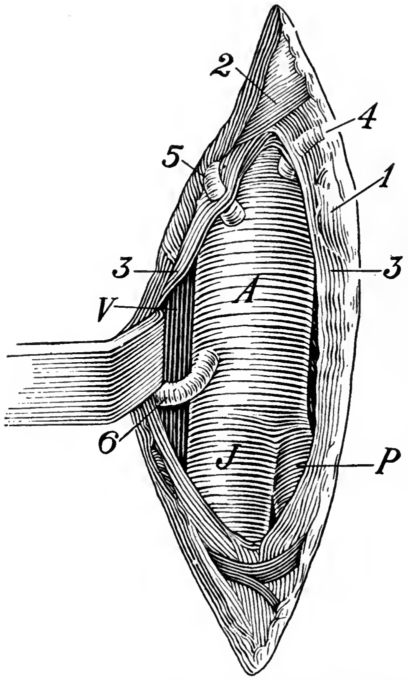


Fig. 24.—Left Femoral Artery Exposed by Incision of the Integument and the Cribriform Fascia. 1, Lymph gland; 2, inguinal ligament; 3, 3, edges of the divided cribriform fascia; 4, superficial circumflex artery; 5, superficial epigastric; 6, external pudendal artery; A, femoral artery; J, superficial femoral; P, deep femoral.

**Operation.**—LIGATION OF THE COMMON FEMORAL.—The patient is placed in the dorsal position with the thigh flexed and rotated out. An incision is made parallel to and just below Poupart's ligament, corresponding to its middle third.

The skin and superficial fascia are divided and the deep fascia exposed. This is then carefully incised in the line of the incision and retracted, bringing to view the artery with the vein to its inner side and the iliopsoas to the outer side. The sheath of the vessel is divided over the artery and an aneurysm needle passed from within outward, or the vessel may be exposed through a vertical incision (Fig. 24).

Results.—Ligation of the common femoral is said to be followed by gangrene in 25 per cent. of the cases (Wolff, 29). But 5 cases are referred to by Monod and Van Vert (18), when the common femoral was ligated without any disturbance in the nutrition of the leg.

LIGATURE OF THE SUPERFICIAL FEMORAL AT THE APEX OF SCARPA'S TRIANGLE.—The patient is placed in the dorsal position with the thigh flexed and rotated outward. An incision about 10 cm. (3.94 in.) long is made along the line extending from the mid point of Poupart's ligament to the adductor tubercle and terminating just below the junction of the upper and middle third of the thigh. The sartorius is exposed and retracted to the outer side. The artery can be felt beneath the fascia. The sheath of the vessel is carefully incised and an aneurysm needle passed from within outward. The vein lies behind and to the inner side of the artery in this situation (Fig. 24).

LIGATURE OF THE SUPERFICIAL FEMORAL IN HUNTER'S CANAL.—The patient is placed in the dorsal position with the thigh and leg flexed and the thigh rotated outward. An incision about 10 cm. (3.94 in.) long is made in the line of the vessel, having its center at the junction of the middle and lower third of the thigh. The line of the vessel is the line drawn from the middle of Poupart's ligament to the adductor tubercle of the femur. The sartorius muscle is exposed and retracted inward. The fibrous membrane extending over the artery from the tendon of the adductor magnus to the vastus internus is divided. This exposes the artery with the long saphenous nerve resting on it. The nerve is freed and held to one side by a retractor, and an aneurysm needle is passed about the vessel from without inward. The vein lies behind the artery and sometimes a little to its outer side (Fig. 25).

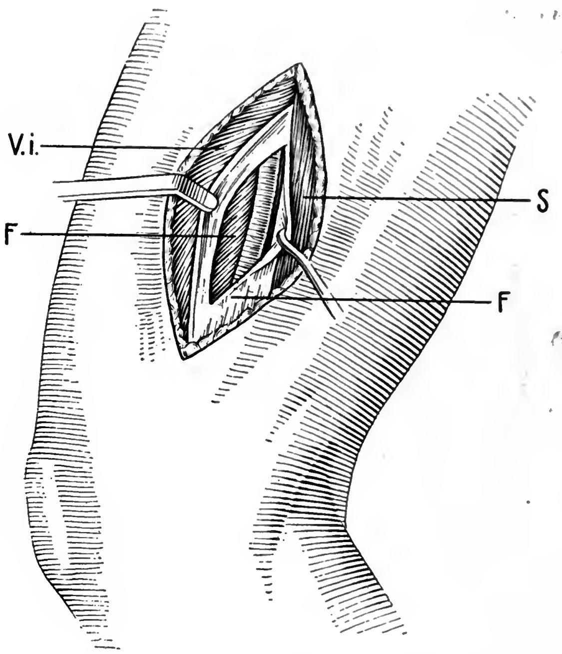

FIG. 25.—EXPOSURE OF THE FEMORAL ARTERY. V.i., Vastus medialis; S, sartorius. The fibrous sheath of Hunter's canal is divided exposing the femoral artery and vein.

RESULTS.—According to the table of Wolff (29), there has been necrosis of the extremity following the ligation of the superficial femoral in 4.2 per cent. of the cases reported.

## POPLITEAL ARTERY

**Anatomy.**—The lineal projection of the popliteal artery is represented by a vertical line which bisects the popliteal space. In the upper part of the space the vessel lies a little to the mesial side of this vertical line, beneath the lateral border of the semimembranosus.

The femoral artery terminates at the point where the popliteal emerges from the opening for the vessels in the adductor magnus, at the upper part of the popliteal space, under cover of the semimembranosus. The popliteal artery terminates at the lower border of the popliteus, on a level with the lower part of the tuberosity of the table, where it divides into the anterior and posterior tibial arteries. From its origin the artery descends with a slight lateral inclination to the interspace between the condyles of the femur, whence it continues its course vertically downward to its termination.

From above downward it lies upon the popliteal surface of the femur, the posterior ligament and the fascia covering the popliteus.

Superficial to the artery above is the lateral border of the semimembranosus. At about the middle of its course it is crossed in a direction downward and inward by the popliteal vein and more superficially by the tibial nerve (internal popliteal). In the lower part of its course it is overlapped by the adjacent borders of the medial and lateral heads of the gastrocnemius and crossed by the plantaris and the nerves to the soleus popliteus and plantaris.

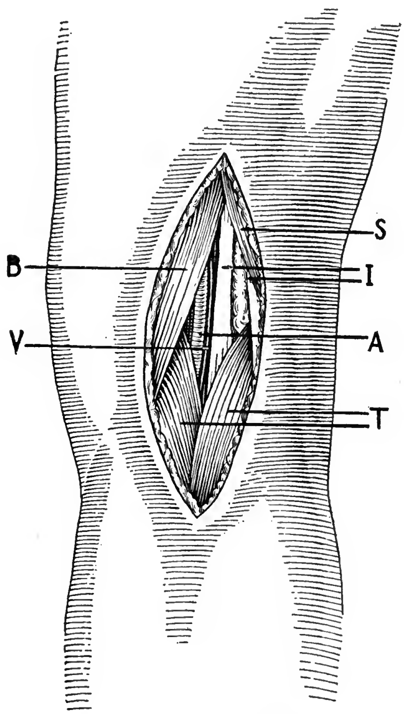

Fig. 26.—Exposure of Popliteal Artery. S, Semimembranosus; B, biceps; T, lateral and medial head of the gastrocnemius; A, artery; V, popliteal vein.

On its mesial side from above downward are the semimembranosus, the mesial condyle of the femur, the tibial nerve, the femoropopliteal vein and the mesial head of the gastrocnemius.

On its lateral side from above downward are the tibial nerve, the femoropopliteal vein, the lateral condyle of the femur, the lateral head of the gastrocnemius, and the plantaris. Lymphatic glands are distributed about the vessel in an irregular way.

**Operation.**—Ligature of the artery in the upper and lower parts of the popliteal space will be described.

UPPER PART OF THE POPLITEAL SPACE.—The patient should be on his back, the knee somewhat flexed and supported by a sandbag, the thigh rotated outward.

An incision 10 cm. (3.94 in.) in length is made parallel and a little posterior to the adductor magnus, and carried down to the level of the adductor tubercle. The saphena magna (internal saphenous vein) is retracted inward and the fascia lata divided, exposing the sartorius. This is retracted inward and backward, and together with it the saphenous nerve. The tendon of the adductor magnus is now exposed, with the tendons of the hamstrings lying behind it. A division is made between the hamstrings and the adductor magnus, and the former retracted inward and the latter outward toward the bone. The artery now comes into view with the femoropopliteal vein lateral to it, and the tibial nerve (internal popliteal) still more lateral and not in contact. The sheath of the vessel is opened and the needle passed from without inward.

LOWER PART OF POPLITEAL SPACE.—The patient should be prone. An incision 10 cm. (3.94 in.) in length is made along the linear guide to the vessel, opposite the lower half of the popliteal space. This incision is carried down through the tendinous intersection of the gastrocnemius, so as to separate the upper parts of the two heads of the muscle. The tibial nerve is now exposed and retracted laterally. The femoropopliteal vein is next identified and retracted mesially, exposing the artery. Care should be taken in passing the needle about the artery not to injure the middle, the inferior lateral or the inferior mesial arteries of the knee, given off at this level (Fig. 26).

**Results.**—If the collateral vessels are free, ligature of the popliteal is not followed by gangrene.

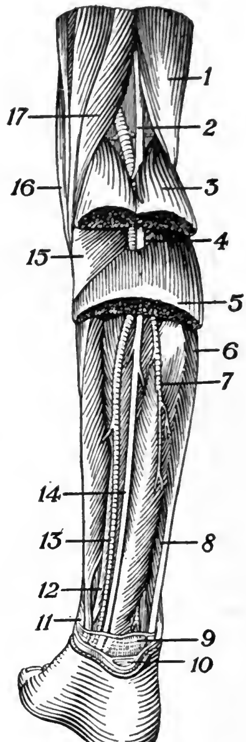


FIG. 27.—THE COURSE AND RELATIONS OF THE POSTERIOR ARTERIES OF THE LEG. 1, Biceps; 2, the tibial nerve (internal popliteal); 3, the cut sections of the upper portions of the gastrocnemius; 4, the tibial nerve and the popliteal artery just before they pass through the opening in the soleus; 5, section of the soleus; 6, long peroneal muscle; 7, long flexor of the great toe and the peroneal artery; 8, short peroneal muscle; 9, deep aponeurosis; 10, section of the tendo Achillis; 11, long flexor of the toes; 12, tendon of the posterior tibial muscle; 13, posterior tibial artery; 14, tibial nerve; 15, popliteal muscle; 16, tendon of the sartorius semitendinosus; 17, semimembranosus.

## POSTERIOR TIBIAL ARTERY

**Anatomy.**—The linear projection of the posterior tibial artery is represented by a line drawn from the center of the popliteal space to a point midway between the mesial malleolus and the tuberosity of the calcaneum.

The posterior tibial artery commences at the lower border of the popliteus and terminates at a line drawn between the tip of the mesial malleolus and the prominence of the tuberosity of the calcaneum at the level of the lower border of the ligamentum laciniatum (internal annular ligament), where it divides into the mesial and lateral plantar arteries.

The artery pursues a downward and inward course along the back of the leg, lying upon the deep layer of muscles and covered by the fascia cruris (deep transverse fascia) and superficial layer of muscles.

From above downward the artery lies upon the tibial posterior, the flexor longus digitorum, the posterior surface of the tibia and the ligamentum talotibiale posterius. The artery is crossed from within outward, about 3 cm. (1.18 in.) below its origin, by the tibial nerve. It is covered throughout its course by the fascia cruris. More superficially it is covered in the upper part of the leg by the gastrocnemius and the soleus, with the plantaris between them. In the lower part of its course the artery is covered only by skin and fascia, except at its termination, where it passes beneath the ligamentum laciniatum (internal annular ligament) and the origin of the adductor hallucis. The artery has a vein on either side. The tibial nerve (posterior tibial nerve) lies at first to the mesial side of the vessel, then crosses superficial to it, and is continued down on the lateral side. As the vessel curves forward behind the mesial malleolus, it lies upon the tendons of the posterior tibial and flexor longus digitorum, with the tendon of the flexor longus hallucis behind and lateral to it (Fig. 27).

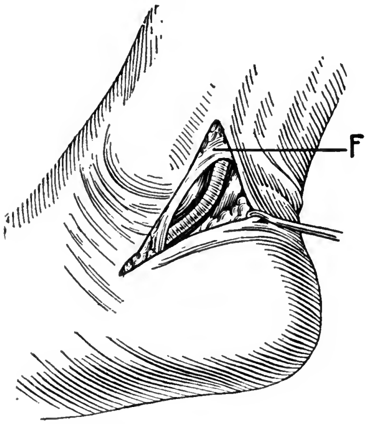


Fig. 28.—Exposure of Posterior Tibial Behind the Medial Malleolus. The fascia is divided exposing the artery with the veins. (Zuckerkandl.)

**Operation.**—The patient should be on his back, with the thigh rotated externally and the knee flexed to a right angle and supported upon a sandbag. The artery can be ligated at any point in its course. Ligature in the middle of the leg and behind the medial malleolus will be described.

In the Middle of the Leg.—An incision 10 cm. (3.84 in.) in length, beginning opposite the most prominent part of the calf, is made parallel to, and about a finger's breadth posterior to the mesial border of the tibia. The large saphenous vein (internal saphenous vein) and saphenous nerve are identified and retracted. After division of the fascia lata the mesial border of the gastrocnemius comes into view and is retracted laterally, exposing the muscular fibers of the soleus which arise from the middle third of the mesial border of the tibia. These are divided in the line of the skin incision exposing the fascia cruris (deep transverse fascia of the leg). This is opened in the same direction and the flexor longus digitorum with the posterior tibial lying lateral to it is exposed. The artery lies between these muscles with the tibial nerve lateral to it. After the artery has been freed from its veins, the needle should be passed from without inward.

Behind the Medial Malleolus.—The position should be the same as in the preceding operation.

A curved incision 8 cm. (3.15 in.) in length, with its concavity anterior, is made a finger's breadth posterior to the mesial malleolus. The ligamentum laciniatum (internal annular ligament) is divided in the same direction, exposing the artery lying upon the tendons of the posterior tibial and flexor longus digitorum, with the tibial nerve and tendon of the flexor longus hallucis behind and lateral to it. After freeing the vessel from its accompanying veins, the needle is passed from behind forward (Fig. 28).

## PERONEAL ARTERY

**Anatomy.**—The linear projection of the peroneal artery is represented by a line drawn from the posterior border of the head of the fibula to a point midway between the lateral malleolus and the tendo calcaneus (Achillis).

The peroneal artery commences about 2.5 cm. below the lower border of the popliteus, curves laterally across the upper part of the posterior tibial to the medial crest (postero-internal border) of the fibula, along which it descends to the lower part of the interosseous space, and terminates about 1 inch above the ankle joint by dividing into anterior and posterior terminal branches.

As the artery passes laterally from its origin, it lies upon the posterior tibial muscle and is covered by the fascia cruralis (deep transverse fascia) and by the soleus. As it descends along the medial crest (postero-internal border) of the fibula it lies in a fibrous canal upon the posterior tibial and is covered by the flexor longus hallucis. It is accompanied by two venæ comites (Fig. 27).

**Operation.**—The artery can be ligated at any point in its course. Ligature in the upper and lower third of the leg will be described.

UPPER THIRD.—The position of the patient is the same as in the two preceding operations. The incision and steps of the operation are the same as in the ligature of the posterior tibial in the middle of the leg. After the division of the fascia cruris (deep transverse fascia) the artery is found lying upon the posterior tibial and partially overlapped by the flexor longus hallucis. After it has been separated from its veins, the needle may be passed in either direction.

LOWER THIRD.—The patient should be face down, with a sandbag under the ankle. An incision 8 cm. (3.15 in.) in length is made along the line of the vessel on the lower third of the leg. After division of the deep fascia, the soleus is exposed and drawn inward, bringing the flexor longus hallucis into view. The attachment of this muscle to the fibula is divided in the direction of the skin incision, exposing the artery lying upon the lateral border of the posterior tibial muscle. The artery is separated from its veins and the needle passed in either direction.

## ANTERIOR TIBIAL ARTERY

**Anatomy.**—The linear projection of the anterior tibial artery is represented by a line drawn from the superior tibiofibular articulation to a point on the anterior aspect of the ankle joint midway between the mesial and the lateral malleoli.

The anterior tibial commences opposite the lower border of the popliteus and terminates in front of the ankle joint, where it is continued into the dorsalis pedis.

From its origin it passes forward between the two uppermost slips of the posterior tibial and above the upper border of the interosseous membrane upon which it lies for the upper two-thirds of its course down the leg. In the lower third it lies upon the shaft of the tibia and the anterior ligament of the ankle joint. In the upper third of the leg it lies between the extensor longus digitorum externally and the anterior tibial internally; in the middle third between the extensor longus hallucis and the anterior tibial; in the lower third the extensor longus hallucis crosses in front of the artery to its inner side, and the lower part of the vessel lies between the tendon of the extensor longus hallucis and the innermost tendon of the extensor longus digitorum.

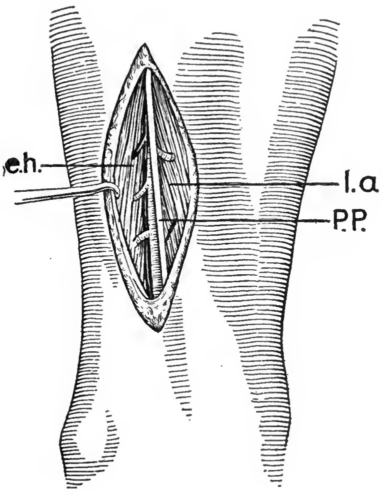


FIG. 29.—EXPOSURE OF THE ANTERIOR TIBIAL OF LEFT LEG. The fascia is divided and the anterior tibial muscle (I.a.) retracted medially and the extensor hallucis (e.h.) laterally; in the interval between the muscles the deep peroneal nerve and under it the artery and veins accompanying it are visible.

The anterior tibial nerve lies to the lateral side of the artery above, in front of it in its middle third, and to the lateral side again below, where it intervenes between the artery and the innermost tendon of the extensor longus digitorum.

The artery is accompanied by two venæ comites.

In the greater part of its extent the artery is easily accessible from the surface, being crossed by the nerve and tendon, as already described, and covered by skin, fascia, and the ligamentum transversum cruris (Figs. 29, 30 and 31).

**Operation.**—The anterior tibial artery can be ligated at any point in its course after it has gained the anterior aspect of the leg. Ligature of the artery in its upper and lower thirds will be described.

IN THE UPPER THIRD.—The patient should be on his back, with the knee slightly flexed, and supported by a sandbag.

An incision 10 cm. (3.94 in.) in length is made along the line of the artery, commencing about two fingers' breadth below the lateral condyle (external tuberosity) of the tibia, and deepened to expose the aponeurosis covering the extensor muscles of the leg. This aponeurosis is incised in the line of the skin incision, the anterior tibial muscle and the extensor digitorum are separated by blunt dissection, thus exposing the artery on the interosseous membrane. The artery is separated from its accompanying veins, which lie to either side of it, and the needle passed from without inward. The deep peroneal nerve lies to the lateral side and not in contact with the artery.

IN THE LOWER THIRD.—The position of the patient is the same as in the preceding operation.

An incision 10 cm. (3.94 in.) in length is made along the line of the artery, just to the lateral edge of the tendon of the anterior tibial muscle, and carried through the fascia lata. A division is made between the tendons of the anterior tibial and extensor longus hallucis, care being taken not to open the sheath of

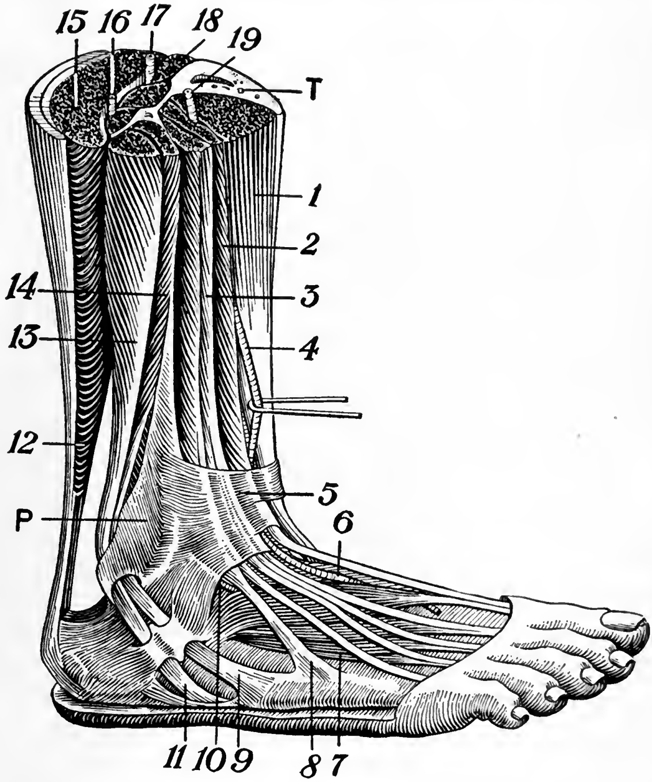


FIG. 30.—MUSCLES AND ARTERIES OF THE LEG AND DORSUM OF THE FOOT. 1, Anterior tibial; 2, long extensor of great toe; 3, extensor longus digitorum; 4, anterior tibial artery pulled out of its bed by a loop; 6, dorsal artery of the foot.

the anterior tibial muscle. The artery is now exposed, lying upon the lateral surface of the tibia, with a vein to either side and the deep peroneal nerve in front of it above, and lateral to it below. The needle should be passed from without inward (Fig. 28).

## DORSALIS PEDIS ARTERY

**Anatomy.**—The linear projection of the dorsalis pedis artery is represented by a line drawn from a point on the anterior aspect of the ankle joint midway between the two malleoli to the apex of the web between the great toe and second toe. The artery is subcutaneous throughout the greater part of its course, and its pulsations can ordinarily be felt (Figs. 30 and 31).

The dorsalis pedis artery, a direct continuation of the anterior tibial, extends from the front of the ankle joint to the posterior extremity of the first interosseous space, through which it passes to the plantar surface of the foot, and, by anastomosing with the lateral plantar, completes the plantar arch.

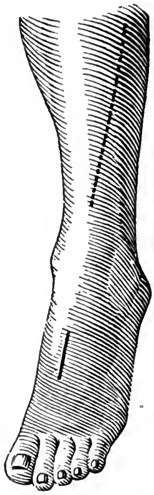

Fig. 31.—Line of Dorsal Artery of the Foot and of the Anterior Tibial.

In its course along the dorsum of the foot it lies upon the anterior ligament of the ankle joint, the head of the astragalus, the astragalonavicular ligament, the dorsum of the navicular bone, the dorsal naviculocuneiform ligament and the dorsal intercuneiform ligament between the internal and middle cuneiforms. The medial terminal branch of the deep peroneal nerve, the extensor brevis digitorum and the innermost tendon of the extensor longus digitorum are placed laterally. The tendon of the extensor longus hallucis lies medially. It is covered by skin, fascia and the lower part of the annular ligament. It is crossed near its termination by the innermost tendon of the extensor brevis digitorum.

**Operation.**—The patient should be on his back with the foot extended.

The dorsalis pedis can be ligated at any point between its origin and the posterior extremity of the first interosseous space. Owing to the shortness of the vessel, ligature at any point in the vessel's course can be accomplished through one incision.

An incision is made along the line of the artery, beginning at a point opposite the tips of the two malleoli and carried to the posterior extremity of the first interosseous space. After division of skin and fascia, the tendon of the extensor longus hallucis will be seen lying to the mesial side of the incision, with the innermost tendon of the extensor longus digitorum lateral to it. In the upper angle of the incision, these two tendons are bound down by the lower part of the annular ligament. In the lower angle of the incision the innermost tendon of the extensor brevis digitorum crosses from without inward. To expose the artery in the upper part of the incision the lower part of the annular ligament must be divided in the line of the skin incision, and the tendons retracted to either side. The artery lies between the tendons with a vein to either side and the deep peroneal nerve to its lateral side. In the lower angle of the incision the innermost tendon of the extensor brevis digitorum must be retracted laterally to expose the artery. In both instances, after the artery has been separated from its veins, the needle should be passed from without inward. In closing the wound care should be taken to repair the divided lower part of the annular ligament.

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# CHAPTER XII

## PLASTIC SURGERY, INCLUDING HARELIP AND CLEFT PALATE, ALSO THE PLASTIC SURGERY OF THE LIPS, CHEEKS, EYELIDS, AND EARS

PERCY R. TURNURE

Plastic surgery is that branch of surgery which deals with the repair of defects or malformations, either congenital or acquired, and the improvement of cosmetic conditions.

### GENERAL PRINCIPLES

To obtain successful results in any plastic operation, two fundamental principles must be observed: first, as perfect an asepsis as possible in order to obtain primary union; and, second, no interference with the vitality of the parts.

Complete asepsis is of the utmost importance, and the greatest care must be exercised to insure it. Strong antiseptic solutions must never be used, as they undoubtedly diminish the healing ability of the tissues. Therefore, if infection does take place, the operation will not only fail, but the final result may be much worse than the condition before operation.

To insure the nutrition of the transposed parts, the operation must be so planned that the blood supply is sufficient, and that the vessels remain patent and are not obliterated by either twisting or tension after the parts have been secured in their new positions.

Treves (24) sums up these principles in the most excellent and comprehensive way, as follows:

"1. The common feature which underlies plastic surgery, as the term is usually understood, involves the ready and secure union of refreshed or divided surfaces. The operations for the most part concern the skin, and are dependent upon the vascularity and elasticity of the skin, its mobility, the readiness with which wounds made in it unite, and the comparative ease with which it may be displaced and with which it moulds and adapts itself to a new situation.

"2. In the actual planning of incisions and the mapping out of flaps, little can be done by following blindly any especial method. Each case must be considered upon its merits, and each operation arranged as the needs of the particular case suggest. No branch of operative surgery demands more ingenuity, more patience, more forethought or more attention to detail. In connection with certain operations it may almost be said that no two cases are alike.

"3. As sound and rapid healing is essential in these operations, it is of primary importance that the patient be in the best possible health and that the tissues in the operation area be free from disease. Scar tissue can never be relied upon, and it is needless to speak of the recklessness of plastic operations in the vicinity of active syphilitic disease, or of lupus, or in aged or broken-down subjects. In many cases the operation cannot be repeated; there is little before the surgeon but success or a condition more lamentable than mere failure. A plastic operation may leave the deformity in a worse condition than it was before the case was approached, and before the prospects of success are compromised the surgeon should be convinced that no possible element of failure has been overlooked.

"4. In planning the flaps, it is necessary that they be derived from sound tissues, that they be thick and include the subcutaneous tissue, that their vascularity be assured and that they be so cut as to inflict the least possible damage upon the arteries which supply them. The flap must be large enough, and as a rule should be one-sixth larger than the space it has to fill; it must be gently handled, carefully adjusted and most tenderly and precisely sutured. The pedicle of the flap must not be so twisted or extended as to occlude the nutrient vessel. It is of the utmost importance that there be no undue tension upon the parts, and that the edges of the wound be not merely dragged together.

"5. The margins of any surfaces of skin which are to be brought together must be evenly and liberally freshened. Throughout the whole progress of the case the strictest antiseptic[1] precautions must be carried out, and the minutest care must be paid in the after-treatment."

## METHODS USED IN PLASTIC SURGERY

The following are the general methods used in plastic surgery for the repair of loss of tissue or malformation on the surface of the body or mucous membrane:

**1. Suture and Tension.**—This method consists simply in the freshening of the edges of the skin or mucous membrane surrounding the area to be filled in, and in the drawing together of the freshly cut edges by the correct insertion of sutures. It is only applicable in small defects, or on parts of the body where the skin is loosely attached or where a considerable amount of subcutaneous fat exists. Liberating incisions through the neighboring healthy tissues are sometimes useful to relieve tension and insure the vitality of the parts (Fig. 1).

**2. Gliding Flaps.**—By this method the parts to be replaced are filled by adjacent tissue. It is the one most commonly used. In its simplest form it consists in undermining or undercutting the skin and subcutaneous tissues from the deeper parts to an extent which will allow them to be placed in apposition without tension (Fig. 2).

If the area to be covered is so extensive that this simple method cannot be

[1] Aseptic.

used, it is then necessary to make liberating incisions, usually 2 in number, parallel to each other, thus forming a flap (Fig. 3).

If the area cannot be covered by the last procedure, either because of its size or the difficulty in obtaining one flap of sufficient area, 2 flaps can be made, 1 on each side, as shown in Figure 4. To obtain a smooth surface in this case, it may be necessary to remove small triangles of skin, as shown at A, B, C, and D. To cover a triangular defect, one of the 3 methods illustrated in Figures 5, 6, and 7 may be employed.

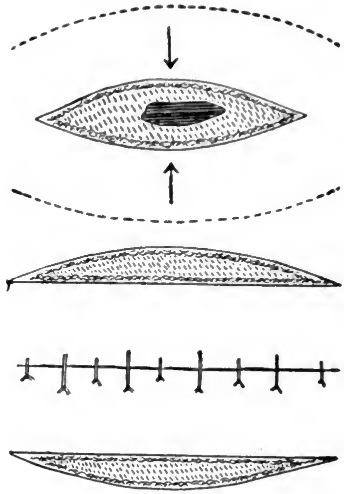


Fig. 1.—Method of Closing Defect by Suture and Tension.

**3. The Gliding Flap with Rotation.**—This method also makes use of adjoining tissues to fill the parts to be repaired. It is much used and most useful, and is well illustrated in the Estlander operation for restoring the lower lip (page 502) and in the Davies-Colley operation of uranoplasty (page 481). Always in this procedure care must be taken not to interfere with the vitality of the flap by too sharply twisting its base or pedicle.

A most useful modification of this method is described by Croft (2), which may be called the *"granulation method."* It is especially recommended for the relief of cicatricial tissue following burns, and Mr. Croft has had remarkable success with it. The method consists in freeing a flap of sufficient size from its deeper parts, leaving it attached at both ends. The flap must be as thick as possible, especially toward the center, and consists of all the tissues down to the deep fascia. A layer of rubber tissue or oil silk is placed between the raised flap and the deeper parts, and the wound allowed to granulate for from 2 to 3 weeks, when one of its attachments is cut and the flap rotated into the position desired. By using this method, Croft claims that: "1. The risks of sloughing of any part are greatly diminished. Instead of being transplanted when recently drained of blood and reduced in temperature, it is removed when abundantly vascular and full of active, living, plastic matter. 2. The transplantation being made two or three weeks after the first operation, the local effects of shock are avoided or reduced to a minimum." In this procedure the need of perfect asepsis, not only for the operation, but during the time of granulation, is obvious and cannot be too strongly emphasized.

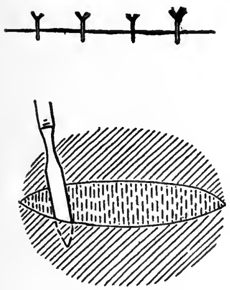


Fig. 2. — Method of Closing Defect by Undermining the Skin.

**4. Pedunculated Flaps.**—These are flaps, lifted from their subjacent tissues and left attached to the deeper parts by only a small pedicle, by means of which

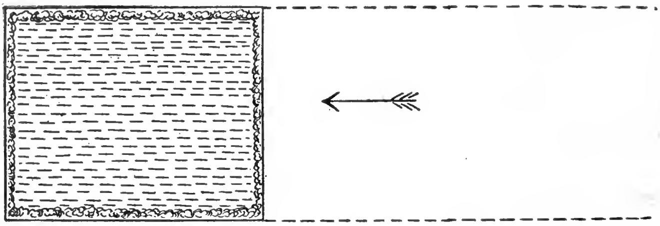


Fig. 3.—Method of Closing Defect by Single Gliding Flap.

the flap is nourished in its new position until healing and a new vascular supply take place, and which is then severed. By the use of this type of flap it is

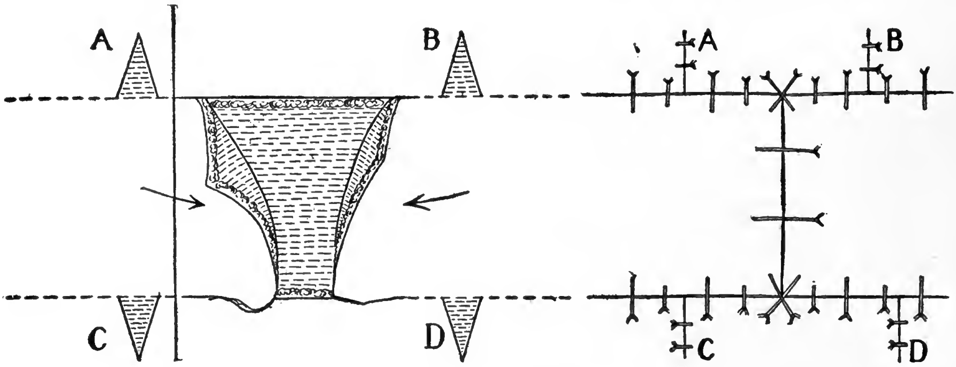



Fig. 4.—Method of Closing Defect by Double Gliding Flap.

possible to transfer to the part to be repaired a flap which has been derived from a distant part of the body. A typical example of this method can be seen in the operation of rhinoplasty as done after the Indian technic, where a flap from the surface of the arm is transferred to the face.

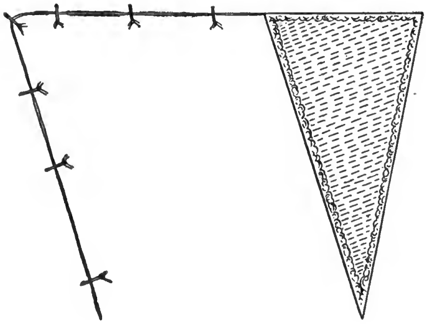


Fig. 5.—Method of Closing Triangular Defect by Gliding Flap.

The reverse of the above is the so-called *pocket method,* in which the defect to be closed is brought to the flap. For example, when it is desired to restore the tissues on the back of the hand, a bridge of skin and subcutaneous tissue of sufficient size is raised from the abdomen or chest and the hand inserted and fixed until union between the raw surfaces has taken place, when the attachments of the skin to the abdomen are cut (Fig. 8).

5. **Transplantation of Free Grafts.**—These grafts may consist of skin, or skin and subcutaneous tissue, or bone or cartilage, and can be taken from the

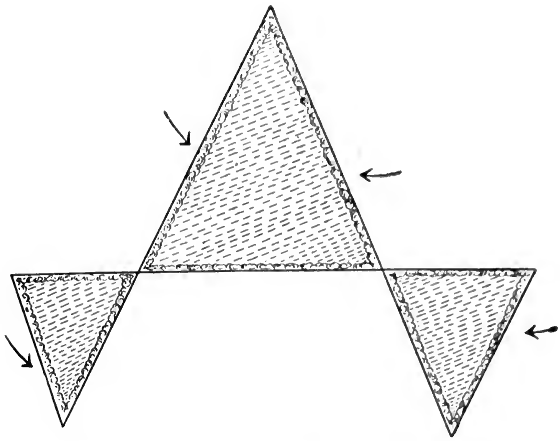


FIG. 6.—METHOD OF CLOSING TRIANGULAR DEFECT BY DOUBLE GLIDING FLAP.

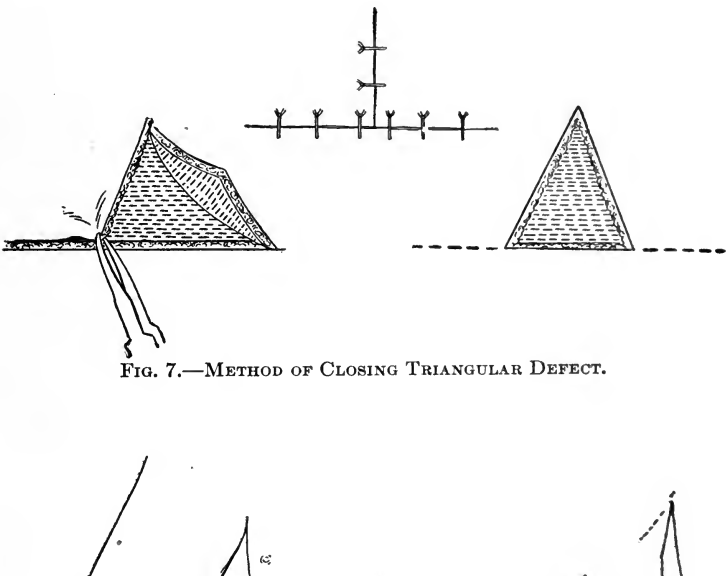


FIG. 7.—METHOD OF CLOSING TRIANGULAR DEFECT.

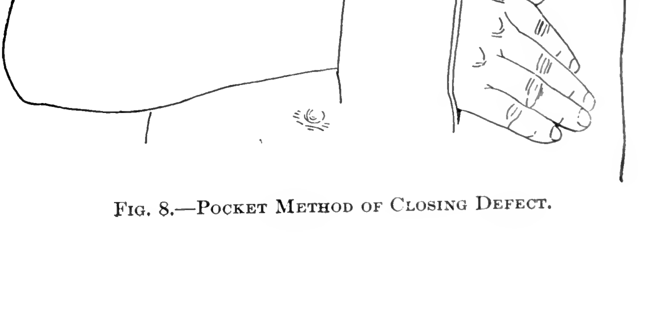


FIG. 8.—POCKET METHOD OF CLOSING DEFECT.

surface of the abdomen or thigh. This method is especially useful in the closing of fresh defects caused by operation wounds, and a great advantage of it is that the scar resulting from the removal of the flap is out of sight.

6. **Skin Grafting.**—For skin grafting, see page 519.

**Cause of Failure.**—The causes of failure are either infection or gangrene, or both.

1. If infection shows itself along the suture line or in the deeper parts, the wound must receive the regular treatment for such a condition. The sutures must be removed, drainage established, and wet dressings applied.

2. If, after 3 or 4 days, gangrene has developed, its character must be determined as soon as possible, because if it is gangrene of the moist type, it is due to infection, and the gangrenous area must be removed immediately. On the other hand, if it is gangrene of the dry type, it is due to interference with the blood supply of the flap, in which case it is best to allow the area to remain until the line of demarcation is distinctly formed, when the gangrenous area loosens by itself from the underlying tissues and may then be easily lifted off.

## HARELIP AND CLEFT PALATE

Congenital fissures or clefts of the lips, the nostrils, the alveolar arch, the hard palate, and the palatine velum are closely related, from the operative as well as the embryological point of view. These malformations are frequently associated, and their treatment consists in a sequence of restorative procedures upon a very limited area.

*Harelip* is a fissure or cleft in the lip occurring as a congenital deformity in children. It usually occurs in the upper lip and is very apt to be complicated by an alveolar or velopalatine fissure.

*Cleft palate* is a congenital deficiency of the palate, in which there is a fissure running in an anteroposterior direction, often involving the uvula, the soft palate, or the hard palate, separately or together. Unless the condition is congenital, it cannot properly be spoken of as a cleft palate.

Until the end of the second or the beginning of the third month of fetal life, cleft palate is physiological. It has been shown by His that up to this time the tongue lies above the free palatine margins, which later ascend and unite above the tongue. Occasionally the same patient will have a harelip with a divided velum or posterior portion of the hard palate and with the intermediate segment of the palate intact. Malformations consisting of a labial and a velopalatine fissure are not necessarily continuous, but are generally found to be so in cases of double harelip associated with a deep double alveolar fissure. The solution of continuity in these cases extends in the direction of the hard palate and the velum, reaching from the upper lip to the posterior margin of the roof of the palate.

*Labiofissure* or *harelip* has a predilection for the left side. Statistics indicate that more male than female children are born with harelip. The relative frequency of the deformity is illustrated by the occurrence of 1 case among 2,400 infants in the St. Petersburg Asylum (Freobelius). The proportion of the different varieties of deformities is well brought out in Hang's statistics of 555 cases:

| | |
|---|---|
| Simple unilateral harelips | 130 |
| Simple bilateral harelips | 18 |
| Unilateral labiomaxillary clefts | 21 |
| Double labial clefts with one or two clefts of the alveolar margin | 6 |
| Unilateral labiopalatine clefts | 27 |
| Bilateral labiopalatine clefts | 12 |
| Unilateral labiomaxillary palatine clefts | 226 |
| Double harelip with unilateral labiomaxillary palatine cleft | 32 |
| Bilateral labiomaxillary palatine clefts | 83 |
| Total | 555 |

Summary of relative proportion of the cases:

| | | |
|---|---|---|
| Simple unilateral harelips | 130 | (25 per cent.) |
| Simple bilateral harelips | 18 | ( 3 per cent.) |
| Complicated unilateral harelips | 274 | (49 per cent.) |
| Complicated bilateral harelips | 133 | (23 per cent.) |

The simple cases accordingly amount to 28 per cent., and the more or less complicated cases amount to 72 per cent. or nearly ¾ of the total number.

According to the statistics of these large compilations, about ¼ of the harelip cases are bilateral. With special reference to the unilateral cases, ¾ of these concerned the left side and only ¼ the right. This remarkable predominance in the left side has never been satisfactorily explained.

## VARIETIES OF HARELIP AND CLEFT PALATE

**Median Harelip.**—This deformity (Fig. 9) is rare, and may vary in extent from a slight notch in the vermilion border of the lip to a complete cleft extending upward into the nasal septum. In the latter case the frenum is also split. In a form described by Witzel, the cleft in the nasal septum extends to the vomer.

An apparent median cleft may in reality be a bilateral cleft, with the median portions of the lip and maxilla entirely lacking.

**Simple Unilateral Harelip.**—The division in this malformation varies increasingly toward the nostril from the mildest cases, where it is merely a notch in the outline of the mucosa (Fig. 10), to where, in the severest cases, it separates the nostril into 2 halves (Fig. 11). The mucosa is usually more or less everted on the cutaneous aspect of the lip. The more extensive forms of harelip are characterized by atrophy of the external border of the cleft, an extensive opening and a flattening of the nostril, combined with lowering of the nasal ala.

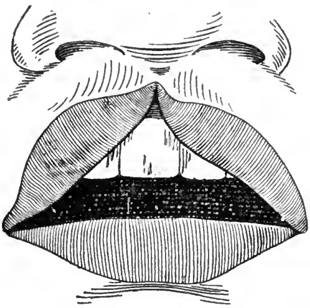


Fig. 9.—Median Harelip.

**Unilateral Harelip with Fissure of the Bony Parts.**—This presents, in addition to the above described deformities of the soft parts, a more or less marked cleft of the alveolar arch with or without irregularities of the teeth. In the severer cases the division involves the full height of the alveolar margin as well as the most anterior portion of the palatine roof. The cleft is directed obliquely backward and inward toward the anterior palatine foramen, where it either stops or is combined with, and prolonged into, a complete velopalatine fissure. In other cases of labiopalatine fissure there is no continuity of the superficial with the deep malformation. Simple as well as complicated labiofissure may be associated with a divided velum and an intact palate. In simple or double harelip cases complicated by bony fissure, the soft parts are sometimes partially absent, the portions of the lip which should furnish the flaps for a restorative operation being irregular, retracted, and atrophic. The intermaxillary bone leans obliquely toward the normal side, which is due to the more advanced growth of the vomer; the latter, having lost its lateral support and its growth being impeded, pushes the intermaxillary bone forward into an oblique position, which interrupts the alveolar arch.

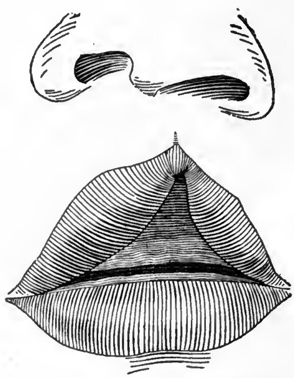


Fig. 10.—Simple Unilateral Harelip.

**Simple Bilateral Harelip** (Fig. 12).—In these cases the features of simple unilateral harelip are present on both sides, although the malformation is not necessarily symmetrical or of the same degree. On one side the fissure may be incomplete, while on the other it may involve the lower border of the nostril. Bilateral harelip without any bony malformation is rare (18 among 555 cases, according to Hang).

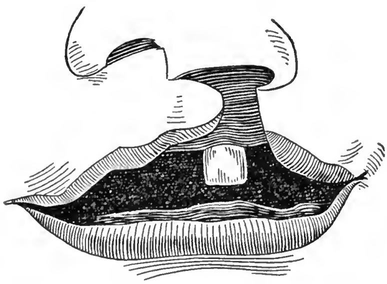


Fig. 11.—Simple Unilateral Harelip with Deformity of Nostril.

**Complicated Bilateral Harelip** (Fig. 13).—In exceptional cases, simple alveolar fissure on one side may be associated with a complete cleft on the other side. As a rule, the deformities are more or less symmetrical, the bony complications assuming one of the following types: a purely alveolar fissure of both sides, with slight protuberance of the maxillary bone; a deep fissure, which extends between the margins of the bony gaps with preservation of the nasal and buccal mucosa; or a complete fissure involving the mucous membranes as well as the bone substance and terminating at the anterior palatine foramen by two lines converging in an internal posterior direction; and with the palatine roof practically always divided. The forward protuberance of the intermaxillary bone increases in proportion with the depth of the fissures, while the middle labial lobe proportionately diminishes in size.

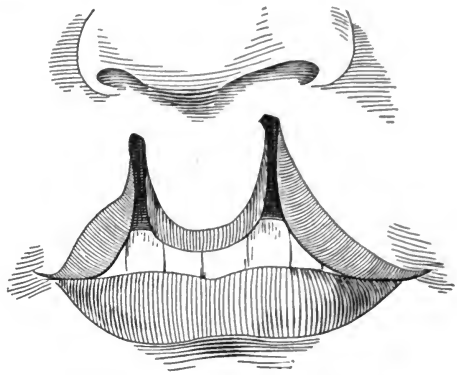


Fig. 12.—Simple Bilateral Harelip.

**Fissure of the Bony Palate (Palato-fissure).**—Cleft palate may occur independently or in combination with cleft lip (harelip). Congenital clefts of the bony palate are always associated with a divided velum.

**Palatofissure Not Complicated by Labiofissure.**—In the mildest cases the malformation consists merely of an anomaly of the uvula, but as a rule the velum is split more or less extensively. The hard palate is also apt to be defective, having usually a triangular cleft near the posterior portion of the bony roof; or it may be split longitudinally or altogether absent.

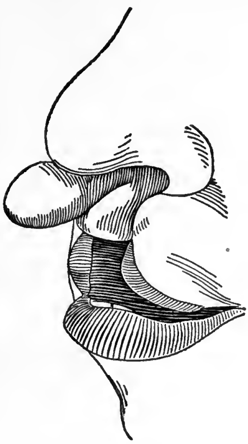


Fig. 13.—Complicated Bilateral Harelip.

**Palatofissure Combined with Bony Labiofissure.**—The prolongation of the palatine cleft beyond the anterior palatine foramen gives rise to common bony fissures. The mild cases present a large palatine gap, bifurcated anteriorly, with a middle flap consisting of bone, mucous membrane, and skin. Sometimes, when the arrest of development is very marked, the upper lip is represented only by a small mass of soft parts attached to the nasal septum.

**Displacement of the Premaxillary Bones.**—Although displacement of the premaxillary bones is always more or less associated with clefts of the palate, the premaxilla may occupy its normal position in any form of harelip. Protuberance and deflection of the premaxilla are more or less marked in cases of unilateral harelip with complete cleft palate. When the protuberance and deflection are very slight, the bone may resume its normal position spontaneously after the surgical repair of the harelip. The premaxillary process is chiefly responsible for the deformity seen in cases of complete double harelip with complete cleft palate. It is attached by a pedicle of variable width and strength to the lower anterior end of the nasal septum and projects in front of the lips, resulting in a most distressing deformity.

### TREATMENT OF HARELIP

**Age at Which to Operate.**—The best results can undoubtedly be obtained by operating between the ages of 4 and 6 months. This is especially the case if the labial cleft be extensive or double or complicated. At this age the tissues are firm and of a moderate size and the stitches hold well. If the deformity of the ala of the nose be present, the correction of it is much more easily accomplished at this time than in the first few weeks of life. Jacobson gives the following reasons for not preferring an operation before the second month:

1. Newborn children do not stand operations well.

2. Children born with this deformity are apt to be weak, and many die in early infancy from causes not related in any way to the deformity. Operations, if performed on these children, are usually ascribed as the cause of death.

3. The difficulty of feeding a child with harelip, even if complicated by cleft palate, has been exaggerated. The feeding can practically always be accomplished, with care and attention; and if the nursing bottle has a nipple of the proper shape with an opening of good size in the under side, the child will usually have little difficulty in obtaining sufficient nourishment. The position of the child while nursing has also much to do with the ease with which it can be fed.

On the other hand, some surgeons, especially the advocates of the early cleft palate operation, maintain that the cleft in the lip should be repaired as soon as possible, for these reasons:

1. The child's nutrition is improved. 2. The operation is very easy—with less hemorrhage. 3. If a cleft of the palate be present, the repair of which is delayed, the early closure of the lip has a marked tendency to diminish the width of the cleft of the palate.

In any case, the lip should be operated upon before the end of the sixth month, that is to say, before dentition occurs. If a cleft palate be present, upon which it has been decided to operate later, there can be no harm, as Jacobson has pointed out, in closing the lip; for when the time comes to do the uranoplasty, and the smallness of the mouth interferes with the clear operative field in spite of the use of suitable mouth gags, the lip can be split and re-sutured when the cleft palate operation is completed.

### Operations: Cheilorrhaphy or Cheiloplasty

Numberless procedures have been devised, recommended, and abandoned for the correction of the facial deformity. A method which involves the cutting of 1 or 2 flaps is alone worthy of consideration. Simple cheilorrhaphy, or labial suture after simple freshening without preliminary cutting of flaps, is not to be recommended. When the inferior margin of the nostril is intact, the entire operation consists in the cutting of 1 or more flaps, with the necessary freshening and suturing. In complete harelip with division of the nostril, the liberation of the nasal ala is of great importance.

The important steps of all operations on either harelip or cleft palate consist in: First, trimming the edges of the deformity and sewing together the raw surfaces in perfect apposition; second, the abolition of absolutely all tension on the suture line. If this be not done, the chances of success are very slight. In many cases it is necessary to free the cheek from the superior maxilla in order to overcome the tension. Much difficulty is usually encountered in

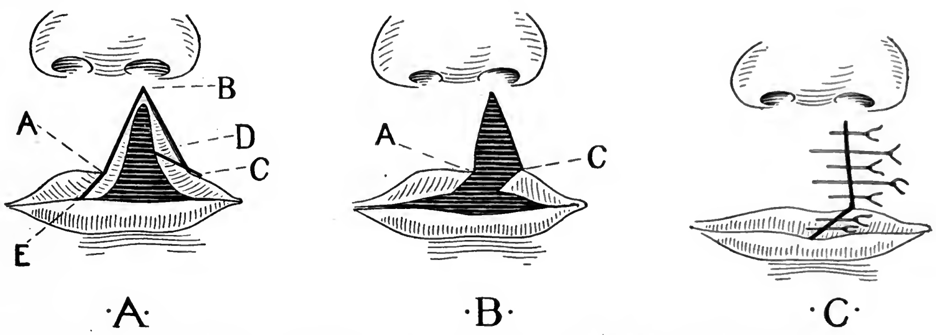



Fig. 14.—Method of Paring and Suturing for Simple Unilateral Harelip.

preventing an unsightly notch in the lip or in the skin margin, and several incisions have been devised for the correction of this defect. An uninterrupted line should result from the union of the two lines of mucocutaneous junction if the trimmed edges have been properly shaped and fitted together.

**Position.**—Dorsal, with head slightly flexed on a firm pillow.

**Anesthetic.**—For very young children, chloroform by the open method is preferred. For children over 5 years, ether by the open method.

**Instruments.**—No special instruments are required for this operation, but all those used must be fine, light, and well made. A fine, thin, and sharp scalpel is necessary. The needles should be well curved and small, and the needle-holder one that really holds the needles firmly.

**Operation for Simple Unilateral Harelip.**—It must be realized that every patient requiring a plastic operation presents problems which have to be worked out for the individual case, and there is no one operation which is applicable to all. The following is, in my experience, by far the most satisfactory operation, and the same principles may also be applied to the repair of a complete unilateral cleft, as will be shown later:

Apply Murphy's intestinal forceps (Fig. 51) on the upper lip, as near the angle of the mouth as possible. By using these, much of the troublesome hemorrhage which always occurs at the beginning of the operation may be easily controlled. Make sufficient traction with an ordinary anatomical forceps on one angle of the split lip to hold the edge of the cleft tense, and with a very sharp pointed scalpel, transfix the lip at point A (Fig. 14), and cut to point B. It is essential to insert the scalpel in a direction at right angles to the skin, and at a point just internal to the junction of the skin and the mucous membrane, thus insuring the cutting of a solid, thick flap, which must consist of all the layers of the lip. A similar incision is then made from point C to B, and short almost horizontal incisions from points C to D and from A to E. Thus the pared edges are removed. If the coronary arteries at this stage show a tendency to bleed, they may be ligated, using the finest mosquito clamps and the very finest catgut possible. Any other oozing may be disregarded. The flaps formed by these incisions are now drawn gently down (Fig. 14, B) and a fine silkworm-gut suture inserted so as to proximate points A and C. The suture should be placed about 6 mm. from the cut edge and passed into the tissues at right angles down to but not through the mucous membrane. The stitch is now drawn taut, and if no tension be present, it is loosened and the remaining sutures inserted, but not tied. These may be of very fine silkworm-gut, Pagenstecher thread, or horsehair, and usually 4 will be sufficient. If, however, on tightening the first stitch, tension is seen to be present, it will then be necessary, in order to obtain a good result, to incise the mucous membrane on the alveolar border as high as possible; and, by inserting a sharp-edged periosteal elevator, to lift the cheek and soft parts away from the superior maxilla. By keeping the instrument pressed firmly against the bone, the amount of hemorrhage from this procedure will be small and no damage will be done to the soft parts. The extent to which this lifting must go can only be determined by the amount required to absolutely abolish all tension on the pared edges, when the stitches are tied. It is far better to lift too much of the cheek than too little. The sutures now inserted can be tied, great care being taken to get a perfect approximation of the skin edges, to avoid tying the sutures too tight and to see that the points where the mucous membrane of the lips and the skin meet are on exactly the same line. The projecting tabs of the vermilion border can now be sutured. It is well to have a slight downward projection of the lip at the suture line, so that if the labial scar contracts, the formation of a notch will be prevented. Fine silk and fine curved needles are best used here, and 2 or 3 sutures should be inserted on the inner side of the lip in the vermilion border. The cut mucous membrane heals well without sutures, and there seems to be less infection when they are not used (Fig. 14, C).

Sterile vaselin is now applied on the external and internal wounds and frequently no dressing at all need be used. If the cheek has been raised and some hemorrhage still persists from the resulting wound, or if, in spite of all care, the stitches appear to have some strain upon them, a strip of sterile adhesive plaster may be cut into a butterfly shape and applied to each cheek, thus relieving the tension in the wound. A few layers of gauze may be placed over the wound. Care must be taken that the child does not get its hands free and tear the wound apart.

**Operation for Single Complete Harelip** (Fig. 15).—The same procedure can be used in most cases of single complete harelip. The incisions are prac-

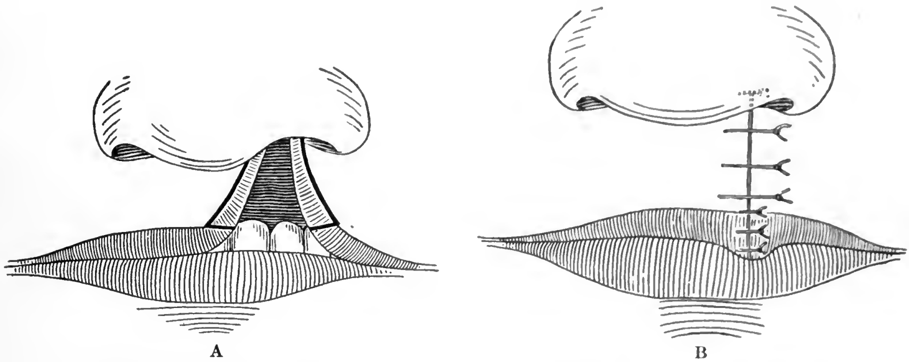



Fig. 15.—Method of Paring and Suturing for Single Complete Harelip.

tically the same, but of course extending upward into the cleft nostril. The elevation and liberation of the cheek from the superior maxilla is again the all-important step, and is absolutely essential in order to obtain a good cosmetic result and reëstablish the proper shape to the nostril. In an upward direction, this freeing of the cheek may have to extend even as high as the inferior orbital

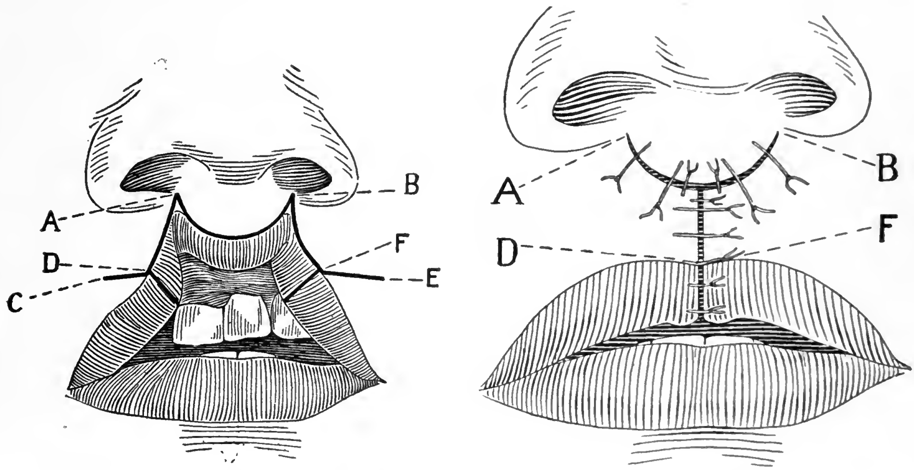



Fig. 16.—Method of Paring and Suturing for Double Harelip.

foramen. If the nostril is much distorted, the ala must be completely loosened. The first stitch should be placed within the nostril as high as possible, using a fine sharply curved needle and fine chromic gut, and the suture should be tied tight enough to just over-correct the deformity. If the parts do not stay in apposition without tension, the cheek will have to be still further freed. The remaining sutures are placed as in the single incomplete harelip operation.

**Operation for Double Harelip** (Fig. 16).—Transfix the lip at point A, cut to B as near the vermilion border as possible, and follow its outline even if irregular; for in this operation all the tissue must be saved that is possible to save. Less blood will be lost if this incision be made first. Next transfix the lip at C and cut to A; then make incision D almost at right angles to and through the vermilion border; then cut from E to B and make incision F in a similar way. The lifting of the cheek, as described above, will frequently be required in this operation. The guide stitch can now be inserted to proximate the points D and F and drawn tight, but not tied. If the tension is correct, the remaining sutures are inserted as shown in Figure 16.

**Operation for Complicated Harelip with Projecting Premaxillary Process.**—The premaxillary bone may be replaced by either a simple fracture or by the excision of an area of the nasal septum.

1. SIMPLE FRACTURE.—When the premaxillary stem is slight and the child is very young, provided, however, that the distance between the external alveolar ridges is sufficient to admit the introduction of the premaxillary bones between them, it is often possible, by direct pressure of the operator's thumb on the projecting premaxillary process, to produce a fracture of its attachment. If this is done, the fracture must be complete and must allow free motion of the bones and their easy replacement in their new and proper positions. The use of this method is advised when possible, because there is little shock, practically no hemorrhage and very little chance of infection.

2. EXCISION OF A WEDGE OR QUADRILATERAL AREA FROM THE NASAL SEPTUM.—Before making any resection of the septum, Berry and Legg recommend incising the lower free edge of the septum just behind the premaxillary bone, and with a periosteal elevator removing the soft parts and periosteum from the septum. The usual operation is then to resect a wedge with a strong pair of scissors. The great objection to a wedge-shaped incision is the new and backward position assumed by the alveolar border, causing the incisor teeth to project in a posterior direction. To avoid this, a quadrilateral section may be removed, which will allow the teeth to assume a normal position (Fig. 17).

The following figures of classic operations for the repair of harelip are reproduced not only for their historical interest, but also for the suggestions they may offer to operators who have to treat atypical or complicated cases. As they readily explain themselves, no description is given (Figs. 18, 19, 20, 21, 22).

**After-treatment and Complications.**—If the wound heals without infection, firm union takes place early; and as a general rule, the sooner the stitches are removed, the less scar will remain and the less chance exists of a late infection occurring. It is often possible to remove every alternate superficial stitch as early as the second or third day. The deeper or retention sutures should remain 6 days. It is important to properly restrain the child, not only in regard to the hands and arms, but also to prevent its turning on its face and rubbing the lip on the pillow.

It is best to make no change in the diet, and as a rule, the child can be given some liquid nourishment within 3 or 4 hours of the operation.

Complications and poor results are almost always due to either a weak condition of the child at the time of the operation, or to sepsis. Death, if it does

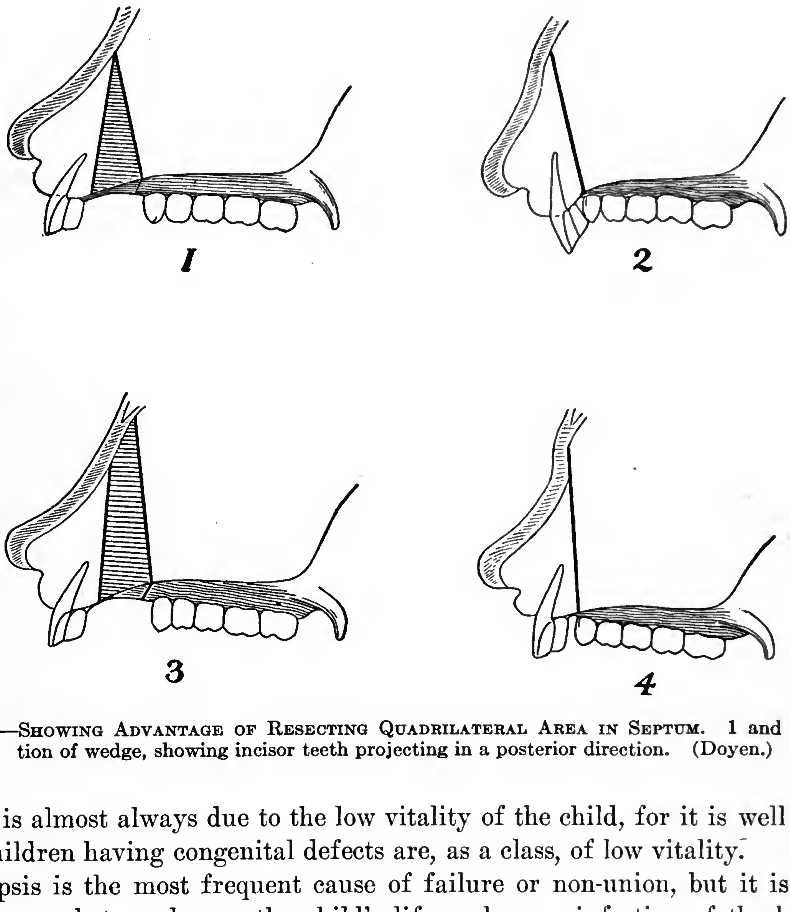



**Fig. 17.—Showing Advantage of Resecting Quadrilateral Area in Septum. 1 and 2, resection of wedge, showing incisor teeth projecting in a posterior direction. (Doyen.)**

occur, is almost always due to the low vitality of the child, for it is well known that children having congenital defects are, as a class, of low vitality.

Sepsis is the most frequent cause of failure or non-union, but it is rarely severe enough to endanger the child's life, unless an infection of the bone occurs—fortunately a very rare condition. If the wound has become infected and the operation on the fourth or fifth day has the appearance of a total failure, the parts if properly drained—that is to say the sutures removed and a wet dressing applied—will in many cases heal by granulation and the result be surprisingly good.

In all operations involving the air passages, a not infrequent complication is pneumonia or bronchitis. The possibility of either of these complications is much diminished by taking care during the operation to prevent the entrance of blood and mucus in the trachea.

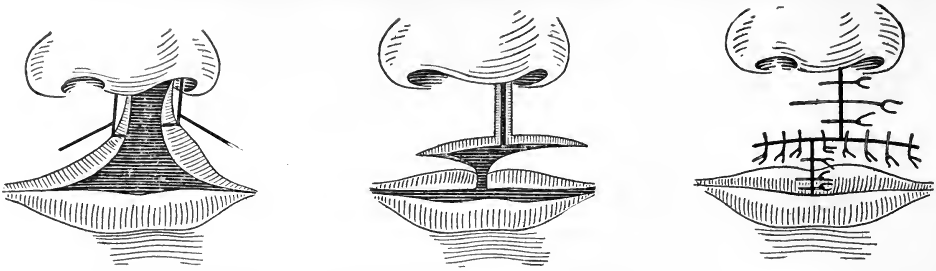


Fig. 18.—König's Method of Paring and Suture.

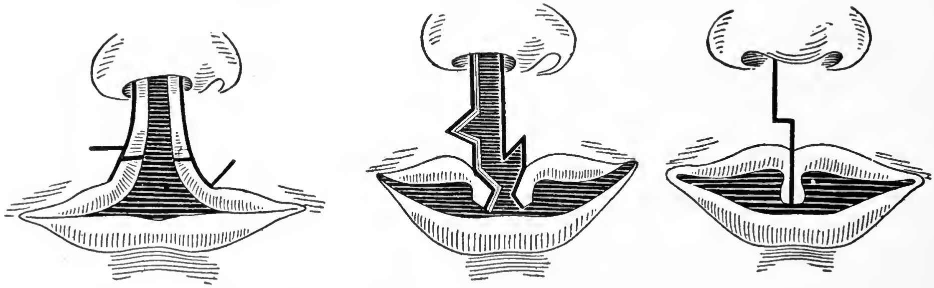


Fig. 19.—Hagedorn's Method of Paring and Suture.

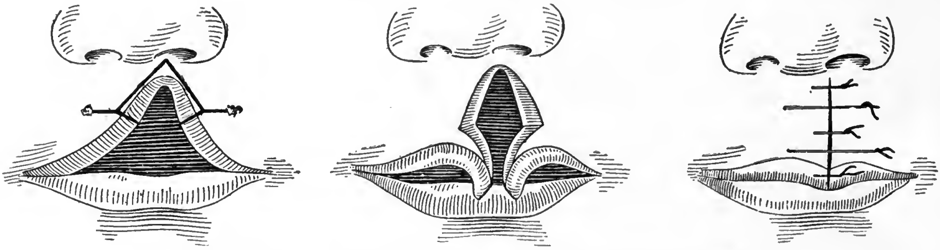


Fig. 20.—Malgaigne's Method of Paring and Suture.

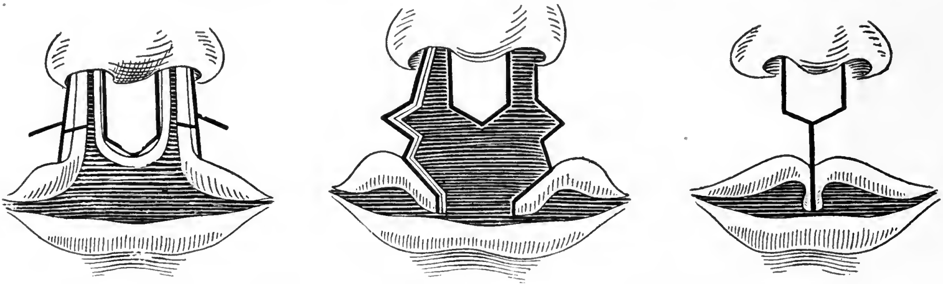


Fig. 21.—Hagedorn's Method of Paring and Suture for Double Harelip.

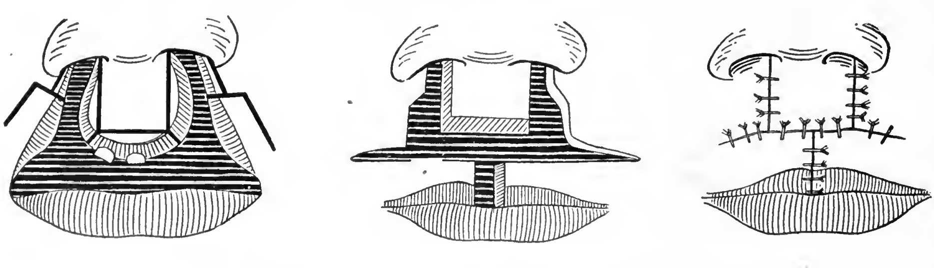


Fig. 22.—Modification of Hagedorn's Method of Paring and Suture.

An unusual and serious complication is described by Jacobson, where death is caused by asphyxia. "Thus, where the cleft has been a large one and the upper lip when restored is tight, when it overhangs the lower, if the nostrils are flattened and partially closed by the operation, owing to the tension of the parts, so little breathing space may be left that temporary interference with respiration may occur, with grave and even fatal results, before the breathing can be accommodated to the altered circumstances and before the parts dilate and stretch."

Rose suggests, to obviate this possibility, that the nurse depress the tongue of the child from time to time; or paint a strip of collodion from lip to chin to hold the lip open. In case the aperture is known to the operator to be dangerously small, an intranasal tube, such as a good-sized catheter, may be inserted. This allows the child to breathe automatically and may be withdrawn after twenty-four hours.

**Results.**—As a general rule, the results of these operations are good, although frequently not as perfect as the operator and the parents desire. So many factors enter into the composition of the end result that it is wise to give a fairly guarded prognosis, and before operating to explain to the family the possibility that the necessity may occur for a second operation. However, if a second operation proves to be necessary, it is usually of a very slight and simple character, and ought always to be done after a lapse of several years.

## TREATMENT OF CLEFT PALATE

**Age at Which to Operate.**—The indications for surgical intervention in cases of harelip and cleft palate are incontestable and obvious; but opinions differ as to the most favorable period for the performance of the operation. From the point of view of the operative risks, statistics show conclusively that operations on children less than 2 years of age are more dangerous than operations after that age in spite of the brilliant results of certain operators.

I strongly endorse the view held by Jacobson and Berry, and consider that the best results can be obtained by operating not earlier than the second or the beginning of the third year instead of in early infancy, for the following reasons:

1. The parts are larger, more easily manipulated and tear much less.
2. Hemorrhage is more easily controlled and better stood by the patient.
3. Children congenitally deformed are apt to be weak and do not stand operations well.
4. The after-care of the patient is easier and more satisfactory.
5. The liability to such postoperative complications as pulmonary infection, convulsions, and diarrhea is minimized.
6. It is possible to elect a time when the patient is properly prepared and in good physical condition.

As opposed to these advantages, J. B. Roberts (22) writes as follows:

"The view that operations upon fissures of the palate should be delayed until the child has become two, three or four years old is erroneous. It is better to operate when the infant is only a few days old, unless there be some grave physical disability. In that event, the operation may be delayed a few weeks, but such delay is a misfortune. The time thus occupied in building up the infant's health may be profitably employed in digital compression applied daily to the two halves of the upper jaw. Squeezing the separated segments of the hard palate together a few dozen times every morning and evening will tend to lessen the breadth of the cleft and give the surgeon a better opportunity of obtaining a bony roof to the mouth by operation."

Lane and Brophy advocate early operation on cleft palate, that is to say from the first day after birth up to three weeks, and maintain that:

1. The surgical shock is less than when the child is older and there is no mental apprehension.
2. The anesthetic is well borne.
3. The newborn child is usually healthy.
4. The tissues heal very readily.
5. The digestion is good.
6. There is slight, if any, postoperative pain, and the child takes food at once.
7. The loss of blood is necessarily slight, due to the small size of the blood vessels.
8. A well vascularized flap is very easily obtained.
9. The muscles of the palate are at once brought into use, and do not atrophy.
10. The passage of air through the nares in the proper channel has a marked effect on the growth and shape of the bones of the nose and face at a period when their greatest development takes place.
11. No faulty habits of speech result.
12. If the Brophy operation is performed, the bones may be bent and moulded without fracture.

## Operations

**Position of the Patient.**—The so-called Rose position (Fig. 23) is in many ways the most satisfactory. The child should be on its back on a hard mattress, wrapped snugly in the sheet to prevent the movement of the hands and arms, and a firm pillow placed underneath the shoulders. The head must be toward the light, projecting a few inches beyond the head of the table and allowed to assume a position of marked extension.

The advantages of this position are: 1. A clear field and direct illumination; 2. The blood has no tendency to flow into the trachea, the time taken in sponging and preventing it from so doing is saved, and the chances of postoperative complications are thus reduced; 3. The low position of the head tends to overcome any untoward effect of the anesthetic.

Practically the only disadvantages of this position are those resulting from the increased congestion of the head and neck, and the frequent postoperative pain in the back of the neck.

**Anesthesia.**—Ether is undoubtedly less dangerous than chloroform, and is therefore to be preferred, but it should always be administered by a competent and experienced anesthetist. Some English surgeons prefer chloroform be-

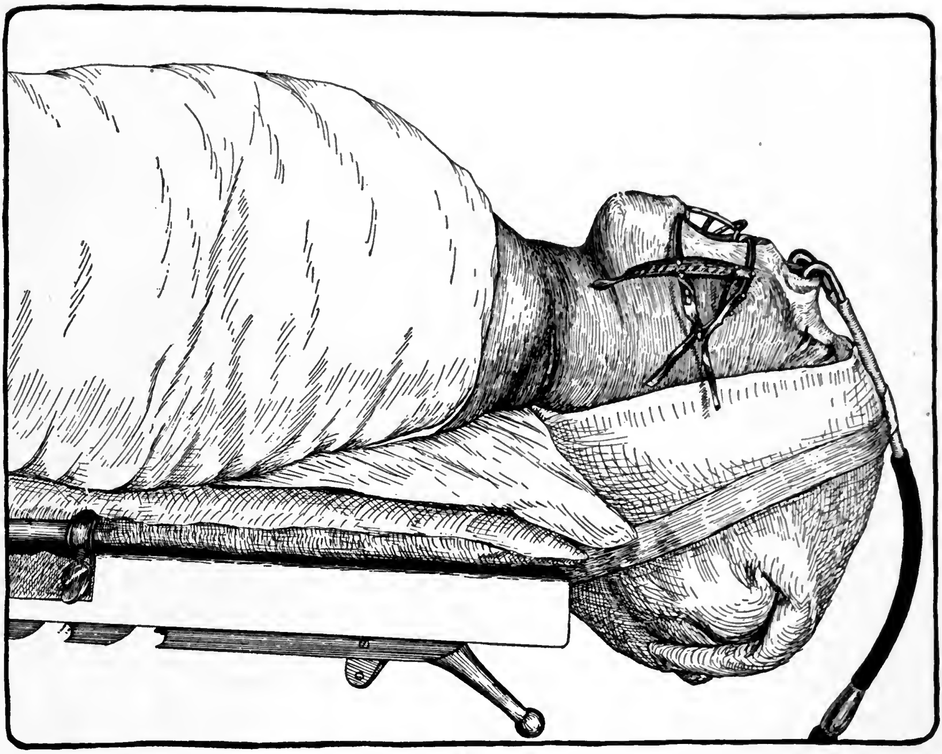


FIG. 23.—ROSE POSITION.

cause it is more easily administered than ether, and does not cause as much congestion of the tissues or produce as much mucus and saliva; but its disadvantages far outweigh its advantages. For the convenience of the operator and to prevent unnecessary delays, an apparatus which administers intranasal anesthesia should be employed. Keep the patient only just under the influence of the anesthetic and at no time should he be so profoundly under that the pharyngeal reflexes are absent.

**Choice of Method of Operation.**—I consider the operation of choice to be the one described by Berry and Legg, for practically the same reasons as those already given in favor of operations in the second year instead of in early infancy. The operation is comparatively simple, anatomically correct and theoretically sound; and has fewer difficult technical details than most other procedures described below. At the same time it must be borne in mind that any operation undertaken to repair cleft palate is per se one of the most difficult in surgery, requiring, as it does, foresight in planning the work to be done, great care and patience in its performance and, to obtain a good result, a considerable degree of surgical skill. The field is small and frequently inadequate to work in, the parts to be dealt with are small, delicate, and easily injured

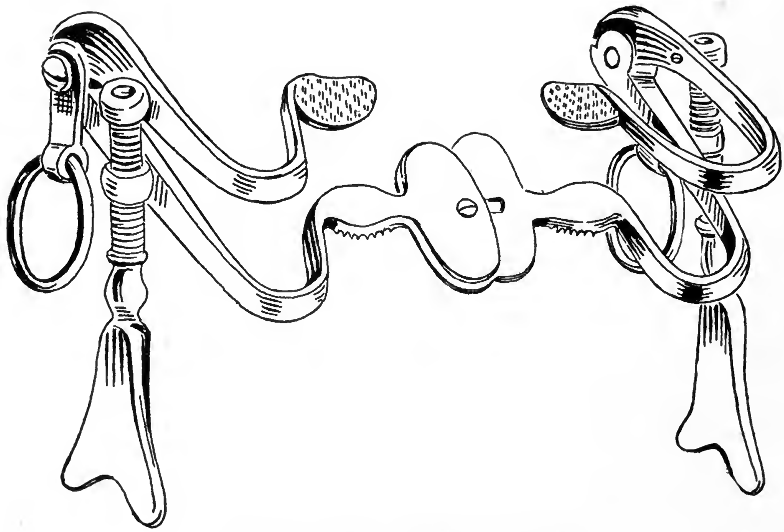


Fig. 24.—Smith's Cleft Palate Gag.

permanently, and their final readjustment must be exact. The instruments, especially the needles, the needle-holder, and the sutures, must be fine and delicate, and therefore difficult to use. It is one of the few operations to-day requiring special instruments and it would be almost disastrous to attempt any of these operations without the special instruments, which have been designed to make possible the accomplishment of the different steps.

**Berry and Legg's Operation.**—The operation described by Berry and Legg is divided by them into 5 parts:

1. Detachment of the mucoperiosteal tissues of the palate from the oral surface of the bony palate.
2. Detachment of the soft palate from the posterior edge of the palate bones.
3. Paring the margins of the cleft.
4. Suturing the pared edges.
5. Making, if necessary, lateral incisions to relieve tension.

The instruments required are:

Smith's cleft palate gag (Fig. 24).

Long-handled forceps, both with and without teeth (Fig. 25).

Raspatory (Fig. 26).

A sharply curved blunt-pointed scissors (Fig. 25).

A rectangular knife (Fig. 25).

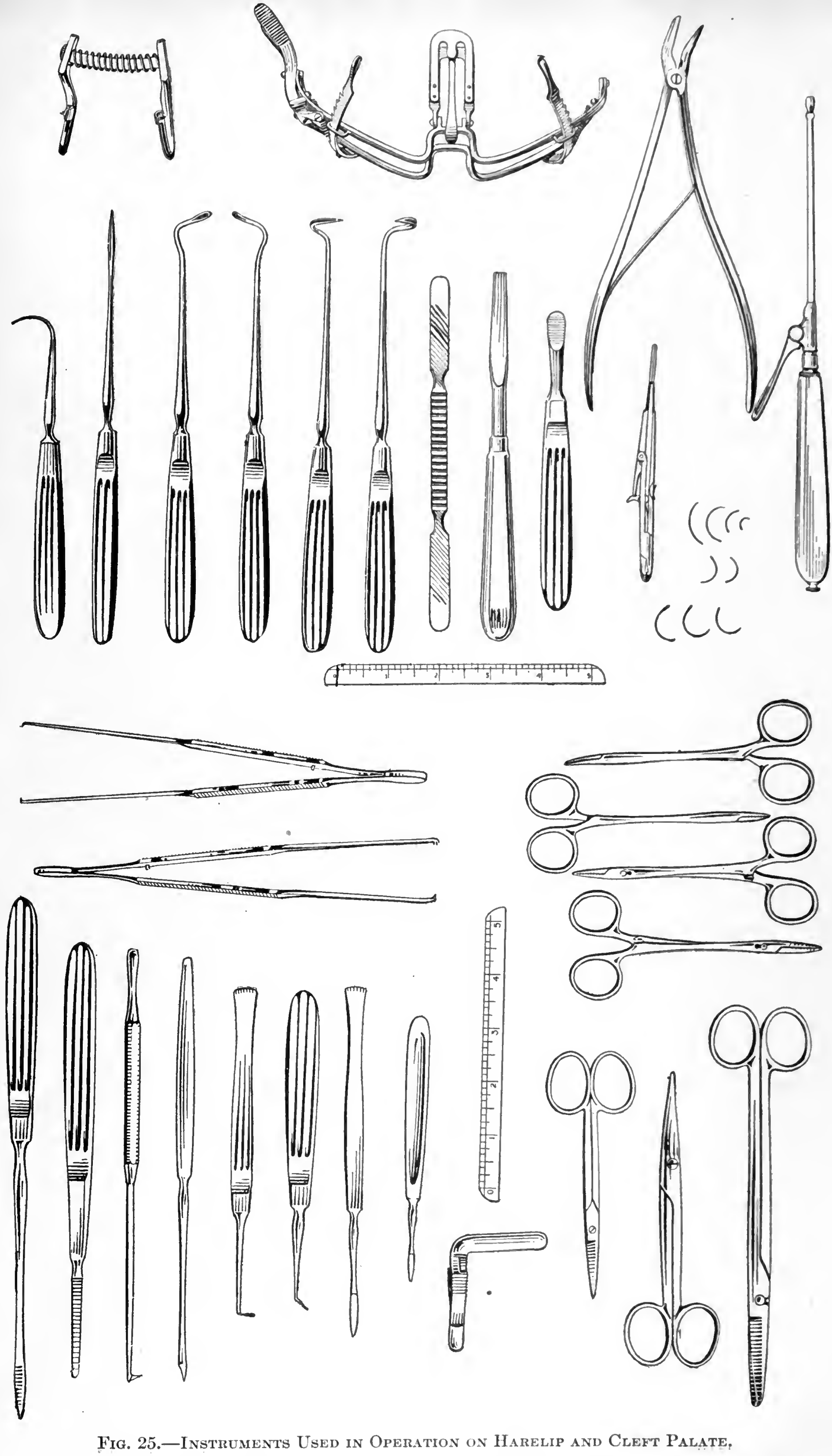


Fig. 25.—Instruments Used in Operation on Harelip and Cleft Palate.

Sharp and blunt-pointed knives (Fig. 25).
A rectangular needle, for inserting sutures (Fig. 27).
A curved needle, for inserting sutures (Fig. 27).
A needle with double elbow (Fig. 27).

Fig. 26.—Berry and Legg Raspatory.

The first stage is best accomplished by making a small linear incision or a puncture near the alveolar border (Fig. 28). The situation of this puncture depends on the width of the cleft and the height of the arch of the hard palate. If the cleft be wide or the arch low, it will be necessary to make the puncture very near the alveolar margin in order to gain a sufficient mucoperiosteal flap, and it will in that case be external to the outlet of the posterior palatine artery.

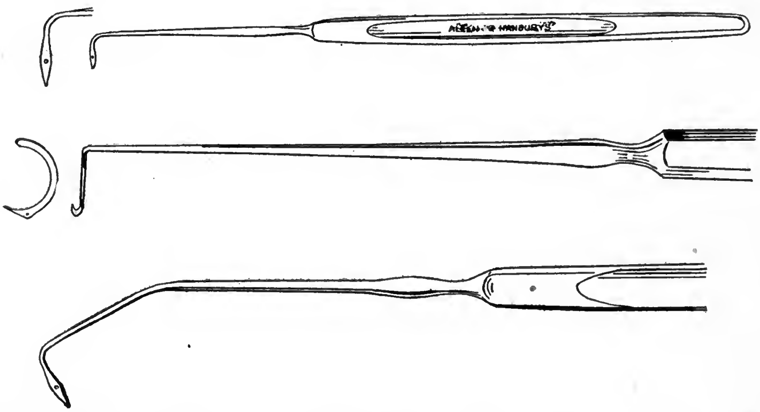



Fig. 27.—A, A Rectangular Needle, for Inserting Sutures; B, a Curved Needle for Inserting Sutures; C, a Needle with Double Elbow. (Berry and Legg.)

Into this wound, which of course should extend directly down to the bone, a periosteal elevator or raspatory is inserted. The instrument is then moved toward the middle line with a slight anteroposterior motion, maintaining a firm and steady pressure against the bone until the tip appears at the margin of the cleft through which it should now be pushed. Into this last wound, the point of an ordinary curved aneurysm needle is inserted, and by moving it backward as far as it will go, and forward to a line with the anterior notch of the cleft, the required amount of mucoperiosteal tissue is freed from the hard palate (Fig. 29). The same procedure takes place on the opposite side. If at any time the hemorrhage becomes troublesome, it can be arrested by direct pressure on the under surface of the flap by means of a sponge or gauze held by the operator's finger.

The small puncture wound made in the edge of the cleft must now be extended by means of the rectangular knife in a posterior direction to the point where the junction of the hard and soft palate occurs.

The second step—the detachment of the soft palate from the posterior edge of the palate bone—the authors call "the most important in the whole operation," because if not properly and completely accomplished, the closure of the cleft of the soft palate without tension is impossible.

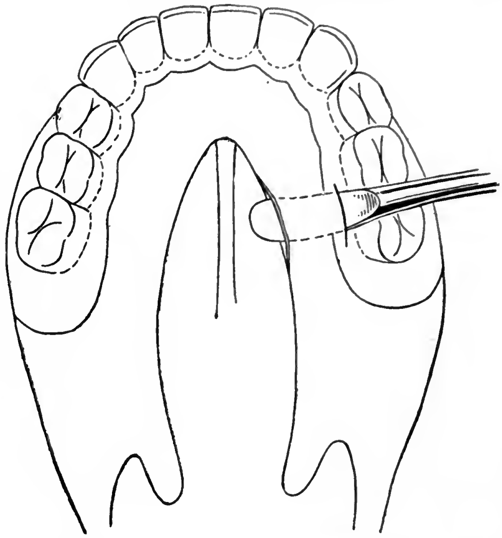


FIG. 28.—BERRY AND LEGG OPERATION (1). Situation of first incision and method of passing periosteal elevator or raspatory between mucoperiosteal flap and surface of hard palate.

This part of the operation is done by inserting one blade of a pair of sharply curved blunt scissors into the space between the lower surface of the hard palate and the mucoperiosteal flap, at the point where the junction of the soft and hard palates occurs (Fig. 30, A and B). The other blade is introduced over the nasal surface. Care must be taken that the length of the cut be not sufficient to injure the posterior palatine artery.

The third step—paring the margins of the cleft—is most easily accomplished by grasping with a fine-toothed forceps the edge of the cleft at a point where the junction of the hard and soft palates formerly occurred. A very fine and sharp scalpel is then thrust through the whole thickness of the soft palate as near its internal edge as possible, transfixing all its layers. The incision is then made in an anterior direction as far as the notch. The scalpel is then withdrawn and re-inserted slightly posterior to the forceps at the same distance from the free edge, and the incision continued in a posterior direction toward the uvula. As soon as this becomes difficult, due to the unsteadiness of the tissues, the scalpel is again withdrawn, and the bridge of tissue, left within the grasp of the forceps, is divided. Then, by making traction in an inward and backward direction on the edge that has already been removed, the remaining edge can be easily pared off.

The fourth step is the suturing of the pared edges. Berry and Legg consider the best suture material to be silkworm-gut, and recommend the use of the so-called Smith needle (Fig. 27). The pared edge is now grasped at a point near the anterior part of the soft palate and there the first suture is inserted. The needle should be passed in at a point from 3 to 5 cm. from the cut edge, and in a direction through the tissues slightly outward. As it is passed back into the mouth from the nasal surface, the needle should point inward, the object of this being to increase the tendency of the cut edge to evert when the sutures are tied, which is very important. The next suture, passed in a similar manner, should be about 5 or 6 cm. from the first, the same distance from the edge and in a posterior direction. When the tip of the uvula is reached, in order not to interfere with its circulation, the last suture must be made in a transverse direction. As these sutures are passed, they may be tied, much care being taken not to endanger the vitality of the flaps by too great tension. The accurate approximation of the edges and the avoidance of any inversion whatever is absolutely essential. The help of an assistant with delicate tenacula may be necessary at this point to accomplish this end. The suture of the tissue over the hard palate now takes place from behind forward. If it appears that the tension is becoming too great, it may be necessary at this point to perform step No. 5. If this is not the case, the suture is completed (Fig. 31).

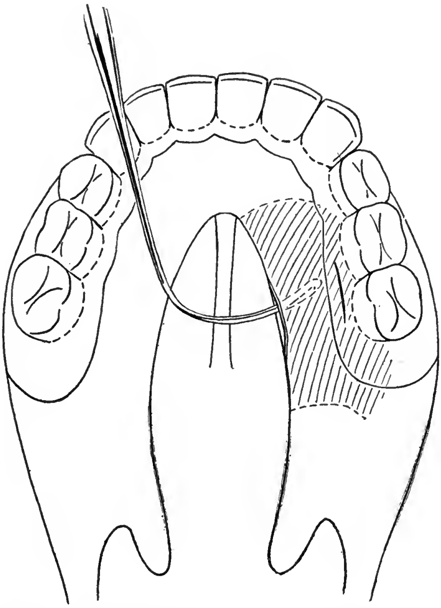
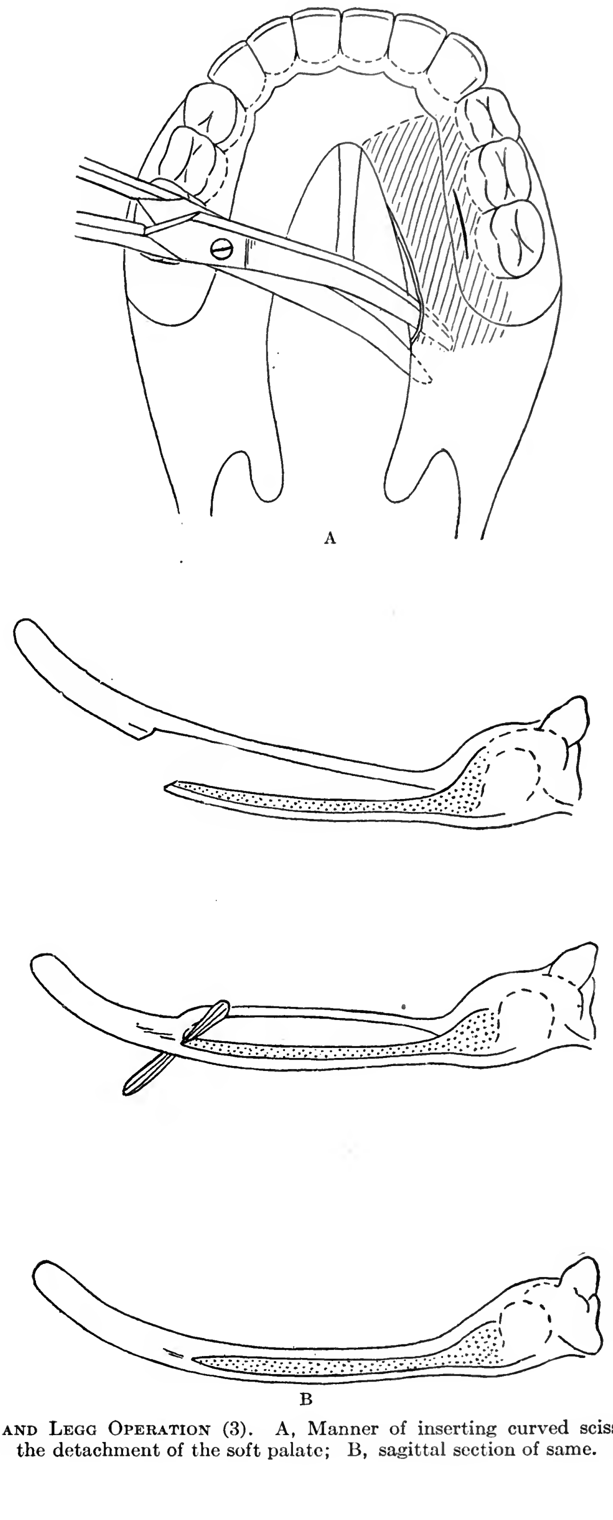


Fig. 29.—Berry and Legg Operation (2). Insertion of aneurysm needle into wound on edge of cleft. Dotted area indicates the extent to which mucoperiosteum is lifted from the bone.

If difficulty is encountered in using the Smith needle, the 2-loop method of passing sutures, as described in Brophy's operation, may be successfully resorted to. Berry and Legg also advise the use of a tension suture of slightly heavier material, passed at a point in the soft palate near its most anterior edge, through all its layers about 15 mm. from the internal edge and tied just tight enough to relieve tension.

The fifth step provides for the making, if necessary, of lateral incisions to relieve tension. In most cases it will be noticed at this stage that a certain degree of tension exists in the suture line, and unless this be relieved, the chances of failure of the operation are much increased. The best incision to relieve tension in most cases is one "beginning a little in front of the junction of the hard and soft palates near the alveolus, but internal to the posterior palatine foramen; it should extend obliquely backward to a point nearly halfway between the posterior end of the alveolus and the posterior margin of the soft palate. The incisions may be straight or with a slight curve, the concavity of which is outward."

Care must be taken not to make these incisions too long, or too far anterior, or too near the middle line—for each one of these errors has a tendency to lessen the vitality of the flap.



A

B

**Fig. 30.—Berry and Legg Operation (3).** A, Manner of inserting curved scissors to accomplish the detachment of the soft palate; B, sagittal section of same.

**Langenbeck's Method of Uranoplasty as Modified by Helbing.**—This procedure presents but few changes from the original, but these changes are important and have markedly improved the results. The operation consists of 4 steps:

1. Paring the margins of the cleft.
2. Lateral incision through the involucrum palati duri.
3. Detachment of the mucoperiosteal flap from the hard palate.
4. Suturing.

The majority of surgeons perform the entire operation in 1 stage. Helbing, however, prefers to follow Wolff's modification of 2 stages, with an interval of from 2 to 5 days. If this be done, the lateral incisions and detachment of the flaps (steps 2 and 3) are done at the first operation; while paring the margins of the cleft and suturing (steps 1 and 4) are left to the second operation.

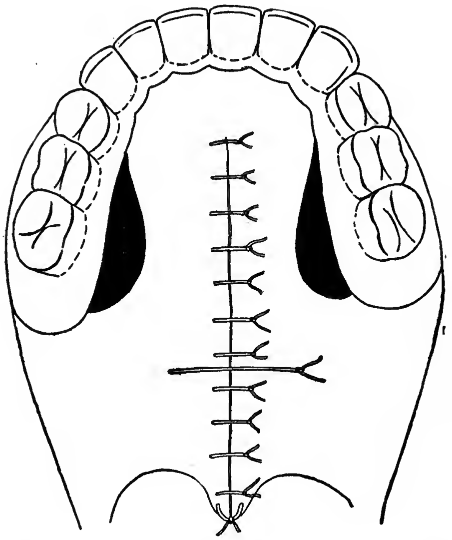


Fig. 31.—Berry and Legg Operation. (4) Method of suture, and also showing lateral incisions to relieve tension.

Wolff divides the operation into 3 stages for very small children, making the 2 flaps at separate operations and paring the edges and suturing at a third operation, which takes place 9 days after the first.

The advantages of performing the operation in 2 stages are:

1. The more radical phase of the operation, the lateral incisions and the detachment of the flaps, usually accompanied by loss of blood, takes place at the first operation; it is, therefore, not only less dangerous, but allows the child time to recuperate before the suturing takes place.

2. As soon as the effects of the anesthesia have passed off, the child can be nourished as usual. This factor is of considerable importance for the success of the suture, as is also the fact that the child has time to recover from the rise of temperature (38° C.) which usually follows the first operation.

3. The circulation and nutrition of the flaps become reëstablished before suturing. By this means the small, circumscribed patches of necrosis which usually occur along the cleft margins are avoided and in consequence the sutures hold better. Should there be, however, any necrotic patches, they can be removed at the second operation.

4. The flaps become thickened and more vascular after a few days, and thus accelerate the healing by enlargement of the raw surface.

5. The hemorrhage at the second operation is very slight and the suturing can be done with greater exactness, as the view of the field is not obstructed.

6. The gaping of the lateral incision, which some surgeons endeavor to

remedy by packing, is avoided except in cases of very wide clefts. When the flaps have been previously loosened they become adherent again in a better position, and are only detached from the subjacent structures along the line of suture at the second operation, when the sutures are in place. It is only in very wide clefts that it is necessary to detach the flaps by means of elevators when the sutures are tied. In ordinary cases the tension of the sutures is sufficient to place the flaps in position without completely detaching them from the underlying structures, and to avoid the gaping of the lateral incision. The danger of a fistula is thus greatly diminished.

It may be argued that 2 operations are unnecessary, and that danger of infection is thereby increased. The advantages of 2 stages, however, far outweigh the extra time and trouble. Helbing states that he has followed this method in over 100 cases without infection in a single one.

STEP 2.—The lateral incision through the involucrum palati duri.—A perpendicular incision is made with a pointed scalpel close to the alveolar process at the right side, passing down to the bone. The length of the incision depends of course upon the size of the cleft. Bleeding is checked by pressing the left forefinger against the bone along the incision.

In cases of unilateral cleft through the alveolar process, the incision extends over the alveolar process between 2 teeth. The incision is carried from behind over the alveolar process and ends in an inward curve in the buccal mucous membrane. The latter portion of the incision is superficial, so as not to injure the palatal muscles. This long incision, confined to the oral mucosa of the velum, has two advantages, the increased mobility of the velum, and the preservation of the margin between the hard and soft palates, which materially lessen the danger of fistula at this place. Helbing has never found that it makes any difference if the palatine artery be injured, and whenever that accident has occurred, he has never allowed it to interfere with the proper detachment of the flaps.

STEP 3.—The mucoperiosteal flap is then raised from the subjacent tissue, with much care, as described in Berry and Legg's operation.

The soft palate is then separated from the horizontal portion of the palate bone at the margin of the cleft, but laterally it is left attached to the bone. The 2 halves of the soft palate are next approximated by blunt dissection between the 2 flaps of mucous membrane. It is of importance that the mucoperiosteal flaps be sufficiently detached to allow apposition of their mucous surfaces. It is essential that each flap be loose enough to extend to the middle of the cleft of the other side without tension.

When this procedure is completed on the right side, the left side is attacked.

Treatment in the interval does not differ from that of other patients—after 12 hours, liquid and soft diet until the third or fourth day, when general diet is given. Small children have usually a slight rise of temperature (38° C.) during the first 2 days.

STEP 1.—The paring of the edges.—The second operation takes place on the fifth day. To insure a full view of the operative field a silk thread is passed through the tip of the tongue so that it can be drawn well forward before inserting the speculum. The lateral incisions and the cleft margins are painted with dilute tincture of iodin.

The right uvula is grasped with a pair of long fine forceps and a double-bladed slightly concave scalpel is inserted about 1 cm. from the tip of the uvula and 2 mm. from the cleft margin. The scalpel is guided obliquely downward and inward with a sawing motion, cutting a strip 1 to 2 mm. wide from the cleft margin.

STEP 4.—The suturing of the cleft margins.—The first suture is laid at the tip of the uvula and Helbing is very particular to have the two freshened ends held at an equal distance from the median line. He uses horsehair and silk alternately, No. 0 or 1 silk for the velum, and No. 1 or 2 silk for the hard palate. The sutures are laid at a distance of 2 to 3 mm. on the soft palate, and 3 to 4 mm. on the hard palate. The sutures are alternately deep and superficial. In the posterior 1½ cm. of the uvula, the oral mucosa only is penetrated. In the anterior portion, both mucous membranes are caught in the suture.

It is not practicable to tie each suture, because it would be difficult to insert the next suture with accuracy. Here Helbing's suture-holder is a great convenience. It is made of metal and is 1 cm. wide and 17 cm. long. Through each side are inserted 13 loops of steel wire between which each pair of sutures may be clasped until they are tied—the first pair in the first right interspace, the second pair in the first left interspace.

In tying horsehair sutures a certain amount of dexterity is necessary, as they are apt to break, especially in tying the second knot. Horsehair is, nevertheless, superior to silk for the following reasons: 1. One is not so apt to pull it too tight. 2. It does not unravel like silk, and therefore does not become saturated with food particles.

For the uvula a crescent-shaped needle 6 mm. across is best, and a needle-holder with a long handle. A Hagedorn needle is used for the other sutures. According to the size of the cleft, from 2 to 4 retention sutures of silver wire are placed at a distance of 10 to 12 mm. from each other. These are deeper than the other sutures and are added for the purpose of reinforcing the silk and horsehair during coughing, sneezing, and vomiting. The posterior silver suture is placed in the soft palate. None of the silver sutures should be closed until the other sutures are tied.

The silk sutures are removed on the eighth day, the horsehair on the ninth, the silver wire on the tenth. In children under 4 years of age, all sutures are removed under anesthesia on the ninth day.

**Brophy's Operation for Patients whose Deciduous Teeth Are Well Erupted and Whose Bones Are Well Ossified.**—1. Denude the hard palate on its inferior surface, of its covering of mucous membrane and periosteum, by inserting a special

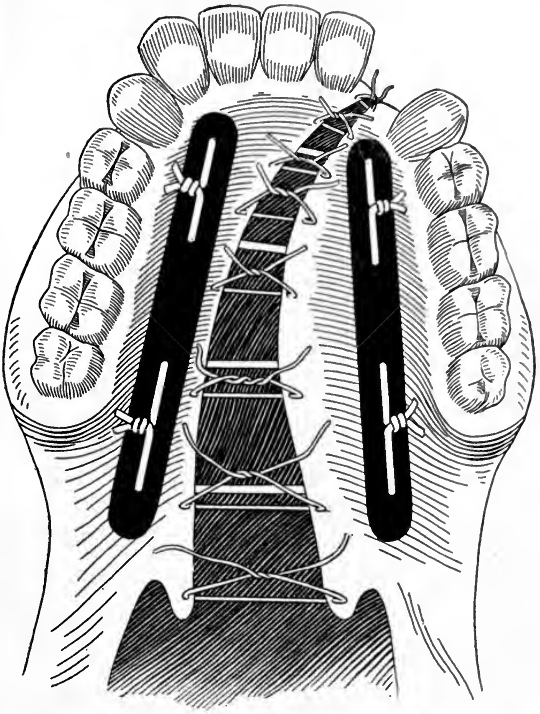


**Fig. 32.—Brophy Operation** (1). Showing method of inserting tension sutures and application of lead plates.

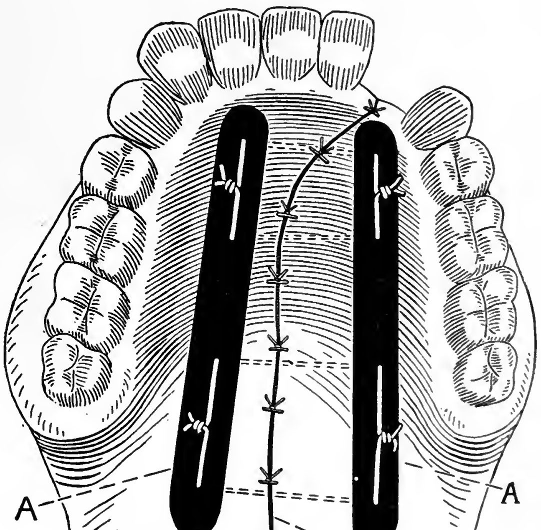



**Fig. 33.—Brophy Operation** (2). Showing approximation of edges of cleft by means of increased tension on silver wires. A, A, Lead plates; B, closed palate; C, coaptation sutures.

curved periosteatome in the edge of the cleft at a point about half way between the notch and the juncture of the hard and soft palates. Care must be taken to press firmly upon the bone while this is being done, in order to insure the complete removal of the periosteum with the flap. The denuded area must extend anteriorly as far as the notch, or if the cleft be complete, it must extend along the alveolar border as far forward as the teeth. Laterally it should extend to the edge of the alveolar margin and posteriorly to the point of union

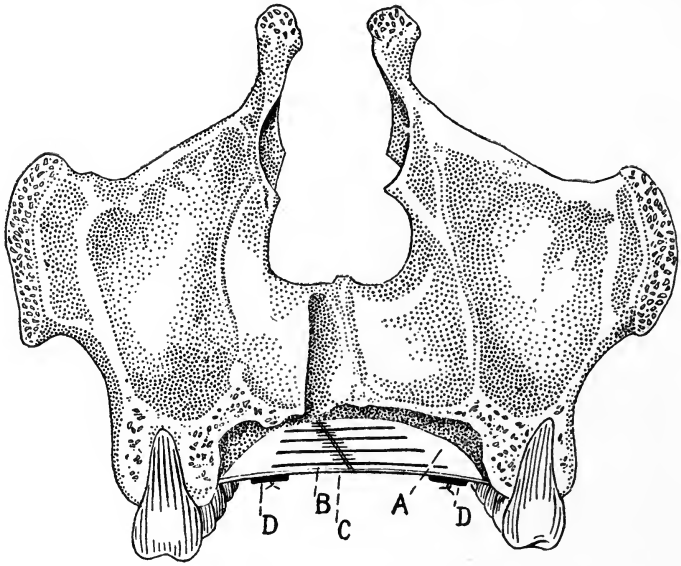



Fig. 34.—Brophy Operation (3). Transverse section of superior maxilla, showing relative position of mucoperiosteal flap and hard palate. A, Mucoperiosteum dissected away from the palatal surface of the superior maxillæ; B, silver tension sutures; C, coaptation sutures; D, D, lead plates. (Brophy.)

between the hard and soft palates. Hemorrhage, if troublesome, can be controlled at this stage by simple pressure.

2. Paring the edges of the cleft throughout may be done in the same manner as described under operation of Berry and Legg (page 473).

3. Separation of the soft from the hard palate (Fig. 30).

4. For suturing, the author uses a Deschamp needle by means of which 4 strong silk sutures are passed through the flap in pairs, about ½ in. apart, and inserted ½ in. from the cut edge. The first pair is placed near the anterior part of the cleft and the second pair near the junction of the hard and soft palates. By means of these silk sutures, 4 pieces of No. 22 silver wire are drawn through the tissues and lead plates (No. 22 American gauge, shaped as in Fig. 32) are perforated to correspond to the position of the wire. These are then threaded through the plates and twisted together as shown in Figure 32. Interrupted sutures are then placed in sufficient numbers to get exact approximation of the edges. More twists are then taken in the silver wires until tension on the interrupted sutures is absolutely relieved (Figs. 33, 34).

The advantages claimed for this operation are:

"The prevention of the cutting out of the sutures, since the lead plates coming in contact with the soft palate exert pressure thereon, and consequently the tension is not made by the sutures alone, which exert pressure on so limited a portion of the tissue, but it is upon the entire length of the palate covered by the lead plates.

"The lead plates serve as a splint, rendering the palate inflexible to a very great extent. The movements which are almost constant are suspended; the active muscles are put out of use until union of the cleft may take place. After using this method of closing the soft palate, I feel confident that better results can be secured than by the employment of sutures alone. As previously stated, this is not to take the place of the operation of dividing the bones at the malar process, and carrying the greater portion of the maxillary bones together, but it is adapted to the treatment of patients whose bones are well ossified and whose deciduous teeth are well erupted. It is in such cases that I recommend this operation."

**The Davies-Colley Operation** (1) (Fig. 35).—Make curved incision AB through mucous membrane and periosteum down to the bone on the narrow side of the cleft. Point A must be at the posterior limit of the hard palate, at least .4 cm. (1/6 in.) from the free border of the cleft, and point B should be opposite the notch the same distance from the border of the cleft. Raise flap formed from this incision from bone with periosteal elevator, care being taken to include all the soft parts, leaving tissue between points A and B to act later as a hinge.

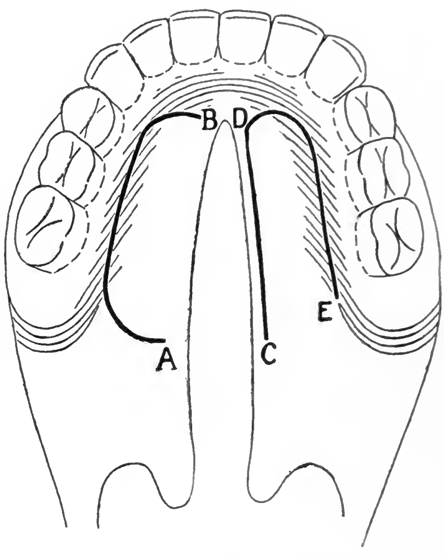


Fig. 35.—Davies-Colley Operation (1). Method of making the incisions.

Then make incision CDE on the wider side of the cleft down to bone. Incision CD should be .3 cm. (1/8 in.) external to free edge of cleft. Now raise flap with periosteal elevator, great care being taken not to damage the tissue lying between the points C and E.

The next step is to turn the flap formed by incision AB downward and inward, and make fast its free edge with 2 fine catgut sutures to the opposite margin of the cleft.

The last step is to slide the apex of the second flap across the raw surface of the first flap, and fasten as is shown in Figure 36. If this last flap appears to lie somewhat loosely in its new position, this need cause no apprehension because the pressure of the tongue will force it upward and thus enable the 2 raw surfaces to adhere.

The advantages claimed for this operation are:

"(1) There is less hemorrhage; (2) less bruising of the parts; (3) less sacrifice of tissue; (4) less tension upon the flaps; and (5) the operation can be easily performed at an early age, e. g. between the ages of one and two years.

"The disadvantages are: (1) The hard palate alone is united; (2) a foramen is apt to be left in the front part of the cleft. (This can be closed later.)"

**Brophy's Osteoplastic Operation.**—This procedure is suitable only in infants less than half a year old, because after that age the bones become too much ossified and hardened. It may be necessary, even in the youngest children, to divide the maxillary bone near its malar junction before the gap can be successfully bridged.

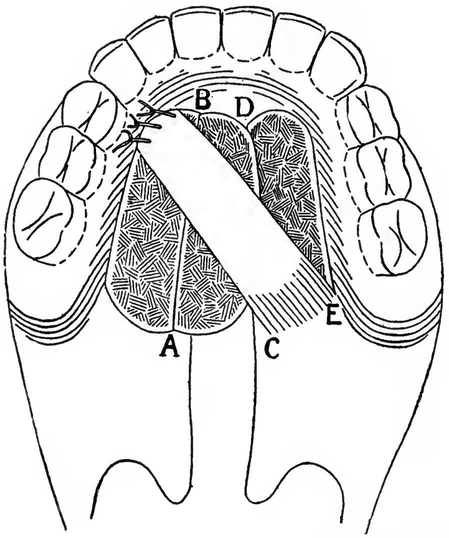



FIG. 36.—DAVIES-COLLEY OPERATION (2). Showing positions of transposed flaps.

The operation can be divided into the following steps:

1. Pare thoroughly and completely the whole free edge of the cleft to such an extent that a small portion of the bones of the hard palate and alveolar border shall be excised. By so doing, it is possible to get real bony union, which cannot be obtained by simply removing a strip of mucous membrane, without freshening the bone.

2. Raise the cheek and, at a point on the buccal surface of the superior maxilla, just back of the malar process, near the extremity of the hard palate and high enough to insure its being above the palate bone, insert a strong needle, carrying a loop of silk directly through the superior maxilla. When the point of the needle can be seen to appear in the mouth, through the cleft, the silk is grasped with an artery clamp and the needle withdrawn. At a similar point on the opposite side a second needle is passed and the loop grasped. Thus 2 loops are now to be found in the mouth. By drawing one loop through the other and making traction (see Fig. 37) a double through-and-through suture of silk is left. To the external end of the silk thread a silver wire No. 20 bent on itself is then fastened, and by a reverse traction, is made to pass through both punctures in the superior maxilla. A like procedure is then repeated at a point anterior to the malar process, the same distance above the inferior edge of the alveolar border.

3. Lead plates 1.3 cm. (1/2 in.) wide of about No. 17 American gauge should be in readiness. These are now cut off sufficiently long to allow a projection of at least 3/5 cm. (1/4 in.) beyond each through-and-through suture. These plates are then moulded to the external or buccal surface of the superior maxilla and perforated at the proper places to allow the passage of the silver wire sutures, which are then twisted together—one pair on each side (Fig. 38).

4. Forcible approximation of the bones of the superior maxilla can be accomplished by increasing the tension on the wire sutures, by twisting the ends together with an artery clamp or small pliers, and aiding by strong digital compression of the bones (Fig. 39). In many cases perfect approximation of

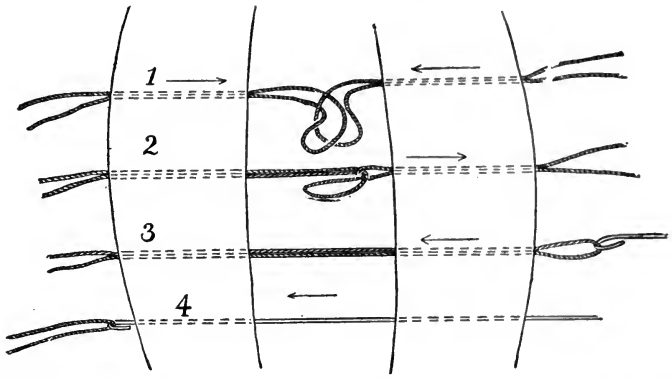



FIG. 37.—"TWO-LOOP METHOD" OF PASSING SILVER WIRE THROUGH SUPERIOR MAXILLA.

the cut edges of the cleft in the palate can be accomplished by this means without any further surgical procedure. If, however, the cleft be very wide or the bones unusually ossified, so that union cannot be accomplished in this way, it may be necessary to divide the malar process. A very small incision is made

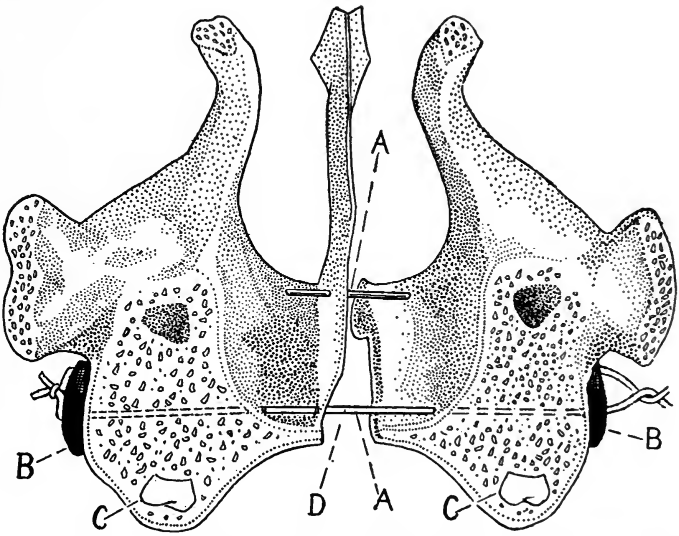



FIG. 38.—BROPHY OSTEOPLASTIC OPERATION (1). A, Silver wire; B, lead plates; C, tooth; D, cleft.

high in the cheek through the buccal mucous membrane, just below the malar process. A scalpel is then passed deeply into the tissue in a horizontal direction, and the malar process and deep parts are severed without allowing the wound in the mucous membrane to become any larger than is absolutely necessary. This can easily be done with any ordinary sharp scalpel. It will now be found that by increasing the tension on the silver wire, the edges of the cleft come readily together.

5. Suture of the mucous membrane in the mouth by interrupted suture insures eversion of the edge and perfect approximation. Fine silkworm or horsehair may be used for this purpose.

It has been advocated by some that the first step, that is to say the paring of the edges of the cleft, be delayed until the wire sutures are inserted and the

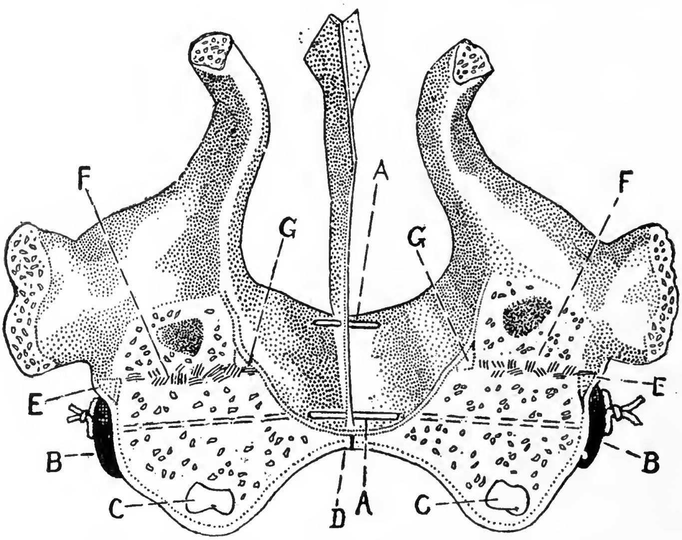



Fig. 39.—Brophy Osteoplastic Operation (2). A, Silver wire; B, lead plate; C, tooth; D, cleft; E, E, mucoperiosteum forming extended wall of the triangular space by forcing the lower fragments of the bone inward; F, F, lines of fracture; G, G, triangular space on nasal surface of bone made by approximation of the palatal process. (Brophy.)

lead plates affixed. This would seem to have some advantages, especially in preventing the amount of blood loss and in making it possible to do all the work in the mouth at one time, with the child in the Rose position.

Brophy recommends that the lead plates be left in place for from 2 to 4 weeks. The sutures in the palate may be removed in from 7 to 10 days.

The objections which have been made to this operation are: 1. The danger from shock and the severity of the operation; 2. The extreme probability of sepsis; 3. Injury to the buds of the non-erupted teeth; 4. Narrowing of the superior maxilla, with resulting disproportion between the sizes of the superior and inferior alveolar borders; 5. The possibility of producing an obstruction of the nares and interfering with proper breathing.

Brophy estimates the mortality to be about 3 per cent. He does not consider the shock resulting from this operation greater than from any other, and maintains that very young children bear so-called surgical shock very well. As to the fourth and fifth objections, he says: "The palatal arch is in some cases contracted, but this will not be permanent, for if the operation is performed early enough, when development is complete, the teeth of the upper jaw occlude naturally with those of the lower jaw. It is a well known fact that the alveolar processes develop with the teeth, and this seems to be a pronounced factor in the formation of the jaw and the guiding of the teeth into their proper position." And he also says: "Through a misconception of this surgical procedure, it has been stated that the closing of the palatal vault, carrying of the bones together and uniting them in the median line would be followed by stenosis. If one keeps in mind the anatomy of the parts, and then understands the details of the operation, he will readily see that the closure of the nasal passage, or even reducing its dimensions, would be impossible."

The *after-treatment,* according to the same author, "is very simple, consisting solely of antiseptic cleansing of nose and mouth, at least twice a day; stimulants, if indicated, the first twenty-four hours; preventing the child from disturbing the parts or introducing into the mouth anything that might interfere with the sutures; paying special attention to the care of the bowels; using alcohol sponge baths if the temperature rises above 100 degrees F. and nourishing the patient on liquid food given by means of a spoon. The nipple should not be used, as the act of suckling may interfere with the process of repair. Abrasions of the mucous membrane caused by the lead plates need not disturb the operator, for they are usually slight. The plates are to be left in place from two to four weeks, but the silk sutures, if employed, should be removed about one week after the operation."

**Lane's Operation** (12).—This is an adaptation of the Davies-Colley method. The operation is very ingenious and very difficult. Great care must be taken in marking out the flaps, and after they are marked out, not to injure them in any way, especially during the process of raising them from the bone. They should be handled carefully and never torn or bruised, if union is expected to take place. It is an operation which should not be attempted by any surgeon who has not acquired the habit of doing delicate and difficult work. If unsuccessful, and gangrene of the flap takes place from any cause, it is almost impossible to do a secondary operation with any satisfactory results. In the hands of the author, Mr. Lane, the most brilliant results have been obtained.

The special instruments required in this operation are: Mouth gag (Fig. 25); scalpel; needle-holder, needles and toothed forceps.

Position: Rose position.

Anesthetic: Ether, internasal.

Lane writes:

"The general principles on which most of the operations are based is that of raising from the roof of the mouth on one side of the cleft a flap, which consists of the mucous membrane, sub-mucous tissue and periosteum of the roof of the mouth; and where this flap extends over the alveolus, care is taken to avoid unnecessary damage to the subjacent teeth. This can only be done efficiently very soon after birth. As time goes on, the damage done to the temporary teeth by the separation of the superjacent mucous membrane becomes steadily greater. Still this is a matter of no very great moment as compared with the importance of the closure of the cleft.

"The manner in which the flap is formed from the mucoperiosteum on one side, and is fixed beneath the separated mucoperiosteum lining the roof of the mouth on the opposite side of the cleft in an edentulous infant, is represented in Figures 40, 41, 42.

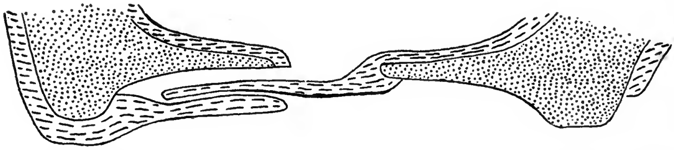


Fig. 40.—Flap Raised and Fixed in Position. In this case, the cleft is not of sufficient breadth to render it necessary to strip the alveolus of its covering of mucous membrane. (Lane.)

"In the soft palate, the flap, which is raised, comprises all the soft parts down to the tensor palati, and may be made as extensive as necessary, by encroaching on the cheek, if there is not enough material in the remains of the soft palate. As regards the soft palate, this method of operating is *incomparably more certain of success than the usual mode of paring the edges of the cleft and bringing them together.* This last is only rendered possible by the free vertical division of the palate muscles on either side, and the junction so effected frequently breaks down. In my operation, the continuity of these muscle planes is unimpaired, no cicatricial tissue existing in their substance and no loss of function arising in any part in consequence, the muscles on both sides being connected by material on which they can exert efficiently their traction normally in their several directions. On the other side of the cleft, the mucoperiosteum is divided along its free margin until the soft palate is approached. The extremity of the uvula or its relic is picked up with forceps, and an incision is made outward from it along the free margin of the palate for some distance; and from its outer limit another is carried forward and inward along the upper part of the soft palate to reach the posterior limit of the incision running along the free margin of the hard palate. The triangular flap of mucous membrane and sub-mucous tissue, intervening between the two incisions described, and the margin of the cleft in the soft palate, is raised off the subjacent muscles and turned inward, and the raw surface left by this procedure is increased in area by turning outward a further portion of the mucous membrane covering the soft palate externally. By this means the area of the upper surface of the soft palate, rendered bare by the removal of its mucous membrane covering, is rendered much greater than before. By means of a stout steel elevator

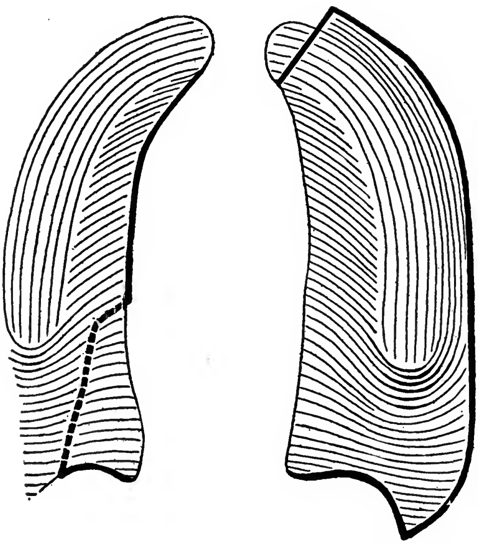


Fig. 41.—Cleft of a Breadth Sufficient to Require the Employment of a Flap from the Entire Alveolus. The heavy lines indicate the incisions, that to the left of the cleft being on the nasal surface of the palate, while that on the right is on the buccal aspect.

introduced between the mucoperiosteum and the bone, through the incision made along the margin of the cleft, the mucoperiosteum is raised from the bone up to the inner margin of the alveolus. The flap, whose edge is attached along the margin of the cleft, is placed beneath the flap which has been raised from, and for a considerable distance beyond, the margin of the cleft; and it is pinned down by fine curved needles and 0000 Chinese twist silk in this position, by a number of sutures which perforate the free margin of the reflected flap and the outer part of the elevated flap, the knots being tied on the under surface of the latter, whence they can be removed with facility when the opposing surfaces have united firmly, which they do in about ten days. Then the free margin of the raised flap is attached by separate sutures to the raw surface of the reflected flap. Finally the opposing edges of the free margin of the soft palate are united in a similar manner."

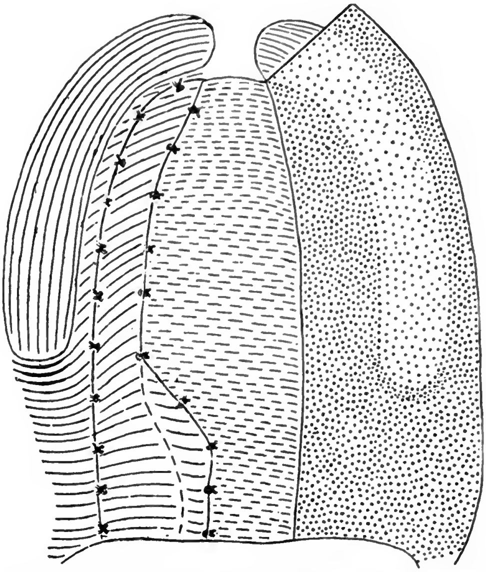


FIG. 42.—FLAPS SUTURED IN POSITION. The shaded area represents the surface laid bare by the removal of the flap.

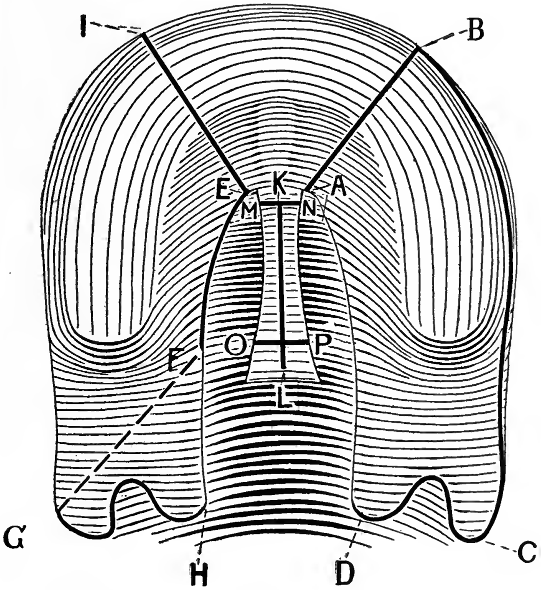



FIG. 43.—LANE OPERATION FOR BROAD CLEFT INVOLVING ALMOST THE ENTIRE PALATE.

1. OPERATION FOR BROAD CLEFT INVOLVING ALMOST THE ENTIRE PALATE (Fig. 43).—The first incision begins at A, goes to B, is continued to C, and then through the free edge of the soft palate to D. The second incision starts at E, extends along the edge of the cleft to the junction of the soft and hard palates F, is continued on the superior surface of the soft palate to a point G. A third incision starting at G is carried along the free edge of the soft palate to H. The fourth incision, starting at E, extends to I in a direction anterior and outward. If the septum is free in the cleft, a fifth incision extending from K to L is made, with 2 smaller incisions M and N, O and P.

The flap bounded by A, B, C, and D is then carefully lifted from the sub-

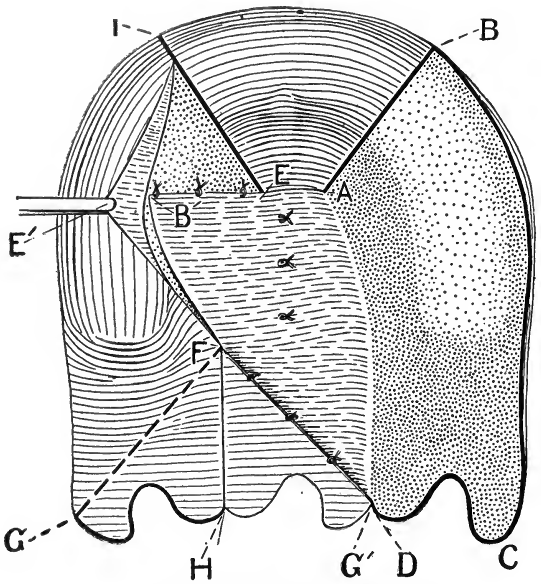



Fig. 44.—Flaps in Position.

jacent structures with a specially designed knife, and must include not only the mucous membrane, but also the periosteum. At the posterior palatine foramen the artery can usually be caught with an artery clamp as it emerges. The flap bounded by the incisions I, E, and F is then raised from the hard palate in a similar manner. The flap on the superior surface of the soft palate, bounded by the incision F, G, and H, must be raised carefully and include only the mucous membrane and submucous tissue. It is turned downward and inward, hinging on a line from F to H. The first flap can now be turned downward and inward, hinging on the line A and D, which is one of the edges of the cleft. This flap is then inserted between the under surface of the hard palate and the upper surface of the raised flap bounded by I, E, and F (Fig. 44).

If the septum appears in the cleft, the small flaps marked out by the incisions N, K, L, and P, and M, K, L, and O are raised and turned down. A small linear incision is then made through the mucous membrane of the first flap to correspond to the area which will be in apposition to the raw surface just produced on the septum when the first flap is turned over and fastened to the opposite side.

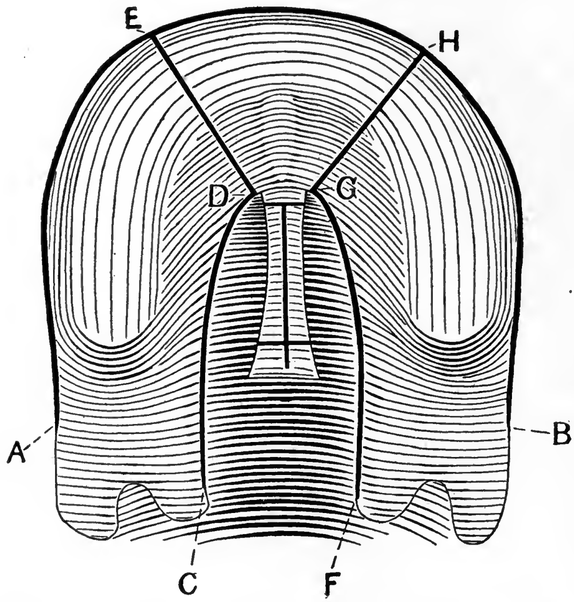



Fig. 45.—Lane Operation When the Width of the Cleft is Extreme.

To complete the operation, interrupted sutures are placed, to fasten the free outer edge of the first flap to a line nearly opposite the alveolar border. A second row of interrupted sutures is then placed, to fasten the free edge of the second flap to the raw surface of the first flap. The flap from the superior surface of the soft palate is then sutured to the raw surface of the first flap, as shown in Figure 44.

2. OPERATION WHERE THE WIDTH OF THE CLEFT IS EXTREME.—It is frequently impossible to close the gap in one operation, so a 2-stage procedure may be adopted:

The first incision extends from A to B, completely surrounding the external surface of the alveolar border (Fig. 45).

The second incision extends from C to D to E.

The third incision extends from F to G to H. It is then possible to lift a mucoperiosteal flap bounded by the incisions D, E, H, and G and leave a small bridge of tissue which must act as a hinge between the points D and G. This flap is then turned downward and backward, and sutured to the raw edges created by the incision C and D, F and G. The next step is to carefully raise the 2 flaps: the one marked out by the incision C-D, D-E, and E-A; the other F-G, G-H, and H-B. These 2 flaps are now rotated or slid toward the middle line, and the lines D-E and G-H are sutured together in the middle line, thereby covering the raw surface of the first flap with mucous membrane (Fig. 46). This completes the first stage.

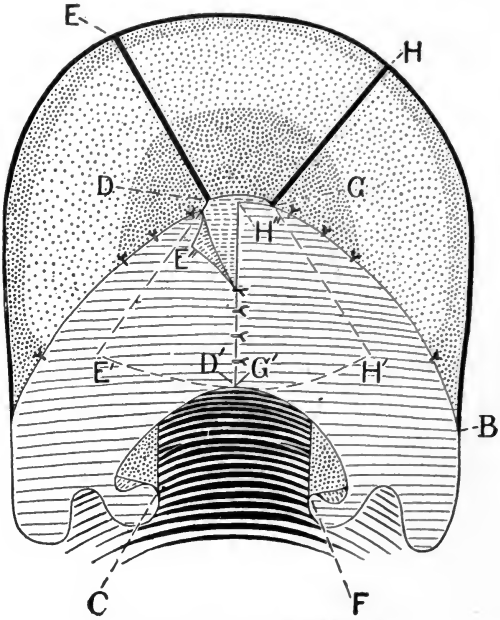


FIG. 46.—FLAPS IN POSITION.

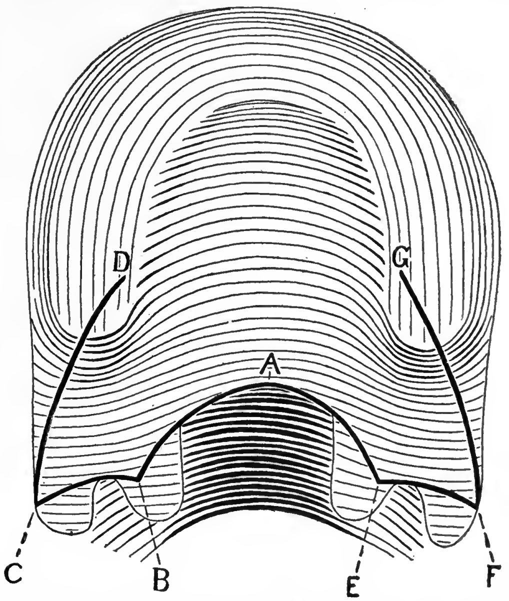


FIG. 47.—LANE OPERATION WHEN THE WIDTH OF THE CLEFT IS EXTREME. Second stage.

For the second stage (Fig. 47), incisions are made from a point A, along the free margin of cleft to B, along the free edge of soft palate to C, and then in an anterior direction toward the alveolar border to a point D. A similar flap is made on the opposite side from the point A, to E, to F, to G. These flaps must include, as is always the case when flaps are taken from the soft palate, only the mucous membrane and submucous tissue. These 2 flaps are now brought together in the middle line by sutures which finally approximate the points B and E. Interrupted sutures are then placed fastening the external edge of the flap to the soft palate B, C′ and G, F′. Finally sutures are placed between the points C′ and F′, establishing the free border of the new soft palate (Fig. 48).

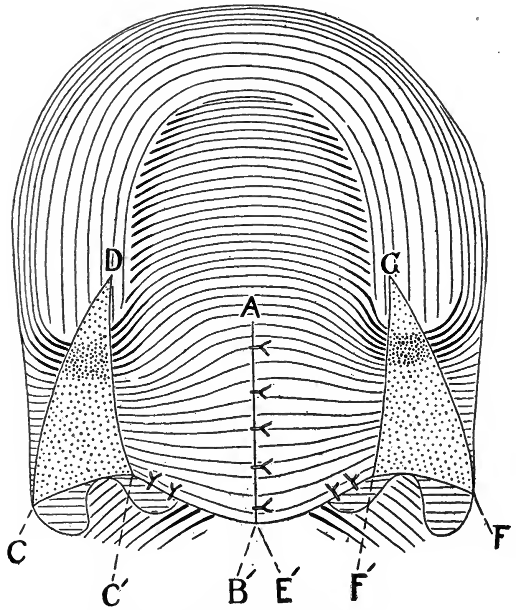


FIG. 48.—FLAPS IN POSITION.

**Roberts' Method.**—The treatment of the child, according to Roberts, should be by what might be called the composite method.

1. Immediately after birth the mother should press the two halves of the upper jaw together firmly with her finger and thumb many times a day. This orthopedic procedure tends to lessen the width of the fissure.

2. As soon after birth as possible, the soft and semicartilaginous bones of the upper jaw should be forced together by means of a clamp or by the more formidable operation of Brophy, with wire tie-beams and lead plates.

3. About the same time that this replacement of the bones is attempted, the alveolus should be reconstructed in front, if there be any great deviation in the alignment.

4. Any protrusion of the intermaxillary bone must be corrected by a plastic or osteoplastic operation at the front part of the nasal septum of the nose.

5. A gap remaining in the roof of the mouth must next be closed by a flap operation.

6. The fissure in the upper lip must not be operated upon until then and should be closed with carefully applied sutures and the deformity of the nostril corrected.

7. When the lower lip is very prominent, the excision of a V-shaped piece and the widening of the upper lip if indicated, by the insertion of this piece or a flap taken from cheek, chin, or hand.

**After-treatment.**—The essential points in the after-treatment of operations on the palate are: 1. Quiet and rest of the parts; 2. Cleanliness.

The first point may be obtained by the use of such drugs as paregoric or chloral for the first 24 hours after the operation. From the second day on the child must be amused, given plenty of toys to play with, made as comfortable and annoyed as little as possible. He should be allowed to be with people he likes. As much sleep as the child can get is very beneficial, and plenty of fresh air is essential.

As to the second point, cleanliness, it is quite a question if the antiseptic sprays and douches often recommended do not frequently do more harm than good. They must necessarily be very weak in antiseptic value, and as the quantity of fluid used must be very small, the cleaning value cannot be great. As the administration of these douches always excites violent and continuous opposition on the patient's part, accompanied by much crying, the harm done is probably greater than the good. Frequent drinks of a small quantity of clean water are, in my opinion, much more useful. Of course, in older children and in adults, local cleanliness can be maintained by direct applications to the wound, and, in these cases, should be employed.

The diet must consist from the first to the sixth or eighth day of fluids only, a very small quantity at a time, and given with a spoon. After the eighth day, custards and soft puddings may be added, but it is best not to give any solid food until the wounds have been examined and the fact established that healing has taken place or has progressed as far as it will go. After the administration of any food, it is well to give a small quantity of water, with the expectation that particles of food, which may have lodged in the incisions, will be washed away.

Unless some serious complication occurs, such as sepsis or hemorrhage, the wound should be let alone for at least 3 or 4 days. If the hemorrhage is secondary and profuse (some cases have been reported as late as the tenth day after operation), it is probably due to bleeding from the posterior palatine artery. This may be controlled by the insertion into the posterior palatine foramen of a small pointed piece of wood, such as the end of a match. Slight secondary oozing is generally due to infection and gangrene and is rarely serious. Much harm has been done by frequent examination during the first week, but it is difficult to abstain from making them.

The use of splints on the child's arm or any other form of restraint after the first 24 hours, is apt to fatigue and annoy the child and make it restless. It is, therefore, better not to use them, provided proper attention can be given the patient by a parent or nurse.

**Results.**—A complete and perfect repair, as a result of an operation, is unusual, and the family should not be led to expect it. It is not uncommon for the line of junction to present some gaps, after the stitches of flap operations have been taken out. These gaps, which are the result of infection, over-tension, or erosion, are usually located at the junction of the hard and soft palates or directly back of the incisors. They are apt to close spontaneously, through granulation, in 8 or 14 days. Healing of small but persistent gaps may be accelerated by the application of mild caustic agents. Large defects sometimes require a secondary plastic operation for their permanent correction.

Gangrene after these operations may be due to a variety of operative causes, aside from the division of the posterior palatine artery, which is sometimes inevitable. A frequent contributing cause is too tight tying of the stitches. When flaps are torn or detached, they should at once be repaired by means of fine silk sutures. A cause of gangrene, for which the operator is not responsible, consists in the necessary detachment of very thin flaps, which may at once become discolored and pale, but which sometimes resume their normal color in the course of the operation. In less fortunate cases, one or several flaps may become partly or entirely gangrenous, especially around the margins, but the loss of substance is often spontaneously repaired to an unexpected degree. Le Dentu mentions a case of repair of the entire palate, after gangrene had destroyed half of the width of one of the flaps, and at least 2 cm. (3/4 in.) of its length. Fistulæ of different sizes usually persist after solutions of continuity larger than 5 to 6 mm. in diameter. Lateral fistulæ, not due to restricted gangrene or ulceration, may form at the level of the incisions and have been attributed by Ehrmann to constitutional or intercurrent diseases. Excessive length of the lateral incisions, the position of the incision too near the edge of the cleft, or traction upon the internal margin of one incision from rapid healing and contraction of another incision, can also be mentioned as causes which have a tendency to produce fistulæ.

**Late Results.**—The remote results of operative closure of cleft palate are discussed by Hageman (8) upon the basis of re-examination of 23 cases which had previously been operated upon according to the Langenbeck method. In the majority of these cases, plaster casts were taken of the superior and inferior maxillæ. Of the seven patients who had been successfully operated upon between the ages of two and seven years, no less than five presented a very characteristic change, which consisted of smallness of the upper jaw in general, more particularly a narrowness in the transverse direction, with a transposal of the teeth in the lower jaw, their crowns having rotated inward. These changes of the upper jaw are explained as due to the traction of the scar tissue, which forms in the under surface of the hard palate. This cicatricial contraction subsequently induces a transverse narrowing of the upper jaw. The change in the lower jaw takes place through the functional adaptation of the teeth of the inferior maxilla to the upper jaw. When these changes are very pronounced, the result is a disfigurement of the face and a general disturbance, on account of the interference with the act of chewing. Upon the basis of his findings, Hageman arrives at the conclusion from a practical point of view, that it is of the greatest advantage in the first place, to apply dental protheses to stretch the upper jaw after operation; and he advocates the postponement of the Langenbeck operation, at least in severe cases, until the change of teeth has been completed, namely until after the tenth year if possible.

The modern operative methods of forcible approximation of the entire upper jaw do not appear very promising for the future configuration of the maxillæ, and are likely to induce an increased degree of transverse narrowing of the superior maxilla. These methods (Brophy, Sebileau, Hammond, Schroeder, Helbing) must therefore be applied with some caution. After the Langenbeck operation, when it is performed at a very youthful age, the growth of the upper jaw should be steadily controlled, that it may be enabled by means of orthodental apparatus to counteract in time the narrowing of the maxilla.

It should be well understood that the repair of the palate, even if eminently successful, does not correct the defects in speech; or, even where the operation is performed in early infancy, prevent them from occurring. All that the operation can do is to make it more possible for the child to learn to speak correctly and therefore it is of great importance that the child should receive careful and intelligent instruction as soon as possible after the operation.

After early operations upon clefts of the soft palate in the first few years of life, no obturator may be required, but these protheses often act as useful adjuvants in the speaking exercises of older children. Elastic obturators filled with air and inserted between the velum and the posterior pharyngeal wall, closing off the nasal cavity, are recommended by J. Wolff and Schiltsky. This prothesis has a palatine plate of hard rubber with a narrow handle, which is made to lie over the soft palate and terminate in a small hollow pharyngeal obturator, made of vulcanized soft rubber. This pharyngeal obturator is compressible and contains air, and when the palatine velum is raised in speaking, it is pushed backward and sideways, with the result, in favorable cases, that the nasopharyngeal cavity is shut off and the patient's speech in consequence saved from a nasal twang.

The postoperative results in regard to speech are especially hampered by the smallness of the soft palate and its lack of adaptation to the posterior pharyngeal wall. Massage of the palatine velum has been recommended for the repair of this defect and for the correction of the resulting nasal speech. This massage, according to Tillmanns, may be applied by means of a small T-shaped instrument of wood or metal, which is curved to fit the hard palate, and with which the velum is stretched toward the posterior pharyngeal wall.

Mechanical appliances with a flexible velum—the so-called artificial palates—were formerly often used as protheses in these deformities, but are not to be recommended at the present stage of surgical technic. They are sometimes necessary, however, as a last resort, after repeated surgical procedures have proven unsuccessful, because of the sloughing of the flaps, or in those desperate cases in which any operative measures seem foredoomed to failure.

## PLASTIC SURGERY OF THE LOWER LIP: CHEILOPLASTY

The closure of small and moderate sized defects of the lower lip, either triangular or curved, is successfully accomplished through the approximation of the flexible parts of the lip, followed by suture without the aid of cheiloplasty.

Large triangular defects which cannot be closed by simple suture without overstretching of the parts may be treated by enlarging the mouth-gap through horizontal incisions from the buccal angles, followed by suture. A total loss of substance, either quadrilateral or curved, of the lower lip may be closed as described by Bruns, by plastic flaps from the cheek, which are turned over into the defect and sutured; or, as described by Langenbeck, by a flap cut from the chin region, which is turned upward into the defect and stitched in place.

## OPERATIONS FOR EXCISION OF PAPILLOMA, ANGIOMA, OR OTHER NON-MALIGNANT GROWTHS

**Simple V-Incision.**—See Figure 49.

**Anesthetic.**—Cocain, 1 per cent., or novocain used 2 per cent. for the skin and followed by 1 per cent. for the deeper parts. Ether is unnecessary in adults. The addition of adrenalin is not recommended. The administration of 6 mm. of Magendie's solution of morphin before the operation quiets the patient.

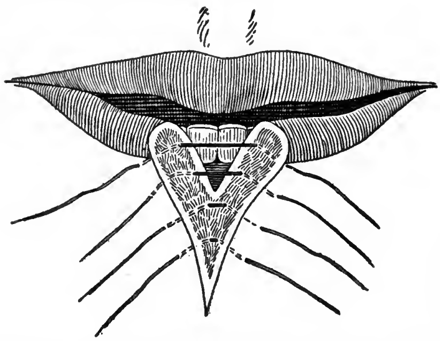


Fig. 49.—A Simple V-incision for Removing Non-malignant Growth of Lower Lip.

**Position.**—Shoulders and head elevated and head slightly flexed, resting on firm pillow or sand-bag.

No special instruments are required.

**Technic.**—Apply Murphy's intestinal clamps as near the angle of the lower lip as possible (Fig. 51). The area to be removed should be a complete section through the lip, consisting of all its layers. The angle made by the 2 incisions forming the "V" should be as acute as possible, and each incision can be easily made with one cut of a sharp scalpel. If the angle is acute and the area removed is not greater than a third of the lip, excellent approximation without tension can be secured. Incise the lip not absolutely at right angles to the skin, but slope the scalpel slightly inward while making each incision, in order to remove a somewhat larger area of skin than of mucous membrane. The hemorrhage from the coronary artery can be controlled by very fine ligatures, and care should be taken to include nothing more than the artery in the knots. The slight venous oozing may be neglected. Usually 3 or 4 fine silkworm-gut sutures passed in at right angles to the skin down to but not through the mucous membrane, will suffice to give perfect apposition and stop all oozing. Care must be taken to get exact alignment of the 2 points where the vermilion border and the skin join. A few silk sutures in the vermilion border may be necessary. Doyen recommends the suturing of the mucous membrane first, and then the skin, with all the sutures superficial, and claims that by doing so, a stronger and firmer lip is obtained.

DOUBLE TRIANGLE METHOD (Fig. 50, A).—The growth is removed by the simple V-shaped incision A B C. An area equal to the area of the section is removed from the cheek, D E C. The incisions for this should be marked out on the skin and an area of mucous membrane D F G C left to restore the vermilion border of the lip as described on page 497. The incisions FE and EG go through all the layers of the cheek. Figure 50, B shows the sutures in position

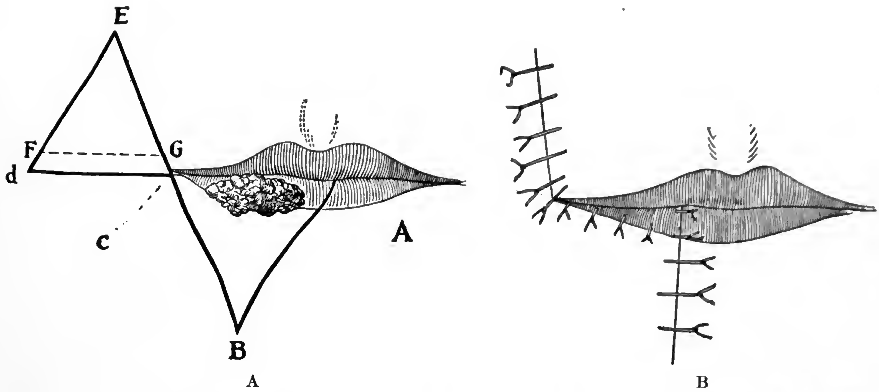



Fig. 50.—A, Double Triangle Method for Removing Non-malignant Growths of Lower Lip; B, Sutures in Position and the Defect Closed.

and the defect closed, with the mucous membrane turned out, making the new vermilion border.

## OPERATIONS FOR EPITHELIOMA OF LOWER LIP

The operation consists of: First, the entire removal of the growth with at least ½ in. of healthy tissue surrounding it on all sides; second, the complete removal of the submental and submaxillary lymph glands; and, third, the restoration of the lip by one of several methods.

### 1. Removal of Growth

If the growth is very small indeed, it may be excised with a sufficient amount of healthy tissue, by a large V-shaped incision, but the amount of tissue removed by this incision is not as a general rule sufficient, and a quadrilateral area gives much more satisfactory results. The excising incisions must be at least more than ½ in. away from the growth.

### 2. Removal of Glands

The question as to whether the lymph glands should be removed or not does not admit of discussion. The only possible reason for not removing them would be the fact that the patient had an inoperable condition. In every case where there is the least hope of a cure the glands must be removed. If this is not done, the operation must be considered a palliative one only, and recurrence must be expected. It has many times been shown that metastases occur extremely early, and that as soon as the growth, by microscopic examination, shows typical epithelioma, the lymph-nodes are by that time involved.

The question as to when to remove the lymphatics is important. Many surgeons recommend that the complete operation, the removal of the growth, the removal of the lymph glands, and the restoration of the lip, be done at the same time.

I much prefer to remove the glands first and to employ a two-stage operation: First, because it is possible to do an aseptic removal of the glands, resulting in primary union of the wounds when the mouth has not been entered; and, second, because, by dividing the operation, the disadvantages to the welfare and comfort of the patient are minimized. The length of time required to do a careful restoration of the lip is necessarily great, and there is always considerable hemorrhage, from which patients frequently show the so-called "surgical shock." Some infection of the lip wound and consequent rise of temperature almost always follow the lip operation, which, by themselves, are sufficient to affect the welfare of the patient. The longer the anesthetic is given, the greater are the chances for postoperative complications, especially when the operative field involves the air passages, and I believe it to be much safer to give 2 anesthetics of moderate duration than one excessively long one.

In almost all cases it is undoubtedly best to remove the glands first, because **they are thus sure of being removed.** It frequently happens that the removal of the growth and the restoration of the lip satisfy the patients, especially hospital patients, and they refuse to accept the second operation; and because the restoration of the lip is a long operation and the after-effects of the anesthetic are often so prolonged and severe, the patient refuses to take ether again.

I recommend incisions as shown in Figure 61. All lymph-nodes should be removed, also the submaxillary salivary glands. The wounds do well if closed with drainage, which can be removed on the third day. For the various methods, see operations on the neck.

## 3. Restoration of the Lip

**First Method** (Figs. 51, 52).—To insure a symmetrical result it is well to mark out with the point of the scalpel on the skin the incisions which it is proposed to make in order to fill the gap. If this is not done before the incisions are made, it frequently will be found, toward the end of the operation, that the flaps are unequal and have a tendency to drag the lip in either one or the other direction. Having marked the cuts, make the convex incision CD, the convexity pointing upward and outward. This incision should be made to follow, so as to surround, the base of the prominence of the chin, and must penetrate all the superficial parts. The blood-vessels, which are numerous, must be caught with fine mosquito clamps and the vessels ligated with the finest possible catgut. Then make incision AB in a horizontal direction of a length equal to ¾ of the space created by the removal of the growth on the lip. This incision should extend down to but not through the mucous membrane of the cheek. When this is reached, the scalpel should be turned upward, separating the mucous membrane from the subjacent tissues for the distance of at least ½ in. Then cut through the mucous membrane parallel to the incision AB. This is done in order to provide sufficient mucous membrane to turn over the raw surface of the new lip, and thus create a new vermilion border. Repeat the same incisions on the opposite side of the face. Care must be taken to stop all hemorrhage at this time. By now gently approximating the cut surfaces IG and JC, it can be estimated whether the lateral incisions have been extensive enough to enable these 2 surfaces to be approximated without any tension whatever. If there is any tension, the lateral incisions must be extended. During this part of the operation, some type of aspirating apparatus, which enables the blood to be removed from the pharynx, is of great value to obviate the need of constant sponging, which not only does not completely remove the blood, but also interferes with the operation, irritates the patient's mucous membrane, and has a tendency to increase the possibilities of postoperative complications.

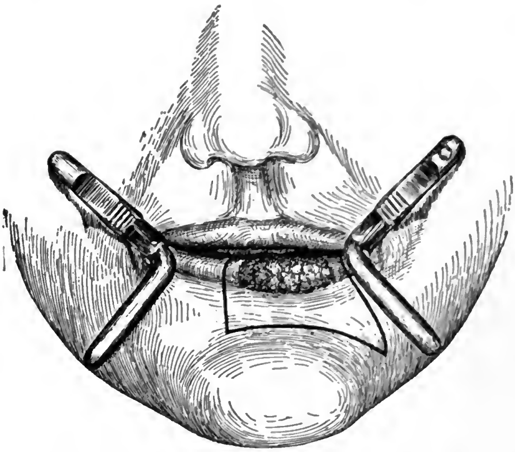


FIG. 51.—RESTORATION OF LOWER LIP (1).

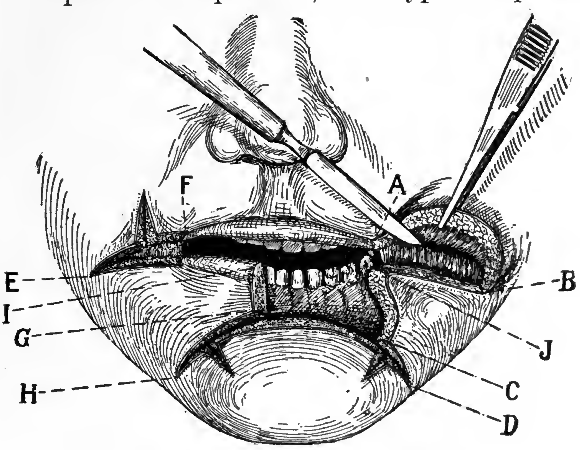



FIG. 52.—RESTORATION OF LOWER LIP (2).

SUTURING.—Begin by suturing the mucous membrane of one of the lower incisions, working on both sides toward the middle line. A medium sized curved needle with fine plain gut, using interrupted stitches about ¼ in. apart, gives the best results. Care must be taken, as in all plastic work, not to tie the stitches too tight or invert the mucous membrane. When these suture lines are complete, one of the flaps created by the incisions AB and CD can be gently held with a sponge-holder and drawn toward the middle line. Fine silkworm-gut stitches can now be introduced, beginning at the outer end of the curved incision CD. If the silkworm-gut has been previously soaked for some little time in warm water, it will be much easier to handle and will adapt itself better to the tissues. These stitches should include all the thickness of the soft parts down to the mucous membrane, but must not pass through the mucous membrane, and must be tied so as to just approximate the cut surfaces. Frequent applications of peroxid, followed by warm salt solution over the raw areas, has been found an excellent cleansing agent and at the same time a mild hemostatic without causing much irritation or interfering with the healing. Following the suture of the 2 lower lateral incisions, a vertical suture of the mucous membrane created by the approximation of IG and JC is now done. Four or 5 fine catgut sutures usually suffice. Silkworm sutures are then passed, as before, in the middle line, care being taken to get exact alignment between the junction of the vermilion border and the skin of the opposite parts. The excess of mucous membrane created when the incisions AB and EF were made, is now drawn forward over the raw surface of the new lip and carefully sutured to the skin with fine silk. If this step of the operation is carefully done, an excellent new vermilion border for the new lip will result.

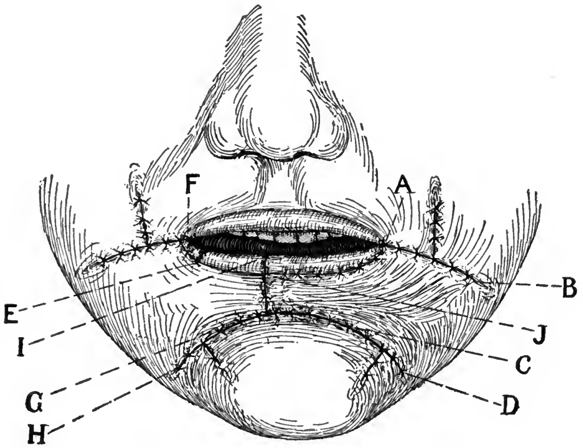


Fig. 53.—Restoration of Lower Lip (3).


Fig. 54.—Morestin's Operation for Carcinoma of the Lower Lip. Showing incision for removal of the growth.

It will now be found that an excess of tissue in the cheek prevents correct approximation of the 2 upper horizontal incisions. To overcome this, a small triangular section consisting of the whole thickness of the cheek can be removed from each side (Fig. 53).

**Morestin's Method.**—Morestin (20) advocates very strongly the excision "ultra-total" of the epithelioma (Fig. 54). The area to be removed is bounded by 3 incisions. The first one is curved in shape and passes transversely in front of the point of the chin, continuing at the level of the border of the inferior maxilla to a point just anterior to the location of the first molar tooth. The 2 others start from the angles of the mouth (which are supposedly not involved in the growth) and pass downward and outward, joining the extremities of the transverse incision. The part thus removed will be of a trapezoid shape, with the base inferior.

Morestin uses this procedure because the lesion has a tendency to infiltrate the muscular tissues and to travel along the lymphatics which pass with the inferior dental nerve, and deplores the removal of the growth by a V-shaped incision which does not consider this chance of metastasis. The removal of this trapezoid gives the best prognosis and removes the greatest possible amount of doubtful tissue. It is, of course, understood that this operation must be either preceded or followed by the complete dissection of the lymphatic nodes and the submaxillary glands.

The area to be filled in is apparently enormous, and at first seems to present a great many difficulties. But the author does not find these insuperable. He considers the most suitable cheiloplastic operation for closing this defect to be that described by Larger (13), but he has made several improvements on this method.

For the sake of perfect accuracy he advocates tracing an incision on the skin. He begins by tracing an incision on each cheek parallel to the edge of the section and at a distance of 3 cm. from it, beginning at the lowest point at the level of the teeth of the inferior maxilla and going in an upward direction toward the nasolabial sulcus and stopping at a point within 1 cm. of the ala of the nose. From the upper extremity of this incision he starts another, which runs obliquely downward and inward toward the border of the lip. This incision reaches to but not through the vermilion border, a certain amount of which is preserved, and this he detaches by transfixion, cutting outward until he meets the angle of the mouth. Thus, a little tongue is formed, attached by its inner extremity to the upper lip, which is used to restore the angles of the mouth to an "excellent condition"; and this he considers the most delicate part of a total removal of the lip.

Fig. 55.—Morestin's Operation Showing Incision for the Formation of the Flaps.

Figure 55 shows the traces of the incision, including that of the little strip of vermilion border destined to repair the angle. Great care must be taken to cut the flaps exactly alike and to give them exactly the same length and size, to insure a symmetrical new mouth. All the soft parts must be neatly cut following the skin incision, and the 2 flaps kept of the same dimensions throughout. It is hardly necessary to use any ligatures.

Figure 56 shows on one side the flap drawn aside and on the other side the flap fastened in its permanent position. It shows, too, the shape of the areas resulting from the change of position of the flaps and small strip of vermilion border detached from the upper lip.

The flaps are sutured to each other in the middle line by 2 layers of silk sutures, the first attaching the skin and muscular layer, the second the mucous membrane. The stitches, as shown in Figure 57, are then inserted.

Fig. 56.—Morestin's Operation Showing Flaps Drawn Down.

When the upper borders of the flaps, which now form the free border of the lower lip, appear to be too thick, which sometimes happens, especially near the angles of the mouth, it will be necessary to thin them down by excising sufficient fat, muscular fiber, and gland tissue to accomplish the thinning. The two strips of vermilion border already described are fastened to the flap with very fine silk. Special, fine silk sutures must be used, both on the skin and on the mucous membrane. Morestin finds the result of this operation usually favorable. The upper lip, which is often stiff at first, rapidly becomes supple. The lower lip will sometimes continue to be a little heavy and rigid. The defect is only temporary, and at the end of a certain length of time will usually adjust itself. If, however, the lip continues too thick, he corrects this by some retouches done under local anesthesia. Usually this is not necessary. The mouth is symmetrical, the angles keep their mobility, and the 2 lips approximate each other perfectly, and also there is no dribbling of saliva as frequently happens in other types of cheiloplasty.

**Morestin's Operation for Very Extensive Loss of Substance of the Two Lips and part of the Cheek.**—Half of the upper lip, nearly all of the lower lip, a large part of the right cheek, and nearly all the coverings of the chin have been removed (Fig. 58). To close this defect, the opposite cheek can be made use of, if this is soft, and especially if the patient is old and has flabby tissues. The cheek is transformed into a huge flap, of which the anterior part must be pulled to the opposite side as far as the posterior limits of the missing area.

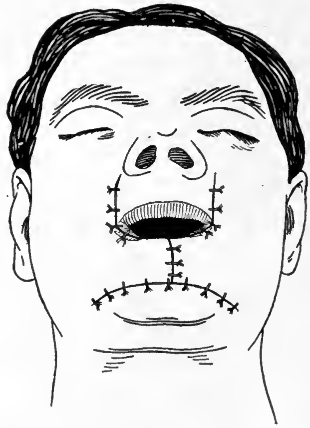


Fig. 57.—Morestin's Operation. Sutures in place.

Two long horizontal incisions parallel to each other are made, the first from the upper part of the cheek, grazing the malar bone, the other in the neighborhood of the inferior maxilla. These cuts are made down to the masseter muscle. The mucous membrane is cut at the bottom of the buco-alveolar junction for its whole length. Everything that interferes with the free movement of this flap must be cut. Even the posterior attachments of the buccinator muscles may be vertically cut without hesitation.

Because of these very extensive freeings, the enormous flap is susceptible of considerable elongation and can be made to pass from one side of the face to

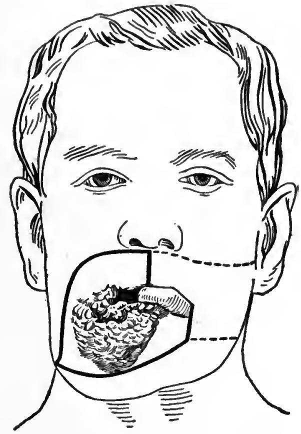


Fig. 58.—Morestin's Operation for Extensive Loss of Substance of the Lips and Cheek.

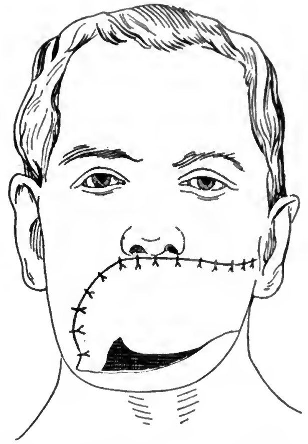


Fig. 59.—Morestin's Operation. Showing flap drawn over to opposite side.

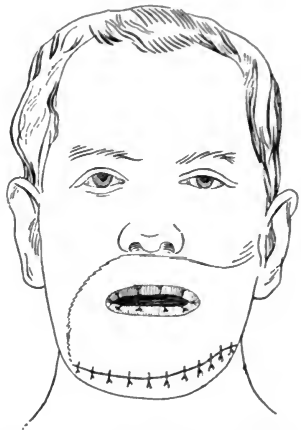


Fig. 60.—Morestin's Operation Showing Flap Suture and New Mouth Formed.

the other. It forms a sort of a veil (opercule) falling in front of the teeth down to the chin (Fig. 59). The inferior border is not sutured until later, in order to make provision for nourishment. The suturing is finished, and after a few days a window made which becomes, after the suture of the mucous membrane to the skin, a sort of new mouth (Fig. 60). The case chosen here is a very extreme one, but more often a much slighter deformity is presented.

**Dowd's Operation** (Fig. 61).—This operation (3) gives excellent results and is recommended as the best procedure if the whole operation is to be performed at one time. As the lymph glands and submaxillary glands are so intimately connected, it is always best to remove the submaxillary gland. No bad results have yet been reported by so doing. The incisions GH and CD should be made first and the glands removed before the growth is removed and before the incisions involving the mucous membrane are made, taking care to leave a considerable amount of tissue attached to the prominence of the chin. An excellent exposure of the submental and submaxillary spaces is obtained. If the glandular involvement is extensive, the dissection will have to extend laterally as far as the great vessels. The ligation of the facial vein is often necessary. If possible, the facial arteries

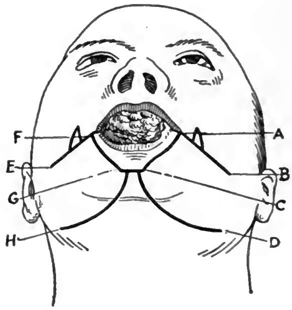



Fig. 61.—Dowd's Operation.

should be preserved, although it is reported by Dowd that their ligation does not seem to interfere with the vitality of the lip flaps. After the glands are removed and the veins ligated, the incisions AC and GF are made and the growth removed. A space of at least ½ or, better, ¾ in. of healthy tissue must exist between the edge of the growth and the incision. If the growth is near the angle of the mouth, it will be necessary to remove some of the tissue of the cheek to accomplish this, in which case incisions AB and FE are then made, of a length sufficient to allow the easy apposition of the surfaces AC and FG.

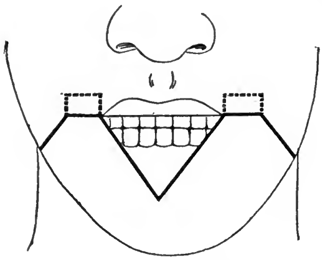


Fig. 62.—Jaesche's Operation.

**Jaesche's Modification of Dieffenbach's Method** (Fig. 62).—Two horizontal enlarging incisions are made at the buccal angles of the mouth, to which are added 2 longitudinal incisions at an outward angle. The enlarging incisions at the buccal angles are made to extend no deeper than the mucosa, which is dissected off a little higher up, corresponding to the dotted lines in Figure 62. This flap of mucosa at the buccal angles is utilized on each side for supplying the vermilion border. A flap at only one side may suffice to fill the gap if the defect is small.

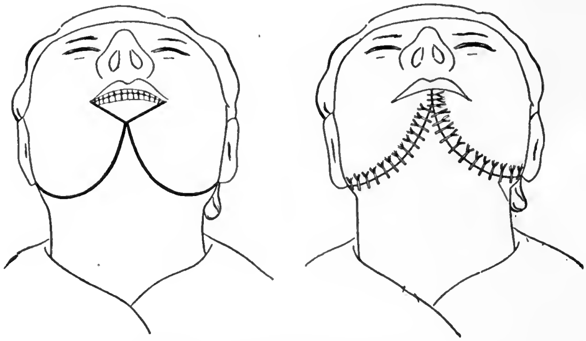


Fig. 63.—Syme's Operation.

**Syme's Method** (Fig. 63).—From the apex of the triangle, make 2 curved incisions of sufficient length to allow the sides of the triangle to assume a horizontal position without tension, when the flaps are lifted. The incisions, if made to follow the inferior border of the lower jaw, will leave little, if any, scar.

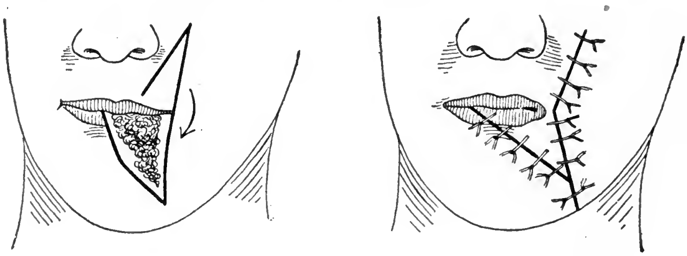


Fig. 64.—Estlander's Operation.

**Estlander's Method** (Fig. 64).—Lateral triangular partial defects of the lower lip are very efficiently closed by a flap cut from the upper lip, which is nourished from a bridge of tissue left at the lip margins. This flap is lifted and turned into the defect of the lower lip and the wound closed by sutures. By taking an analogous flap from the lower lip, the same method can be utilized for cheiloplastics of the upper lip.

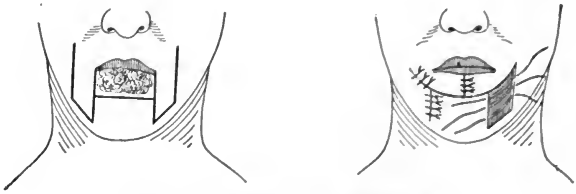


FIG. 65.—SÉDILLOT'S OPERATION.

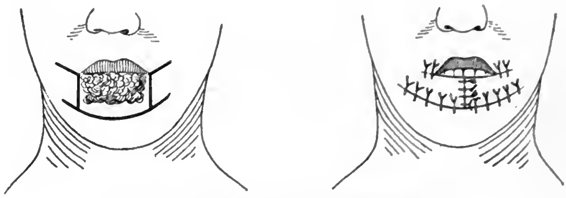


FIG. 66.—MALGAIGNE'S OPERATION.

**Sédillot's Method** (Fig. 65).—Two inferior flaps are formed from the lateral region of the cheek and chin, by cutting in a straight line from the buccal angles downward, through the entire thickness of the soft parts. Two secondary parallel incisions with connecting incisions are then made. The base of the flap or its connecting bridge is situated at the angle of the mouth. This method is equally applicable for cheiloplastics of the upper lip.

**Malgaigne Method.**—See Figure 66.

## PLASTIC SURGERY OF THE UPPER LIP

Aside from harelip operations, plastic procedures upon the upper lip are much more rarely required than on the lower lip. Small defects of the upper lip can be readily repaired by freshening the edges and drawing together the skin and deeper parts by properly applied sutures, as shown in Figure 67.

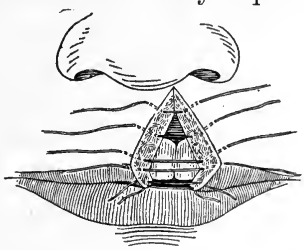


FIG. 67.—METHOD OF REPAIR OF SMALL DEFECT IN UPPER LIP BY FRESHENING THE EDGES AND SUTURE.

Large defects may be repaired by the double curved incisions of Dieffenbach (Fig. 68). This operation consists of 2 incisions on each side. The first begins at the apex of the defect and follows completely around the ala of the nose. At the upper end of this incision the other one begins and in an inverse curve reaches toward the cheek as far as is necessary to allow the flap to fill the defect.

For the complete restoration of the upper lip, the method of Sédillot by vertical flaps (Fig. 69) or that of Szymanowski by lateral flaps (Fig. 70) is recommended.

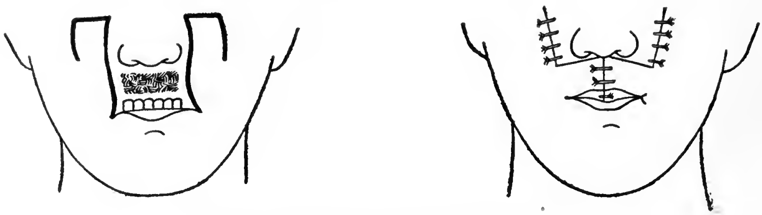


Fig. 68.—Dieffenbach's Operation.

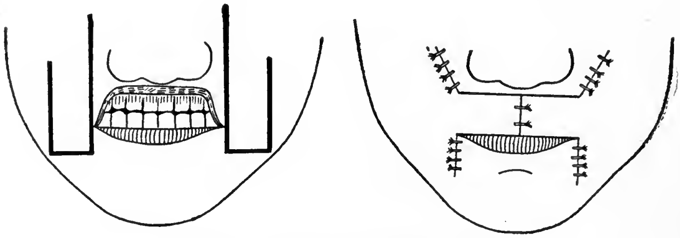


Fig. 69.—Sédillot's Operation.

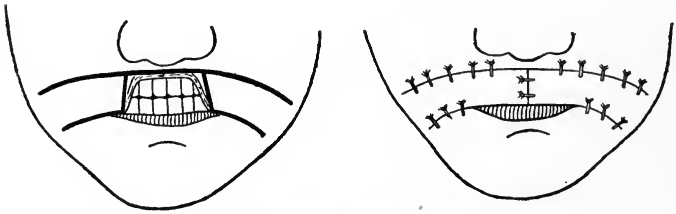


Fig. 70.—Szymanowski's Operation.

The technic of these operations and the formation of the vermilion border on the new lip are the same as described under Plastic Surgery of the Lower Lip.

## PLASTIC SURGERY OF THE EAR: OTOPLASTY

### MALFORMATIONS OF THE LOBULE

These malformations usually consist of an enlargement of the lobule in all directions, and are best corrected by Joseph's method (Fig. 71). The line of the incisions should be carefully marked out on the skin before beginning the operation, especially if both ears are deformed. When this is not done it is very difficult to get a symmetrical result.

The bleeding is profuse, but easily controlled by the sutures. No ligatures need be used.

One of the advantages of Joseph's operation over the one usually practiced —the simple resection of a wedge-shaped piece from the lower edge of the

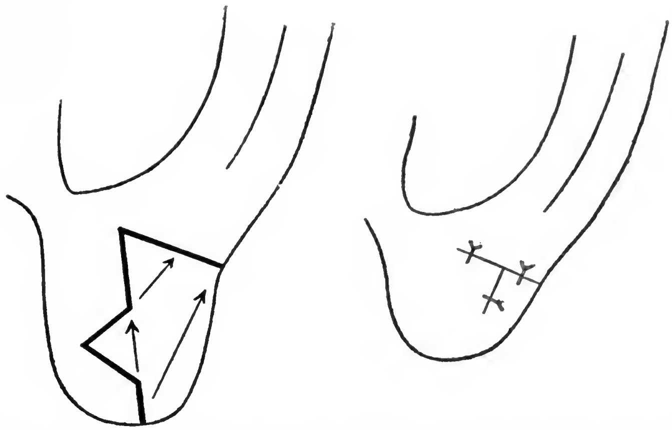


Fig. 71.—Joseph's Method for Diminishing Size of Enlarged Lobule.

lobule—lies in the prevention of the postoperative notch formed on the edge of the ear by the contraction of a linear scar.

### MALFORMATIONS OF THE AURICLE

**Abnormal Enlargement of the Ear (Macrotia).**—This deformity is satisfactorily treated by either the Kolle method (Fig. 72) or the Parkhill method (Fig. 73), combined with the Joseph method for the lobule, if necessary.

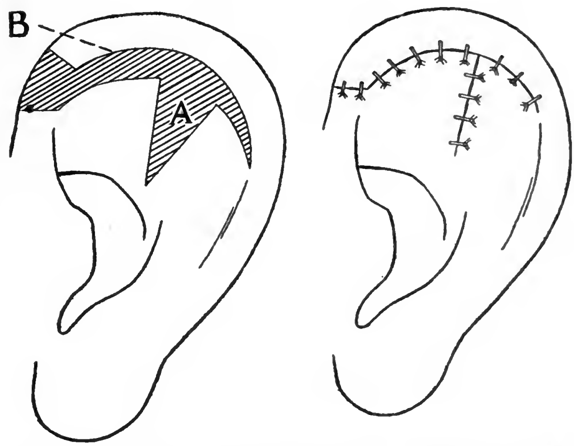



Fig. 72.—Kolle's Operation for Abnormal Enlargement of the Auricle.

Care must be taken to plan the incisions carefully before beginning the operation, and also to make clean, neat cuts with a very sharp scalpel in order that the resulting scar shall be as inconspicuous as possible.

**Abnormally Small Ears or Absence of the Ear (Microtia).**—This is a rare condition and has not yet been satisfactorily treated by plastic surgery. Me-

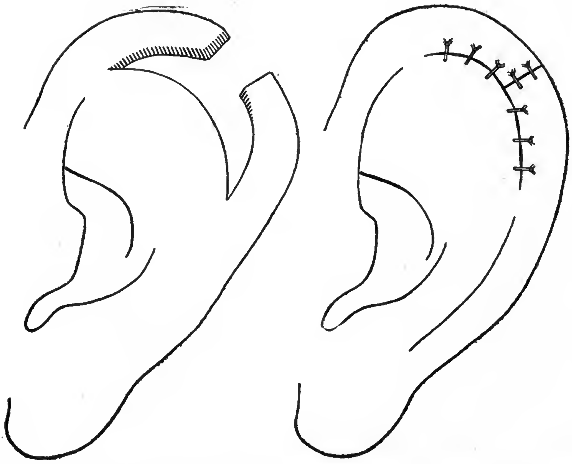


Fig. 73.—Parkhill's Operation for Abnormal Enlargement of the Auricle.

chanical prothesis, that is to say, the wearing of an artificial ear, which has been well modeled and colored, attached to the head by means of spectacles or clamps, is cosmetically much better than any result obtained by plastic surgery.

## MALPOSITION OF THE AURICLE

This condition calls for surgical treatment when an excessively wide angle exists between the auricle and the side of the head, with the ear standing out and the upper portion of the auricle usually curving forward. In early childhood when this condition is seen to be developing, it may often be arrested and permanently corrected by the application of a firm bandage or cap over the ears, which must be worn continuously, however, and not only at night, as is usually done. If the condition shows no improvement as the result of this treatment, the removal of an elliptical area of the skin over the soft and pliable cartilage at the back of the ear will draw the ear into a good position, and will be all that is necessary in the case of young children. (Fig. 74.)

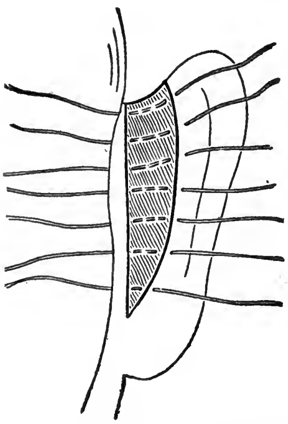


Fig. 74.—Monk's Operation for Abnormal Enlargement of the Auricle.

**Kolle's Method** (Fig. 75).—This method (11) the writer recommends for adults. It is simple and gives excellent results.

Kolle writes:

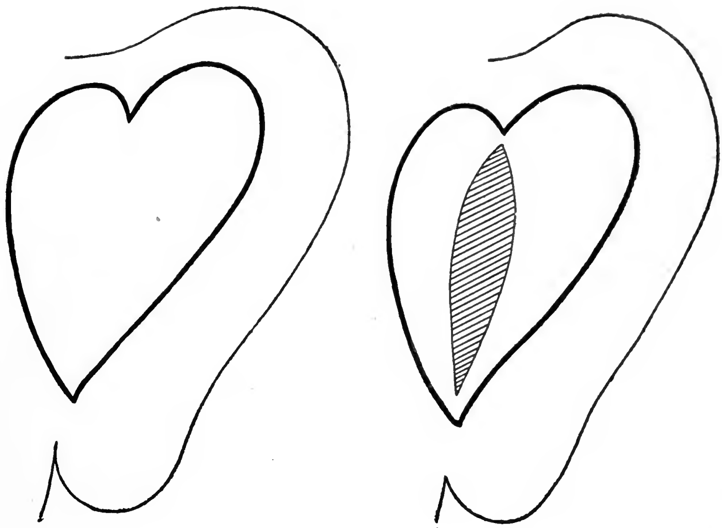
"An incision is made along the whole of the back of the ear as far down as the sulcus, where the retro-aural integument joins that of the neck.

"The incision should involve the skin only, and vary from three-fourths to one-half an inch from the outer border.

"At once, the blood will ooze from the line of incision. The operator now presses the ear backward on the bare skin of the head, leaving an imprint of the bleeding line on the skin there.

"A second incision is made along this line, giving the total outlining incision a heart-shaped form, as shown in Figure 75.

"The skin within this area is now dissected up quickly. . . . The wound



FIGS. 75–76.—KOLLE'S OPERATION FOR MALPOSITION OF AURICLE. Shaded area shows amount of cartilage to be removed.

should be large enough to over-correct the fault, or the ear springs out more or less when healed.

"Sutures are now introduced. When necessary, one or two catgut sutures are taken through the concha—not going through the anterior skin, however—and the deeper tissue back of the ear and tied. These hold the cartilage in place."

Before the skin is sutured, if the ear has the least tendency to spring back into its former position, a piece of cartilage must be removed, elliptical in shape, as shown in Figure 76. In doing this, care must be taken not to buttonhole the skin on the anterior side of the ear.

Interrupted sutures of very fine chromic gut are then passed, approximating the cut edges of the cartilage, after which the skin edges are closed by fine silk or chromic gut stitches. As the result of removing the section of cartilage, a ridge of skin will be formed on the front of the ear. This will often contract and disappear in the course of time, but in case it should persist, it is a very simple matter to excise this small defect by a secondary operation.

## PLASTIC SURGERY OF THE CHEEKS: MELOPLASTY

For the replacement of a loss of substance of the cheek, a large number of plastic procedures have been suggested, from simple approximation with suture of the very flexible wound margins in minor injuries, to the formation of pedunculated flaps from the frontal, temporal, maxillary, or mental regions for the correction of more serious defects. Skin transplantations are sufficient for the closure of superficial defects limited to the external skin.

The replacement of the cheek is a surgical problem of less simplicity than one might imagine, and still awaits an entirely satisfactory solution. The so-called anaplastic Indian or Italian methods, which utilize 2 single flaps or 1 double flap, are both complicated and unreliable. Numerous procedures have been recommended which are not free from disadvantages, such as the insufficient nutrition and low vitality of a flap which is nourished only by means of a connective tissue pedicle. This is also true of the methods of Gersuny, Kraske, and Thiersch, which, however, have the advantage of causing only slight surgical injuries. Imperfect nutrition of a flap exposed to infectious processes through the inevitable presence of bacteria leads almost invariably to negative results, and for this reason failures have been known to follow the methods of Czerny, Israel, Hahn, and Ombrédanne, whose operations, moreover, yield rather imperfect cosmetic results because of the unnecessarily large and hypertrophic flaps. Other procedures, like those of Bardenheuer, Schimmelbusch, Monod, and Vanvert, while more reliable, involve very considerable surgical damage and leave a large amount of scar tissue about the face and neck. It is an additional drawback that in several of these methods hairy skin flaps are made to take the place of mucous membranes.

FIG. 77.—ISRAEL'S OPERATION (1). Position and shape of flap.

Careful attention must be given in all cases of meloplastics to the avoidance of distortion of the lower eyelid and the upper lip.

The operator has at his disposal a variety of plastic procedures which utilize the external skin for the covering of extensive penetrating defects of the cheek for the replacement of the mucosa, as well as of the outer skin covering.

**Israel's Operation.**—A relatively simple and convenient method of meloplastics is that recommended by Israel (10). In the first step of the operation the mucosa is replaced by a very long pedunculated flap, which is taken from the neck, reaching from the front of the ear in the maxillary angle as far down as the clavicle, if necessary (Fig. 77). This is turned with the skin surface inward and allowed to heal in the gap (Fig. 78). The neck wound is drawn together as shown.

In the second step of the operation, which takes place at the end of from 14 to 17 days, the pedicle is cut through and turned on itself over the raw surface of the healed-in flap with the skin side now out, where, after thoroughly scraping off the granulations which have formed on the exposed raw surface, it is sutured in place with drainage (Fig. 79) and forms the new cutaneous surface of the cheek.

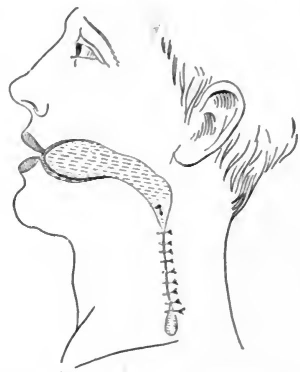


Fig. 78.—Israel's Operation (2). Flap turned and sutured into gap.

One of the chief advantages of Israel's method of meloplastics lies in the simplified after-treatment; the patient is not obliged to hold his head in a fixed or inconvenient position for any length of time, as is inevitable in the methods of Hahn and Hacker, where the flap is formed from the skin of the chest.

**Hahn's Operation.**—In Hahn's procedure, the flap is formed from the skin of the chest, the base beginning at the clavicle, and its end lying near the nipple. The nutrition of the flap is the weak point in this method.

**Hacker's Operation.**—The chief advantage of the procedure used by Hacker lies in the favorable blood supply of the flap formed as he recommends (7). A flap is taken from the skin of the chest, having its pedicle and base at the sternal margin and running parallel with the ribs toward the shoulder (Fig. 81). This method is specially indicated in cases requiring secondary plastic operations, owing either to the partial failure of the first meloplastic or to the necessity for another excision of tissues in recurrent malignant growths of the surroundings. The position of the head is necessarily awkward for the first fortnight, but it is extremely important to avoid displacement or traction upon the flap because of the danger of marginal necrosis. The fixation of the head may be accomplished in several ways, which may be left to the ingenuity of the operator. Hacker cautions against overconstriction of the thorax by the fixation bandages, especially in aged patients.

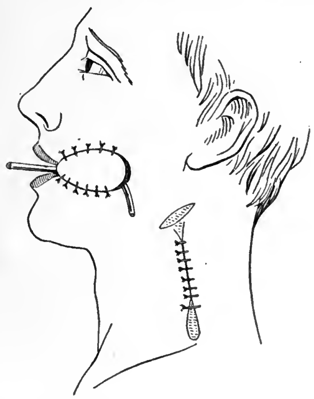


Fig. 79.—Israel's Operation (3). Second stage. Pedicle cut and flap turned on itself and sutured with drainage.

**Lexer's Method.**—The use of a temporofrontal flap is given the preference by Lexer (16). For the substitution of the beard, a strip of the hairy scalp is included in the portion of the flap which comes to lie on the outside of the cheek.

**Lerda's Method.**—Lerda's method is a new procedure for the substitution of the cheeks, and has been recently published by him (15). It offers the following advantages: (1) It is practically devoid of danger. (2) It can be performed in 2 or 3 stages, under simple local anesthesia. (3) The flaps are highly vascularized and, therefore, extremely viable. These flaps, by virtue of their constitution, meet all the requirements especially well, as their mucous lining is perfectly adapted to their physiological function, while from the cosmetic point of view the skin of the lip resembles that of the cheek more closely than any other. The extent of the operation is governed by the existing loss of substance. The procedure may be advantageously used in combination with other flaps in those cases where a more extensive operation is necessary.

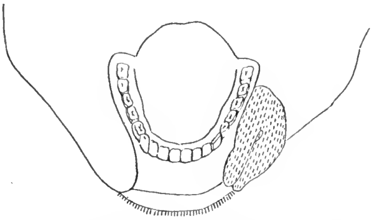


Fig. 80.—Israel's Operation (4). Transverse section of Figure 79.

This new method was successfully employed in a case of cancer of the left cheek of a man 62 years of age and requiring the ablation of the entire cheek. Under infiltration anesthesia (40 gr. novocain, solution 1 : 200), the tumor, which involved the entire cheek, was excised about 2 cm. beyond its margins, thus ablating the entire cheek, from the malar bone to the lower margin of the inferior maxilla, and from the end of the lip to the anterior bundles of the masseter muscles, which were also excised (Fig. 82). In the middle of the posterior margin of the surgical gap the stump of Steno's duct was found and was at once stitched with 2 sutures to the margin of the mucosa of the ablated geniomandibular sinus. At the lower margin of the gap the skin under the submaxillary space was mobilized for the removal of the infiltrated lymph nodules. This completed the first part of the operation, and it was now necessary to replace the extensive loss of substance which exposed the 2 left dental arches beginning with the canines. Two flaps, derived from both lips, were extensively and sufficiently mobilized for the plastic substitution of the defect. To make this possible, 2 horizontal incisions were applied at the level of the duplication of the mucosa of the labioalveolar sinus. The lips were then severed in their entire thickness, the incisions beginning at the operative gap and extending through the right cheek until close to the anterior margin of the right masseter muscle. This served to mobilize a flap with a mucous lining, derived from the lips and the corresponding segment of the right cheek. By means of gentle traction, the free ends of the labial stumps could be placed in contact with the excised mucosa of the geniomandibular sinus and the corresponding skin of the left masseteric region. The labial mucosa was then sutured to the alveolar mucosa with paramucous sutures, and the labial skin was stitched with silk sutures to the skin margins of the gap in the cheek. The mouth opening thus came to lie entirely on the left side, with the right buccal angle at the middle line, the labial margins lying across the left side of the face, showing the left

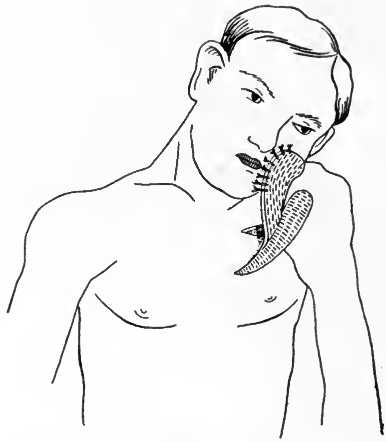


Fig. 81.—Hacker's Operation.

dental arches through the rather drawn and distorted mouth cleft (Figs. 83 and 84). The new left buccal angle came to lie at the anterior margin of the left masseter, at the point where the stump of the ablated Steno's duct had been implanted. The sutures were removed on the eighth day. With the exception of the left buccal angle, where some sutures had given way on account of the flow of saliva, the entire wound had healed by first intention. The second and third step of the operation, for the reëstablishment of the mouth opening in the middle line, were postponed until the wound had completely healed. These 2 simple supplementary operations were performed under local anesthesia at intervals of several days, the first consisting in an incision through the entire thickness of the right cheek, about 3 cm. in length, beginning at the right buccal angle. The mucosa was stitched to the skin, and the red lip margin was reëstablished. At the third operation, the lip margin was freshened, thus removing the vermilion border, and incisions were made freeing the mucosa in both the upper and lower lips, reaching from the left buccal angle to approximately 3 cm. to the left of the middle line. Paramucous and cutaneous sutures were applied, reëstablishing a new cheek through the connection of the 2 labial strips (Fig. 85). Healing proved again most difficult in the region of the left buccal angle, where a small fistula, due to the flow of saliva, persisted for some time. Two months after the first intervention, the patient was free from any pronounced or disfiguring cicatrix. The left cheek was covered with hairy skin, the buccal opening was of normal size and functionated well. The dental arches can be separated by 1½ cm. in the middle line without difficulty. The opening angle of the jaws is increasing daily in consequence of the gradual mechanical dilatation.

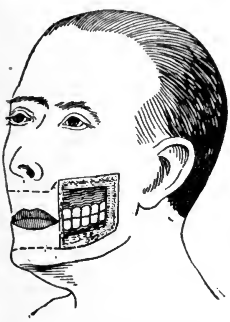


Fig. 82.—Lerda's Operation (1).

Fig. 83.—Lerda's Operation (2).

**Hotchkiss's Operation** (9).—This is an excellent method for an extensive defect, and has given most satisfactory results in the hands of several operators. In the case described by the author (Fig. 86) the defect, bounded by the upper horizontal line and the dotted curved line, was the result of the excision of an extensive infiltrating carcinoma, which necessitated the removal of a part of the inferior maxilla. The operation can be divided into five steps: First, a vertical incision was made from the posterior end of the horizontal line, which formed the inferior boundary of the defect, through the superficial parts, of a length somewhat greater than the total height of the defect. Second, from the inferior end of this last incision a horizontal incision was made of a

Fig. 84.—Lerda's Operation (3).

Fig. 85.—Lerda's Operation (4).

length about equal to the width of the defect. Third, another vertical incision, beginning from the anterior end of this last incision, was made, extending almost down to the clavicle. Fourth, the flap formed by these incisions was raised,

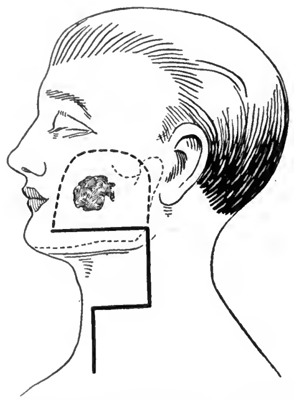


FIG. 86.—HOTCHKISS'S OPERATION (1). Showing amount of defect and incisions.

FIG. 87.—HOTCHKISS'S OPERATION (2). Showing flap lifted and turned outward, giving exposure of deep structure of neck.

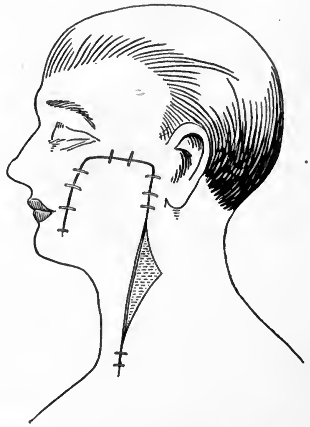


FIG. 88.—HOTCHKISS'S OPERATION (3). Showing flap rotated and sutured into place.

with the platysma muscle, and turned in an outward and anterior direction, exposing the lymphatic and salivary glands of the neck, which were removed (Fig. 87). Fifth, the flap was then rotated upward into the defect and closed with through drainage as shown in Figure 88.

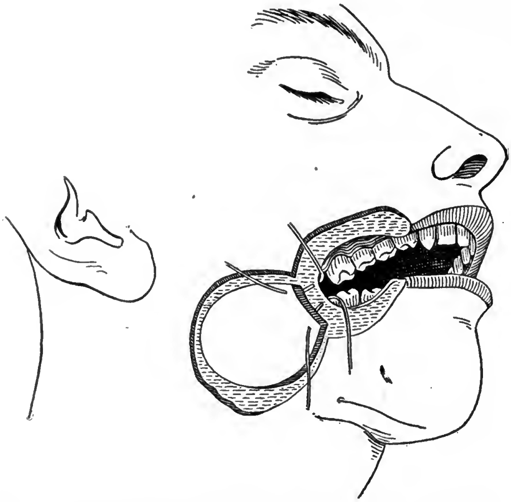


FIG. 89.—KRASKE-GERSUNY OPERATION (1). Showing edges of defect fastener and incision for formation of flap made.

**Gersuny's Modification of Kraske's Method.**—This method has given excellent results and is to be recommended. The failures which have occurred have been due to interference with the nutrition of the flap, either because the pedicle was too small or because the blood supply was shut off when the flap was turned back upon itself.

The first step, after having freshened the edges of the defect, is to outline, on the lower part of the cheek of the same side, an area slightly larger than the defect to be filled (Fig. 89). Second, the skin and subcutaneous tissue are incised around the projected flap down to the muscle. The flap is then lifted from the subjacent tissues, leaving, however, a bridge of tissue of the anterior upper edge of the flap to serve as a hinge.

Third, the flap is turned in an upward and outward direction, hinging on the bridge of tissue and placed in the gap, the skin taking the place of the missing mucous membrane (Fig. 90).

Fourth, the flap is sutured into place, inserting first the sutures shown in

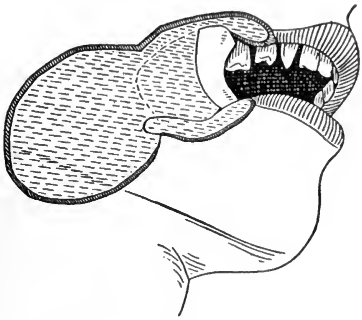


Fig. 90.—Kraske-Gersuny Operation (2). Showing flap turned into the defect by hinging at the upper and anterior end.

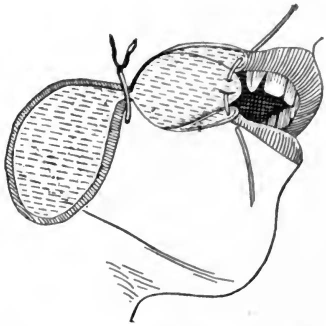


Fig. 91.—Kraske-Gersuny Operation (3). Showing flap in position and first suture inserted.

Figure 91. The skin is closed over the raw surface as much as possible, and the wound is drained with rubber tissue.

**Esmarch-Koleralzig Operation.**—This operation consists of 2 large flaps (Fig. 92, A) thoroughly freed, which are drawn toward each other and sutured as shown in Figure 92, B.

As no provision has been made in this operation for an epithelium lining

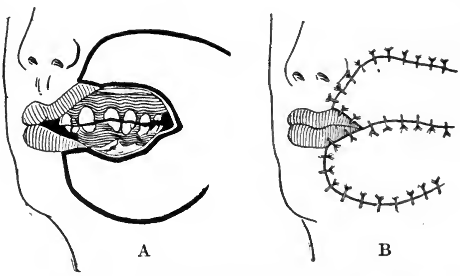



Fig. 92.—Esmarch-Koleralzig Operation.

to the inner side of the flaps, the results of the operation are generally faulty. Much contraction of the scar soon follows, accompanied by deformity of the mouth.

## AUTOPLASTICS OF THE CHEEK REGION

**Gussenbauer's Operation for Cicatricial Maxillary Occlusion** (22).—This procedure consists in the division of the cheek and the implantation of double flaps into the defect, and is only feasible when a sufficient amount of healthy skin is available. In the case of the deformity of a 7-year-old boy, a flap measuring 4 cm. anteriorly and 6 cm. posteriorly was formed from the skin of each cheek. These flaps were dissected free as far as the masseteric margin, where they retained their pedicles. The subcutaneous soft parts of the cheek and the cicatrices of the old wounds (the results of ulcerative stomatitis) were likewise divided transversely as far as the masseteric margin. On each side the dissected skin flap was doubled over into this defect in such a way that its anterior wound margin was united by suture with the preserved mucosa behind the masseter, with its external epithelial surface turned toward the buccal cavity. At the end of 4 weeks the healed skin flap was cut through on each side at its pedicle and the posterior portion of the flap was detached toward the front and turned to the persisting anterior portion of the defect, so that the epithelial side of the entire flap now came to lie toward the buccal cavity. In stitching in the flap, the margin of the cheek cleft at the upper and lower jaw was utilized as a substitute for the gums. Finally, the external defect in the cheek was covered by a rectangular skin flap from the region of the lower submaxillary margin having its base above and behind. The result of the plastic operation was excellent.

Plastic operations on the face are sometimes necessary for the correction of disfigurements due to injury of the facial nerve received at the time of radical operations for middle ear disease. The cosmetic results of anastomosis between the facial nerve and the hypoglossal or the accessory nerve are unreliable and imperfect. The patient may gain control over a few of the muscle groups of the face, but not without associated movements of the shoulder or the tongue. These failures led Lexer to evolve his method of muscle plastics (19).

The procedure permits the partial substitution of the paralyzed areas by muscle plastics: areas taken from parts which are not supplied by the facial nerve.

Nordmann, as the result of favorable experiences with 3 cases of lagophthalmos and facial paralysis urgently advocates, instead of nerve anastomosis, Lexer's simple method, which is certain to yield positive results (18). In cases of incomplete palpebral closure of the eye on the paralyzed side (lagophthalmos), Nordmann recommends severing a bundle from the temporal muscle and implanting it in the lateral ocular angle. The patient is carefully instructed to practice the contraction of the temporal muscle. Although the palpebral closure may be perfect, a drooping buccal angle may still require attention. To lift the drooping mouth and control the salivary flow, and to enable the patient to hold his food, muscle plastics from the masseter may be employed. An incision is made in the nasolabial fold and part of the masseter is fixed to the buccal angle.

The secondary epidermization of freshened pedunculated flaps, which have been turned into the buccal cavity for the substitution of cheek defects, was recently investigated by Lefèvre (14) in experimentation upon dogs. The dissemination of small bits of mucous membrane over the raw surfaces, in the sense of the old Reverdin technic, gave excellent results. The epidermization was found to proceed very rapidly and to be favored by the absence of tension in the flap. It was also favored by having had, when the flap was transplanted, a good control of the hemorrhage and accurate approximation by suture of the mucous margins to the wound surface of the flap. The new-formed epithelium proved sufficiently thick and resistant, although the new cheek was less flexible and not contractile.

Chavannez obtained excellent results on the human subject by this procedure.

**Hydrocarbon Protheses.**—The subcutaneous use of paraffin or vaselin, which solidify at the body temperature, was described by Gersuny in 1900. The method consists in warming a given preparation of paraffin so that it can be forced, by means of a suitable syringe, through the lumen of a hypodermic needle into the tissues, where, on cooling, it will solidify and remain permanently without irritation. This method is used only in the cosmetic corrections of deformities on the surface of the body.

The dangers to be guarded against are many: First, infection. Unless the most perfect asepsis is maintained, a marked redness of the skin and irritation of the tissues surrounding the injected mass are apt to result, which may even progress to abscess formation and destruction of tissue by necrosis. Second, necrosis of the tissue due to the pressure of the injected mass on the neighboring blood vessels. Third, embolism, of either air or paraffin, which is usually due to the accidental insertion of the point of the injection needle into a vein. Fourth, sloughing of the tissues due to the excessive heat of the injected mass. Fifth, over-correction of the deformity by the injection of too much of the mass at one time, which is a serious danger on account of the very great difficulty of removing the solidified paraffin after it has once been injected into the tissues. Kolle (11) gives 4 additional dangers to be avoided: "Secondary infusion of the injected mass. Hyperplasia of the connective tissue following the organization of the injected matter. A yellow appearance and thickening of the skin after organization of the injected mass. The breaking down of tissue and the resulting abscess due to the pressure of the injected mass upon the adjacent tissue after the injection has become organized."

SYRINGES.—A special syringe is made for this purpose, the essential points of which are: First, great strength; second, a screw on the piston, enabling the operator to force a measured quantity of the semi-solid mass slowly out into the tissues; third, the ability to resist the heat of sterilization; fourth, the lumen, large in proportion to the size of the needle.

PARAFFIN.—The paraffin or mass is prepared by mixing together paraffin and white vaselin, usually in the proportion of drams to ounces, and by melting them together over a water bath and thoroughly mixing them with a glass rod. It is most important to know the melting point of the mass. If too low, it will not be sufficiently firm at the body temperature after injection; if too high, there is the danger, already described, from excessive heat. The desired melting point has been found to be between 105° and 110° F., no higher. A simple method, described by Guernsey, of testing the melting point of the resulting mixture is to coat the bulb of a thermometer with some of the mass while in the liquid state. This is allowed to cool, thus forming into a film over the bulb. The thermometer is then placed in a water bath and the temperature of the water slowly raised until the film is melted from the bulb and floats on the surface of the water. The heat of the bath is then slowly reduced. As soon as the floating particles of the mixture begin to become opaque, the temperature of the bath is taken, which is the melting point of the mixture.

By using a mixture of such a low melting point the mass can be forced into the tissues in a semi-solid form, thus avoiding the dangers of excessive heat and fluid injection. This is the so-called method of "cold injection" and has many advantages and fewer dangers than the use of a mass with a higher melting point and a more liquid form.

TECHNIC.—In using this method of protheses, the following technical points must be carefully observed: First, thorough cleanliness of all instruments, of the paraffin, and of the patient's and doctor's skin. Second, thorough sterilization of the mass by heat shortly before its use. The mass should be poured into the injecting syringe while still in a very fluid condition and then allowed to solidify slowly. If this is not done, it is almost impossible to avoid the introduction of air bubbles beneath the patient's skin when the mass is forced out of the syringe.

Third, no anesthetic need be used. The only discomfort to the patient is the slight pain caused by the prick of the needle. The use of cocain has a tendency to infiltrate the parts and distort the contours, thus making the moulding of the injected mass more difficult and more uncertain than necessary. The use of the ethyl chlorid spray tends to cool the tissues to such an extent that the solidification of the injected mass is dangerously hastened.

Fourth, the mass must be injected slowly and in small quantities and moulded into the desired shape at once. Great care must be taken never to inject too much, for it is always possible to add to the mass by a second operation. Always under-correct the deformity.

Fifth, care must be taken that the mass is not emerging from the point of the needle when it is withdrawn from the tissues. This may be avoided either by withdrawing the piston slightly or by waiting long enough after the injecting pressure has ceased to be sure that none is flowing.

Sixth, when the area to be injected is dense or covered by thick skin, firmly bound down, subcutaneous freeing incisions should be made (under novocain) with a fine-bladed tenotomy knife. If this has to be done, it is safer to defer the injection for 3 or 4 days.

AFTER-TREATMENT.—The after-treatment consists in a simple collodion dressing over the puncture wound. If the area injected is painful, the application of cold during the 24 hours following gives much relief.

## PLASTIC SURGERY OF THE EYELIDS: BLEPHAROPLASTY

For plastic surgery of the eyelids, two important principles must be observed. First, the necessity of determining at once whether the outer skin alone is destroyed, or whether the conjunctiva and the tarsus are also involved. Second, when anything more than the outer skin is destroyed, a flap with a suitable lining must be provided.

Operations on the lid are delicate and present many difficulties. A simple skin flap is inadequate for a condition where more than the skin is destroyed. Without a lining, a flap gives distressing results; it adheres to the eyeball which it very imperfectly covers, and its edge becomes inverted and very irritating because of the fine hairs and the scar tissue. The extreme sensitiveness of the conjunctiva of the eyeball makes it difficult to find a suitable lining for the flap to substitute the missing conjunctiva, and much trouble has been taken and many experiments made to find a proper material. The mucous membrane and conjunctiva of animals have been tried, as well as small pieces of human prepuce, and mucous membrane from the lips, vagina, and rectum (17).

### ECTROPION

Ectropion or eversion of the lids may be due: First, to cicatricial formation following burns, the removal of growths, or other injuries of the skin; second, to some nerve injury resulting in the paralysis of the orbicular muscles; third, to some abnormal condition of the mucous membrane of the eye itself, such as chronic inflammatory conditions or new growths. The first type is the one that surgery is most commonly called upon to correct and the following operation is recommended:

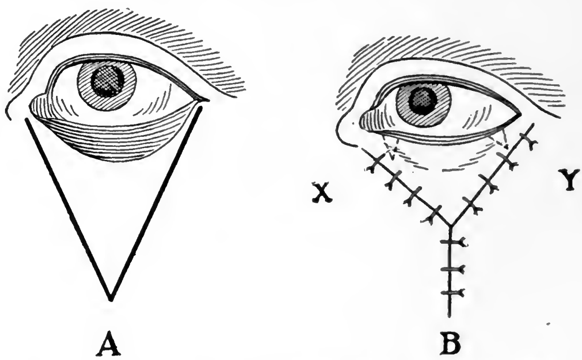



Fig. 93.—Dieffenbach's Method for Ectropion of Lower Lid.

**Operation for Ectropion of Lower Lid: Dieffenbach's Method.**—A V-shaped incision is made through the skin and subcutaneous tissue as shown in Figure 93A. The flap, with all the subcutaneous tissue possible, is dissected from the muscle layer, as far up as the tarsal border, relieving all tension upon it. It is then sutured as shown in Figure 93B. If the eversion has been extreme, it will be found after healing is completed that the amount of tissue in the lower lid is excessive, making the lower lid considerably wider than the upper lid, which is especially marked when the eye is closed. To remedy this defect, 1 or 2 small inverted triangles may be removed from each side of the lid, thus taking up the slack (Fig. 93B, XY).

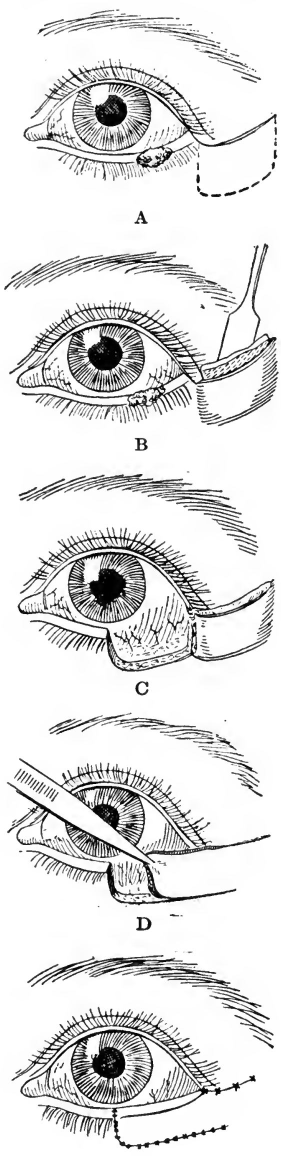


Fig. 94.—Gibson's Operation by a Pregrafted Flap on Restoration of Lower Lid. (Annals of Surgery.)

## RESTORATION OF THE EYELID

There are three general methods of restoring the eyelid to be considered:

1. The gliding flap method, which includes the methods of Gibson, Dieffenbach, and Hasner.

2. The pedunculated flap method, illustrated by the v. Langenbeck operation.

3. The free graft implantation or Wolf method.

**1. The Gliding Flap Method of Restoration of the Lower Lid.**—GIBSON'S OPERATION BY A PREGRAFTED FLAP.—This operation (6) is divided into 2 stages, separated by an interval of about 10 days. At the first stage the flap is prepared; at the second, the deformity is removed and replaced by the flap.

At the first operation an incision is made through the whole thickness of the skin from the external canthus in an outward and slightly upward direction. The length of this incision is determined by the amount of eyelid it is proposed to remove. (For an operation involving the external half of the lower lid, make an incision 1¾ in. long.) By dissecting downward from this incision and lifting the skin from the deeper parts, a pouch is formed, having the outline of the proposed flap (Fig. 94A). Into this pouch is slipped a skin graft, previously prepared, the raw surface of which is turned anteriorly (Fig. 94B). This graft is cut sufficiently large to project slightly from the pocket, and is turned outward and downward, covering the inferior raw edge of the original incision with epithelium. A simple dressing is applied and the graft allowed to heal in place, which takes place in about 10 days.

At the second operation the growth on the eyelid is first removed by a quadrilateral incision (Fig. 94C). The cut, as shown in Figure 94D, is then made of the same length and parallel to the original incision, thus forming a flap which can now, by gentle traction, be made to slide over toward the middle line, where it is sutured as shown in Figure 94E.

There are two great advantages to this method: The first being that an epithelial lining is given to the posterior surface of the flap, thus avoiding most of the disadvantages of other methods; and, second, that there is slight, if any, postoperative contraction of the flap, which obviates the necessity of planning a flap larger than the defect to be filled.

DIEFFENBACH'S METHOD (Fig. 95).—This method provides no lining for the flap. The area to be filled is represented by the triangle A, B, and C. An incision is made starting from the outer canthus in an outward and slightly upward direction, CD, in length somewhat greater than the width of the gap to be filled between A and C. Another incision is made parallel to the first, from the apex of the triangle BE. The flap so outlined, including the skin and subcutaneous tissue, is dissected from the subjacent muscle and drawn toward the middle line where it is sutured as shown in Figure 95B.

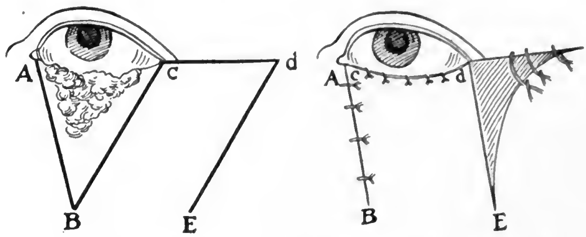



FIG. 95.—DIEFFENBACH'S METHOD OF RESTORATION OF LOWER LID.

HASNER'S METHOD.—Hasner's method is especially valuable when the defect is so large as to have involved the outer canthus and a part of both lids. Line ABC (Fig. 96) defines the limit of the defect, A. Curved incisions CD and BE are made, and the flap formed by incisions DC and CB is made

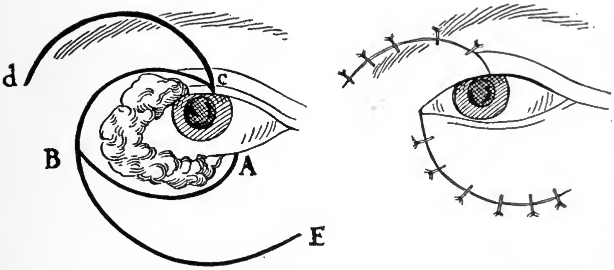



FIG. 96.—HASNER'S METHOD OF RESTORATION OF CANTHUS.

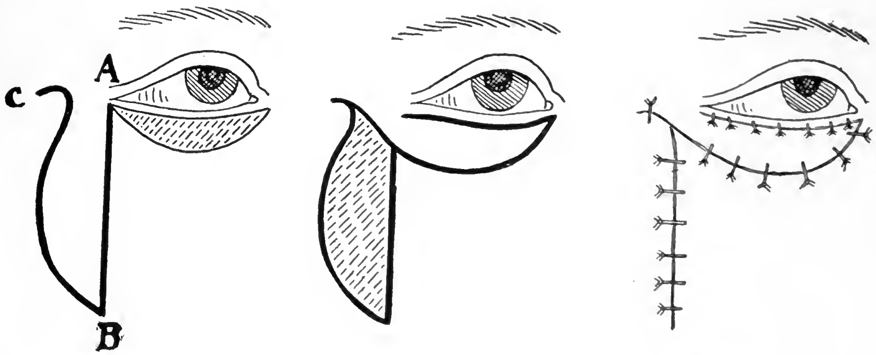



FIG. 97.—V. LANGENBECK'S METHOD OF RESTORATION OF LOWER LID.

outward and slightly downward. Gliding the lower flap formed by incisions AB and BE inward and slightly upward, it is possible to restore the canthus as shown in Figure 96B.

2. **The Pedunculated Flap Method.**—V. LANGENBECK'S METHOD (Fig. 97).—The area to be replaced is represented by the dotted lines. A vertical incision AB is made about 1/4 in. longer than area to be filled in. A curved incision BC is then made and the flap is lifted and rotated upward and inward, on the pedicle of tissue existing between AC, until it assumes the position shown in Figure B. It is then sutured as shown in Figure C.

3. **The Free Graft Implantation or Wolf Method.**—To make it possible to use this method, there must be a sufficient amount of lid left to act as a bed for the graft, and this bed must be covered by healthy granulation. The shape and size of the defect are carefully noted, and from the skin on the inner surface of the arm a piece of skin is removed of a similar shape and about a third larger in size. This is placed over the defect and is carefully sutured in place. To remove all the subcutaneous fat from the graft seems to increase the chances of its taking.

The strictest asepsis is most essential to success in this procedure.

## SKIN-GRAFTING

Alexander Bryan Johnson

**Instruments.**—The instruments required in skin-grafting are:

1. A large, heavy, flat razor with a broad blade, or a special knife with a fixed handle in line with the blade and of such proportions as the surgeon may elect. The razor or knife must have a keen cutting edge to make thin grafts of uniform thickness.
2. A scalpel.
3. 2 or more silver probes 8 in. long.
4. McBurney's hooks.
5. Straight scissors.
6. A sharp curet.
7. Sterile rubber tissue in strips 1 to 1 1/2 in. wide and 6 to 8 in. long.
8. Sterile salt solution in quantity.

**Preparation of Surface from Which Grafts Are to Be Cut.**—For reasons not entirely clear, grafts taken from another individual, even a brother or sister, rarely do well, and never as well as those taken from the patient himself. It must be from some cause similar to that which produces hemolysis when blood from 2 individuals is mixed.

The skin of the anterior, outer and inner surfaces of the thighs is commonly used for cutting the grafts. I have never tried the iodin preparation of the skin for grafting purposes.

Usually the skin is prepared the day before by careful scrubbing with green soap and water, shaving and thorough douching with sterile salt solution. The limb is then enveloped in a dry sterile dressing which is removed before operation.

**Preparation of Surface to Be Grafted.**—The raw surface to which the grafts are to be applied may be a recent wound—as in grafting after amputation of the breast for cancer—to which, if desired, the grafts may be applied at once, a granulating raw surface, soft parts, or bone.

The cleaner and more healthy the granulating surface the better and the greater the likelihood that grafts will unite with the surface beneath and live. Grafts may be applied directly to the raw surface, or the granulations may be removed by gentle curetting. Bleeding must be stopped by firm pressure with gauze pads before the grafts are applied.

**Technic.**—The patient, under a general anesthetic, is so placed upon the operating table as to expose the surface to be grafted and the thigh from which the grafts are to be cut. Antiseptics are not used. Soap and water followed by liberal douching with salt solution suffice for both raw surface and skin.

The wound, if fresh or if curetted, must be free from blood, as a clot beneath a graft will prevent its union with the raw surface.

The first graft is cut from the upper part of the front of the thigh. The skin is lightly scored with the knife in 2 vertical parallel lines, separated by an interval equal to the width of the hooks and 5 or 6 in. long, this being about the practicable limit of length in graft cutting.

The hooks are then caught firmly into the skin above and below. The upper hook is given to an assistant, while the operator holds the lower in his left hand while he cuts the graft from above downward with his right. During the cutting, the hooks are used to stretch the skin and to raise it a little above its natural level. Thus an elevated ridge is made, bordered by the slight cuts in the skin on either side, which determine the width of the graft. During the cutting, the blade of the razor and the skin are kept wet with salt solution by an assistant who allows it to dribble from wet pads of gauze.

The angle of the razor blade to the skin must be slight. It must be held firmly against the surface and gradually advanced with a sawing motion. When the lower limit of the graft is reached, it may be severed with the razor or with a scissors. The blade and the graft, curled up on it, are then brought over the raw surface to be covered and the graft is slid off the blade with a probe. Two probes are used to spread it evenly. The graft should overlap the skin edge of the wound slightly. Other grafts are then cut until the raw surface is covered. Any blood which may collect beneath the grafts is carefully pressed out with wet pads of gauze, and the whole area is then covered with strips of rubber tissue wet in salt solution, after which a firm dressing of dry sterile gauze is applied.

The dressing may be left in place 5 days or even longer. If the grafting is completely successful, the entire surface may be healed at the end of 10 days and left with a light dressing of boric ointment for a few days more.

The dressing of the area from which the grafts were taken is important. It may be dressed in the same way as the grafted surface or it may be dressed with a covering of sterile silver foil and left exposed to the air under a cradle. I prefer the former method.

Other methods of dressing the grafted surface are (1) exposure to the air under a cradle covered with gauze to keep out flies; (2) covering the grafted area with strips of sterile zinc oxid plaster (Vosburgh).

**Other Methods of Skin-grafting.**—The old method of Reverdin, useful to hasten the healing of raw surfaces, consists in sniping minute bits of cuticle from any sound skin surface and applying them to the surface to be covered with epithelium. Rubber tissue may be used as a protective covering.

A method devised by Dr. John M. Woodbury and used by him and others, with good results, in the Roosevelt Hospital Outpatient Department, where he and I worked together so many years ago that I do not wish to calculate how long, was to use the parings of corns from the patient's feet for the grafting of chronic ulcers of the leg. Many intractable chronic ulcers were completely healed in this way. Careful strapping with diachylon plaster aided the healing process.

The Wolf method of using the entire thickness of the skin as a graft and grafting mucous membrane are sufficiently described in an earlier section of this chapter.

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# OPERATIONS ON THE PERIPHERAL AND CRANIAL NERVES. UNILATERAL LAMINECTOMY

# CHAPTER XIII

## OPERATIONS ON THE PERIPHERAL AND CRANIAL NERVES. UNILATERAL LAMINECTOMY

Alfred S. Taylor

## OPERATIONS ON THE PERIPHERAL NERVES[1]

**Indications.**—Operations on the peripheral nerves are indicated for the relief of pain, spasticity, and paralysis, for the repair of injuries to nerves, and for tumors of nerves.

**Anatomical Considerations.**—A nerve trunk is made up of nerve fibers which are bound together by fine connective tissue, *endoneurium,* into fasciculi. These are in turn bound into larger bundles by *perineurium,* while the entire nerve trunk is inclosed in an outer sheath, a thick, resistant layer of connective tissue known as the *epineurium.* Before nerve fibers will pull apart this layer must yield. Often the nerve fibers may be ruptured by pressure and the sheath remain intact. These various connective-tissue structures carry the vessels and lymphatics of the nerves. As a rule, large nerve trunks run with the main vessels of the extremity. The notable exception is the great sciatic nerve.

An increasingly important field for peripheral nerve surgery is within the spinal canal. Here the motor roots come from the anterolateral aspect of the cord, pass outward, backward, and more or less downward, according to the level in the canal, to the aperture in the dura. The posterior roots come from the posterolateral aspect of the cord and run outward and more or less downward to apertures in the dura, separated by very thin septa from the apertures of the anterior roots. Both the anterior and posterior roots receive extensions from the dura as they pass through it. In the intervertebral foramen lies the ganglion of the posterior root, of which it is the trophic center. Except in the cervical region the nerve makes its exit from the spinal canal through the intervertebral foramen next below the bony arch of the corresponding vertebra; i. e. the seventh dorsal nerve comes out below the arch of the seventh dorsal vertebra. In the cervical region the nerves come out above the corresponding

[1] For the histology, physiology and pathology of nerves the reader is referred to other books making a specialty of these topics.

arch. There is an eighth cervical nerve which comes out beneath the seventh cervical arch.

## OPERATIONS FOR RELIEF OF PAIN

### Pain Due to Traumatism and Inflammation

For pain which is the result of traumatism and inflammation in the extraspinal peripheral nerves, the various medicinal and local physical methods of treatment will usually give relief without resorting to operative work. In certain persistent inflammatory conditions, where such measures have failed to give relief, operation is indicated. Such operation consists in making an incision down to the nerve trunk over that portion of it which has been sensitive to pressure. The nerve trunk is then freed from inflammatory adhesions to surrounding structures, and in case the nerve itself seems to be swollen or too tightly constricted within its epineural sheath, this sheath may be split longitudinally and the contained nerve relieved from pressure. This method is most frequently applied to cases of persistent sciatica. The portion of the nerve which is more often the site of inflammatory adhesions to surrounding structures is just at and above and below its exit from the true pelvis through the sciatic notch.

**Operative Technic.**—The incision is made along the line of the sciatic nerve which is about ⅓ of the distance outward from the ischial tuberosity to the edge of the great trochanter of the corresponding femur. The incision is then centered about where the gluteal fold crosses this ischiotrochanteric line. The incision should be about 10 cm. long through skin, fat, and aponeurosis. The gluteus maximus is pulled upward and the hamstrings inward. The nerve is found under the outer edge of the biceps. The nerve sheath is freed from surrounding adhesions well up into the true pelvis. The nerve may then be stretched by pulling upon both the peripheral and central ends. The pull upon the central end must be made with considerable discretion lest some of the roots be torn from the cord. (See page 536.) If the sheath is much thickened, it may be split longitudinally. In either case the exposed portion of nerve may be surrounded by Cargile membrane and the wound closed without drainage.

A similar procedure is not infrequently applied to the ulnar nerve just back of the inner condyle of the elbow, where the nerve, as a result of traumatism or repeated traumatism, becomes the seat of a chronic productive neuritis.

### Neuralgias

For the relief of severe neuralgias, such as persistent intercostal neuralgia, the severe neuralgic pains of tabetic gastric crises, the intolerable pain sometimes caused by new growths, etc., where medical and local physical therapeutic measures have failed to give relief, posterior root section is the only recourse.

**Posterior Root Section.**—TECHNIC.—In doing posterior root section for the relief of pain, it is necessary first to indicate clearly the nerve roots involved in the production of the pain. It is then desirable to divide at least 2 roots above and 2 roots below the upper and lower limits respectively of the roots definitely involved in the neuralgic disturbance. This is necessary because of the anatomical overlapping of the fields of distribution of the posterior roots.

Having determined which roots are to be divided, one may proceed to do a unilateral laminectomy, as described on page 602, through which the roots on

Fig. 1.—Nerve Hook with Blunt Point.

both sides may be readily divided, or one may choose to do the usual bilateral laminectomy, as described elsewhere. In either case, after the dura has been opened the full length of the incision, the edges of the dura are caught by 2 or more silk sutures on each side, which are used as retractors. This retraction of the dura not only gives a better exposure, with increased light into the dural cavity, but also serves to stop the venous oozing which always occurs from the venous plexus which surrounds the dura externally. One then takes a small blunt nerve hook (Fig. 1) and, starting either above or below, divides the posterior roots systematically, first on one side and then the other. Inasmuch as the posterior and anterior roots lie closely approximated at their exit from the dura, the hook is slipped between them sufficiently near the cord to avoid hooking up the motor root and including it in the division. When the posterior root is raised on the hook, it is advisable to clamp it with a broad, strong clamp for a moment or two, then to release it and cut through the compressed area (Fig. 2) with a slender pair of scissors. In this way the small vessels which often run with the posterior roots are completely crushed and occluded so that there is no leakage of blood into the spinal fluid to render the operative field indistinct. This same procedure is carried out with each of the posterior roots to be divided.

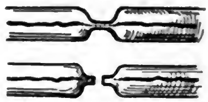


Fig. 2.—Nerve Compressed by Strong Clamp to Prevent Bleeding on Section.

Inasmuch as these nerves are divided between their trophic centers (which are the ganglia of the posterior roots) and the spinal cord, there will be permanent degeneration into the cord and, therefore, permanent loss of function. This, of course, also means permanent relief from pain. Since this upward degeneration is permanent, it is scarcely necessary actually to resect portions of the posterior roots.

After the roots have been divided, such blood as has oozed into the dural canal is carefully removed, the dura is closed tightly, and the remainder of the wound is closed, as indicated in the operation for unilateral laminectomy.

As a rule, these cases will show a reactionary temperature—often as high as 103°—which, in the course of 2 or 3 days, descends to normal and remains there. Frequently there will be considerable pain in the area of the wound, which is probably due to irritation of the divided posterior roots. After about 3 days, when the degenerative process is pretty well advanced in these roots, the pain ceases.

RESULTS.—These cases show very prompt and evident relief from the pain and a rapid improvement in general health. Many cases of this type which are submitted for operation have developed the morphin habit during their long periods of suffering. In these cases the general improvement is not nearly so rapid, and there is the drug habit to struggle against in addition.

If the roots involved are many, the division of all of them may lead to certain sensory and trophic disturbances. The trophic disturbances are usually superficial and frequently show in the form of blebs such as pemphigus. The sensory disturbances take the form of anesthesia. If the nerve roots involved supply the extremities, the division of 3 or 4 complete roots consecutively may lead not only to sensory and trophic disturbances, but may also give rise to ataxia of greater or less degree, according to the number of nerves divided consecutively. Fortunately, the majority of severe neuralgias involving more than 1 or 2 roots, involve the dorsal nerves, in which the sensory, trophic and ataxic disturbances are less troublesome after multiple consecutive section.

One of the chief causes of failure to obtain relief from the pain by posterior root section lies in the division of an insufficient number of posterior roots. There are a certain number of cases which suffer from disturbance of the peripheral nerves in which root section gives no relief. Many neurologists classify these cases as having psychic pain, or memory pains, after the actual causative lesion has disappeared or has been disconnected from the sensorium by posterior root section.

The results vary more or less with the type of case. In the tabetic gastric crises relief is obtained in about 50 per cent. of the published cases. In the other cases where relief has not followed root section the criticism is raised that an insufficient number of posterior roots has been divided. Foerster advocates dividing from the fifth to the twelfth dorsal, inclusive, on both sides. Often, for the first few days, while the process of degeneration is occurring in the proximal stumps of the divided nerves, the patient will feel scarcely any relief from the condition for which the operation was advised, but after the degenerative process is well advanced relief is obtained.

DANGERS.—The chief dangers of the operation are those inherent to a laminectomy, where an accidental slip may cause damage to the cord. The other danger lies in the possibility of infection of the wound, which, of course, occurs but rarely. In 2 of my cases in which infection occurred there was no involvement except in the tissues superficial to the dura, apparently from defective chromic catgut.

## OPERATIONS FOR RELIEF OF SPASTICITY

For the relief of spasticity in muscles (outside of orthopedic measures which may not properly be considered in this section), there are 2 chief methods of procedure which aim at the peripheral nerves and cause a diminution in the overactivity of the spastic muscles. One method works upon the peripheral nerves extraspinally, and the other method upon the posterior roots intraspinally.

### Extraspinal Operations

Two methods of extraspinal operation have been described and the authors report good results.

1. **Alcohol Injection.**—Allison and Schwab (1) advocate the injection of alcohol into the peripheral nerve trunks which run to the groups of spastic muscles. This results in motor paralysis and anesthesia in the distribution of the injected nerve, which last a variable length of time, according to the amount and strength of alcohol injected. During the temporary flaccid paralysis of the previously spastic muscles the extremity is treated by massage, electricity, and the various other methods of physical therapeutics applied to the antagonistic groups so as to improve the muscular balance of the extremity when the temporarily paralyzed muscles have resumed their activity. As power begins to return in the paralyzed muscles, the patient is also educated to control the activities of these muscles. The process may be repeated if necessary.

In general, the operative method consists in determining which groups of muscles are spastic and in identifying the corresponding motor nerve trunks. Under ether anesthesia, incision is then made over the accessible part of the nerve trunk supplying the spastic muscles. This nerve is isolated, elevated on a blunt hook, and injected with alcohol 80 per cent., ½ to 1 c. c. according to the size of the trunk. Immediately spasticity is replaced by flaccid paralysis of the muscles supplied by this nerve. The wound is closed without drainage. No fixation of the extremity is made.

This procedure has been applied to the lower extremities at 4 different sites: the obturator nerve is exposed just below Poupart's ligament in the front of the thigh, and injected for spasticity of the adductor groups; the great sciatic is exposed just below the gluteal fold, and its branches to the hamstring muscles injected; the internal popliteal is exposed in the popliteal space, and the branches to the gastrocnemius and soleus injected; the external popliteal is exposed just below the head of the fibula, at which site branches to either the peronei or the anterior tibial muscles may be isolated and injected. These different exposures have usually been made at different sittings. For more detailed technic reference is made to the publications by the authors above mentioned.

2. **Nerve Resection.**—Another method of extraspinal operation was brought forward by Dr. A. Stoffel (19).

Instead of causing temporary paralysis of muscles by injecting alcohol into the nerves, he resects portions of the motor nerves involved so as to cause a permanent diminution in the activity of the spastic muscles. He has demonstrated that, in nerve trunks, the bundles running to the various groups of muscles practically always maintain a fixed position in the topography of the main nerve trunk. With this knowledge at hand, he is able to expose main nerve trunks and from them to pick out the fasciculi (verified by electric stimulation) which run to the muscles which he wishes to affect by his procedure. The amount of nerve resected depends upon the size of the muscles involved, the degree of spasticity, and the relative activity of the antagonists. The nerve structure is resected in such a way as to maintain a permanent defect. This method requires a very minute knowledge of the topography of the main motor nerve trunks and considerable experience to estimate accurately the amount of nerve to resect in order to give well-balanced muscular activity afterward.

It will readily be seen that both of these methods aim to balance the muscular activities of the extremities by diminishing the amount of power in the spastic muscles. The method of Stoffel would seem to arrive at this result with greater precision and permanence. He and many other writers report most satisfactory results. For minute details of his operative technic reference is made to his publication above cited.

## Intraspinal Operations

Aside from the difficulty of mastering the anatomical and technical operative details of the extraspinal method, it would seem that a method which would relieve the spasticity without impairing the voluntary power of the spastic muscles would be preferable. Such a method was published by Professor Foerster, of Breslau (7, 8, 9).

**Foerster's Operation.**—Foerster conceives that the spasticity is due to hyperactivity of the reflex arc, and that this hyperactivity results from diminished control by the centers of inhibition caused by some lesion of the pyramidal tracts which partially separates the upper cortical centers from the spinal centers. The basis of his method consists in diminishing the reflex activity by causing a break in the reflex arc. The best place to cause this break is intradurally by the division of the posterior nerve roots.

This theory is supported by 2 observations of considerable interest. For a long time it had been observed that in spastic paraplegics, if locomotor ataxia supervened, the spasticity disappeared *pari passu* with the development of the ataxia. It is also known that ataxia begins essentially as a posterior root lesion. The other observation was made many years ago by Fränkel and Beer—that in spastic cases intraspinal injection of a local anesthetic caused relief of spasticity, and with the disappearance of the anesthetic, the spasticity recurred. It seems, therefore, that permanent interference with the function of posterior roots should give release from the spasticity of the corresponding muscles, and this works out fairly satisfactorily in practice.

The method of procedure consists first in determining the relative degree of spasticity in the different groups of muscles, and then in determining which posterior roots are most closely allied with the innervation of the spastic muscles. It must also be determined that the case is one of pure pyramidal tract lesion and that the lesion does not completely obliterate the function of the pyramidal tracts, because, under these circumstances, the relief of spasticity would simply result in flaccid paralysis of the same muscles, and the functional advantage to the patient would be nothing. The presence of symptoms of sensory tract disturbance is considered to contra-indicate this operation, as it is not successful where the sensory difficulty is already present.

The method works out most satisfactorily in the lower extremities. As a rule, the fourth lumbar posterior roots should be left intact, as their division frequently results in undue relaxation of the quadriceps extensor, and locomotion is correspondingly uncertain. Whether the fourth root is related to the quadriceps extensor may be determined at the time of operation by testing the fourth anterior root with the faradic current. If stimulation of the anterior root causes quadriceps extension, the corresponding posterior root should be left intact. Occasionally this muscle is controlled chiefly by the third lumbar root, in which case it should be left, instead of the fourth. The roots involved in spastic paraplegia include from the twelfth dorsal to the second sacral. Nerves below the second sacral should not be divided for fear of damage to the functions of the bladder and rectum. No more than 2 consecutive posterior roots should be completely divided because sensory and trophic disturbances may occur. The surprising fact that 2 or often 3 consecutive roots may be divided without causing obvious sensory disturbances is due to the overlapping of fibers of adjacent roots in the distribution of sensory innervation, as mentioned under Anatomical Considerations. Cases are on record where 3, 4, and even 5 roots have been consecutively divided without obvious sensory or trophic disturbances afterward, but this is distinctly against the rule. The procedure, therefore, resolves itself into choosing which posterior roots shall be divided in a given case, and these must be determined according to the roots which supply innervation to the spastic muscles.

OPERATIVE TECHNIC.—The roots are exposed by the method of unilateral laminectomy or by the more commonly used method of bilateral laminectomy. The nerve roots for the lower extremities leave the dura practically on a level with the middle of the spinous process of the vertebra corresponding in number to the nerve, and the exit from the dura is the only sure way of identifying the nerve.

It is often difficult to exactly locate a definite nerve, and one of the best methods for positive identification is to place a small piece of metal over the tip of the spinous process of what is thought to be the first lumbar vertebra and then to take an X-ray picture of this portion of the spine to definitely identify the spinous process. When the metal is removed, a scratch through the skin should be made so as to keep the identification of the spinous process until the time of operation. With one root thus positively identified, it is easy to get the others. For the relation of the various groups of muscles to the nerve roots the reader may be referred to Bing's "Compendium of Regional Diagnosis."

After the dura has been opened, as in the method of unilateral laminectomy (Fig. 79), silk retraction sutures are passed through the edges of the dura, 2 or 3 on each side, and it is pulled up firmly over the divided bone surfaces, both to give better exposure to the intradural contents and to prevent oozing from the extradural venous plexus. The posterior roots are picked up on a blunt hook (Fig. 1) after proper identification, thoroughly compressed with a heavy clamp, and then divided with blunt scissors through the compressed segment (Fig. 2), This prevents oozing from the divided ends of the nerve, which otherwise would be sufficient to render the spinal fluid murky and interfere seriously with the progress of the operation. As the posterior and anterior roots leave the dural canal they are very closely apposed, and are bound together by a light fibrous-tissue sheath. The line of division can readily be made out by inspection, and they may be easily separated from each other and the posterior root elevated on a hook. After the nerves have been divided and the blood carefully removed from the dural canal, if any has oozed in, the dura is closed by a continuous catgut stitch, and the remainder of the wound closed without drainage, as described in the operation of unilateral laminectomy.

No fixation dressings are applied. Prof. Foerster often puts the extremities in well padded casts to overcome the deformities as far as possible. The patients are very uncomfortable and in 1 or 2 of my cases pressure sores have developed, which have been exceedingly slow to heal. Therefore, I have discontinued using casts, leaving the correction of such organic deformities as may persist after the spasticity has been relieved until a later period when the wound has healed.

RESULTS.—These patients are very likely to have a fairly sharp reaction with a temperature running to 103° or 104° for the first 24 or 48 hours, after which time it descends steadily to normal and remains there. For the first 3 days they usually have severe pains, which are interpreted to be root pains from the irritation of the root-section. These pains disappear, as a rule, after the third day, when the process of central degeneration has become well advanced.

For the first week after operation attempts at moving the lower extremities are very likely to cause pain in the wound, and therefore a defensive rigidity of all the muscles occurs. When this tenderness and pain have disappeared, the release from spasticity in the muscles is perfectly obvious. The knees and feet may frequently be abducted voluntarily with comparative ease. Attempts at voluntary motion of the extremities do not result in the previously noticeable associated spasms of the muscles all over the body, and the general condition of the patient greatly improves. Patients are much less liable to sudden spasmodic responses to any kind of sensory stimulus, such as sudden light, sudden noise, etc. It is noticed that the patient's nervous system is very much more equable and the disposition far less irritable. From this time on the progress of the case will depend very largely upon the education of the patient in the development of the coördinative movements of the extremities and the development of voluntary dissociated control. This process may require 2 to 3 years of educational after-treatment, and with it should be included massage, passive motion, etc., for the maintenance of the nutrition and freedom of motion in the joints and muscles involved.

If the after-treatment, consisting of the physical therapeutics and reëducation of the patient in the use of his muscles, is systematically and patiently carried out, these patients will frequently get well enough to dispense with their crutches or other artificial means of support and to get about with reasonable independence and freedom. They often get so that they can climb stairs by themselves with a fair degree of ease.

DANGERS AND DIFFICULTIES.—The dangers of the operation are chiefly those of infection, which, of course, is preventable. In older cases with very rigid lumbar muscles it is frequently difficult to do a unilateral laminectomy because of the depth of the wound, the rigidity of the muscles, and the fact that often in adolescents the laminæ are composed of very hard bone. The same difficulties apply, but in somewhat lesser degree, to a bilateral laminectomy. If by mistake the third or fourth sacral root should be divided, there may be disturbances in the functions of the bladder and rectum. If more than 2 consecutive roots are divided, there is a possibility of trophic disturbances occurring, even though they may not make their appearance for some few weeks or months after operation.

In cases where the spastic condition has existed long enough so that organic contracture has occurred in many of the muscles and there are fixed deformities of the joints independent of the deformities due purely to the spasticity of the muscles, it may be necessary to use one or more of the various orthopedic measures to put the extremities in proper position to take advantage of the release from muscular spasticity, i. e. tendon lengthening, plaster casts, etc.

INDICATIONS FOR OPERATION.—This procedure is indicated in spastic conditions of all kinds in which there is a pure pyramidal tract lesion which does not cause complete loss of function in the pyramidal tract, i. e.:

Spastic paraplegia.
- Congenital type—Little's disease.
- With hydrocephalus.
- With spinal syphilis.
- Disseminated sclerosis.

Spastic hemiplegia.

Operative attack is contra-indicated in lesions which show active progress.

## OPERATION FOR RELIEF OF SPASMODIC TORTICOLLIS

Closely allied to other forms of muscular spasticity is one of the various types of "wry-neck." The wry-neck which is due to organic change and contracture in the sternomastoid and other rotator muscles of the head and neck, will not be considered here, but rather the type of purely spasmodic wry-neck without organic changes in the muscular tissues. There are some neurologists who maintain that this type of wry-neck is more or less a habit spasm and almost entirely psychical in origin, and that it should never be operated upon, but rather treated by suggestive therapeutics. On the other hand, many cases of persistent spasmodic torticollis have been successfully treated by means of resection of the nerves supplying the muscles involved in the spasmodic process. These nerves include the spinal accessory (resection of which has been described elsewhere), for the purpose of paralyzing the sternomastoid and trapezius muscles; the second and third cervical nerves and the suboccipital branch from the first cervical nerve, for the purpose of paralyzing the splenius capitis, rectus capitis posticus major, and obliquus inferior muscles.

**Resection of the Cervical Nerves (Keen's Operation).**—For the resection of the cervical nerves, Keen's operation is the best procedure.

The patient is laid prone on the table with the head somewhat flexed on the chest and preferably with the head upon a head-rest, such as is described under the section on Cranial Surgery.

There is frequently some confusion in the mind of the surgeon as to which nerves should be resected. Inasmuch as the sternomastoid, trapezius, complexus, and inferior oblique muscles turn the face toward the opposite side, one would resect those posterior nerves which lie on the same side as the spasmodic sternomastoid, and it may be stated that, as a rule, resection of the spinal accessory should be done in conjunction with Keen's operation.

A transverse incision is made through the skin at a level about 2 cm. below the lobule of the ear, and running from the median line outward for a distance of 6 to 10 cm., according to the size of the neck. This section is continued down through the trapezius muscle, which lies just beneath the subcutaneous structures. The trapezius muscle is reflected downward, and at about 1 to 2 cm. below the level of the incision will be found the occipitalis major nerve, where it perforates the complexus muscle, which lies just beneath the trapezius. This nerve is carefully followed through the complexus muscle by means of section transverse to its muscular fibers. On the deeper side of the complexus the nerve is followed to its bifurcation with the second cervical. An extensive piece is then excised from both the occipitalis major and the second cervical. The upper piece of the complexus is reflected upward until the suboccipital triangle is exposed. This is bounded by the 2 oblique muscles and the rectus capitis posticus major. At the antero-external angle of this triangle the first cervical nerve passes outward above the arch of the atlas. A large piece of this nerve is resected. The lower piece of the complexus is then reflected downward, and at a level 2 to 3 cm. below the second cervical nerve, which has already been resected, will be found the third cervical nerve, which supplies the splenius capitis. The external branch of the posterior division of this nerve is widely resected. The cut muscles are now united with catgut sutures in layers, and the skin is sutured with silk, without drainage. Sterile dressings are applied, and a plaster-of-Paris dressing, including the head, neck, and shoulders, is applied, with the head in overcorrected position. This plaster support is retained from 6 to 12 weeks, according to the severity of the case.

The chief difficulty of the operation lies in finding the nerves in a field which is exceedingly bloody. The operation itself is not dangerous.

If failure to obtain relief occurs, either there has been some of the element of organic muscular shortening in the case, or the nerves have not been completely resected. In case the muscles at the time of operation should show evidence of organic shortening, they may be divided and left unsutured in a manner similar to that in which they are treated in spastic wryneck.

Many satisfactory results have been reported, although the tendency to recur is very marked.

**Posterior Root Section.**—There is one other procedure which may eventually prove to have some value. It was tried in a case of spasmodic torticollis some 3 years ago. The procedure was based upon the theory of the Foerster operation for the relief of spasticity. It consisted in the section of the posterior roots of the upper 4 cervical nerves, in addition to the resection of the spinal accessory, as previously described. This posterior root section was done through a unilateral laminectomy involving the upper 3 vertebræ. Great care had to be exercised in cutting the posterior root of the first nerve because of the close proximity of the medulla. In this case no fixation dressing was applied, but the patient was simply put to bed with an ordinary sterile dressing. She was able to lie flat on her back with the face straight forward for the first time in 3 years. In a couple of weeks she was able to get her face straight forward and even to rotate the chin about halfway over toward the opposite shoulder. Under conditions of nervous excitement there was a tendency to return to the original deformity, but never to the original degree. There was no loss of voluntary muscle power after this posterior root section. She was lost to observation after 3 months.

This operation has been done once, with fair success, but cannot be recommended for general use as yet.

## OPERATIONS FOR RELIEF OF PARALYSIS AND REPAIR OF INJURY TO NERVES

Paralysis may result either from lesions in the central nervous system or from those in the peripheral nerves. The lesions of the central system include such conditions as poliomyelitis, hemiplegia, and damage from traumatism, inflammations, and new growths. Paralysis resulting from lesions of the peripheral nerves may be due to injuries, including pressure from callus or apparatus, to new growths, or to inflammations of the nerves which may result from traumatism, infection, or specific poisons.

For many of these conditions non-operative treatment is the most that can be given. For certain of the others there are various procedures, one or the other of which may be used for the relief of paralysis.

A general description of the different procedures may well be given here and then applied to the various conditions as they arise.

## Operative Procedures

**Neurotomy.**—Section of the nerve, either transverse or longitudinal.

**Neurectomy.**—An excision of a greater or less part of the nerve—to be done with a sharp scalpel, never with scissors.

**Neurectasy.**—For neurectasy, or nerve stretching, the nerve is exposed and separated from its surroundings; the finger is inserted beneath the nerve trunk, which is pulled firmly, first from the central end and then from its peripheral end, steadily for about 5 minutes. The amount of force used varies with the size and situation of the nerve. For small nerves, such as the supra-orbital, very slight force is permissible, but for a large nerve, such as the sciatic, the pull may be up to 85 pounds. In pulling from the central end, less force should be used so as to avoid tearing the nerve roots from the spinal cord. After the nerve has been thoroughly stretched, it is dropped back into place and the incision closed without drainage. Motion and sensation will be absent more or less completely and for a varying length of time, according to the amount of compression and traction exerted on the nerve trunk.

**Nerve Avulsion.**—Nerve avulsion is applied in the case of certain sensory nerves which are the seat of an intractable neuralgia. The nerve is exposed and grasped by a curved hemostatic forceps, which is then slowly and steadily twisted, thus winding the nerve around it until the nerve tears away centrally, often many centimeters proximal to the avulsing clamp. The twist is then reversed, and as much as possible of the peripheral portion of the nerve is avulsed in a similar manner.

**Neurorrhaphy.**—Many methods of nerve suturing have been described and pictured, of which 2 types are worth while. Of these 2 types of suturing, one consists of the through-and-through method and the other of lateral tension suturing with peripheral apposition sutures.

THROUGH-AND-THROUGH METHOD.—The through-and-through method is permissible when the nerves to be sutured are of small caliber and apposition can be maintained without tension on the suture. The suture is passed through the center of each nerve end, from $\frac{1}{4}$ to $\frac{1}{2}$ cm. distant from the end (Fig. 3, A and B). Under these circumstances the through-and-through suture causes good apposition and creates a minimum amount of irritation and consequent secondary cicatrization.

The suture is best composed of either very fine, smooth catgut or, when it can be obtained, a fine strand of rat-tail tendon, which is very strong and perfectly smooth. It is undesirable as a rule to use silk for through-and-through sutures because it is practically non-absorbable and is apt to cause a certain amount of chronic irritation, with connective-tissue formation.

In larger nerve trunks, where no tension at all will occur upon the suture, the through-and-through method may be used, the sutures being passed ½ cm. from the ends. In addition, to prevent lateral displacement of the apposed ends, 2 or 3 peripheral sutures may be passed through the 2 nerves to keep them in proper alignment.

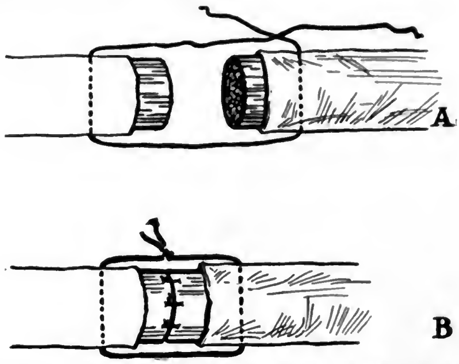



Fig. 3.—A, Epineurium Removed from Nerve Ends and Through-and-through Suture Passed Ready for Tying. B, Through-and-through Suture Tied to Approximate Nerve-ends. A few small superficial sutures have been placed at the junction of the nerves to prevent lateral displacement of their ends.

LATERAL TENSION METHOD.—Where the nerve suture will be subject to some little tension the through-and-through suture is not satisfactory because of the damage to the 2 ends of the nerve consequent to the continuous pull. Under these conditions each of the 2 nerve ends is treated as follows: The sheath is removed by a sharp scalpel for about ¼ cm. from the end of the nerve, which has already been freshened transversely. On opposite sides of the nerve, and about 0.5 cm. from its end, 2 fine silk sutures are passed through the epineurium, getting a good hold and being tied in a square knot so as to get a side hitch (Fig. 4, C). These sutures are left long and, when they have been placed in both nerve ends, the corresponding pairs are tied together so as to approximate the nerve ends (Fig. 4, D). To prevent lateral displacement of the ends, a fine catgut suture may be run around the periphery of the nerve joint, or a few interrupted sutures may be used.

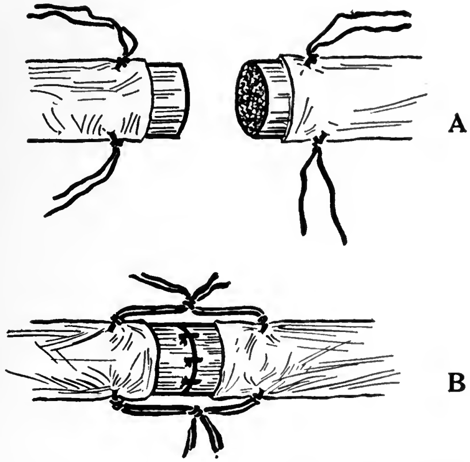



Fig. 4.—A, Side Sutures Which Have Been Passed Through the Epineurium and Tied so as to Get a Side Hitch on Epineurium. These sutures will stand considerable tension. B, Lateral Sutures Tied and a Few Peripheral Sutures to Prevent Lateral Displacement of Ends. The nerve-suture area is then wrapped in Cargile membrane, which is not shown in the drawing.

**General Principles.**—In all nerve suture work there are certain general principles and precautions which must be carefully observed. The object is always to get close apposition of nerve fiber to fiber in the 2 ends, to have a suture which will stand as much strain as may be necessary in the given case, and yet will interfere as little as possible with the structure of the nerves and cause as little compression of nerve fibers as possible. Again, precautions must be taken to prevent the formation of connective tissue in the space between the 2 nerve ends. To have the nerve ends perfectly free from bleeding prevents the formation of a small blood-clot between them, with later cicatrization and interference with union and regeneration.

The epineurium should be removed by sharp dissection for about 0.25 cm. from the end of each nerve to prevent it from slipping forward and curving inward between the nerve ends. To avoid adhesions to surrounding structures and to prevent connective tissue from growing in between the nerve ends, the junction should be surrounded by Cargile membrane or some other similar innocuous organic structure.

Nerves should never be grasped directly with either the fingers or instruments. The best way is to grasp the epineural sheath and then dissect away the surrounding structures from the nerve, causing the least possible traumatism to the nerve itself. All dissection should be done with a sharp scalpel and never with scissors, which have a crushing effect and cause interference with later reunion and regeneration of the nerve ends. The sutures should be passed, when possible, simply through the epineural sheath, at some little distance from the freshened end. As a matter of fact, such a suture always includes a few nerve fibers.

AFTER-TREATMENT.—After the nerve suture is completed and the joint wrapped with membrane, the nerves are laid back in place, the wound is closed without drainage after perfect hemostasis, sterile dressings are applied, and the extremity is put up in such a position as to give the maximum relief from tension. This position may be maintained by some form of brace, by a plaster-of-Paris bandage, or by a simple gauze bandage.

SECONDARY NEURORRHAPHY.—In secondary neurorrhaphy we usually find after the exposure of the nerve ends a large bulbous growth on the proximal nerve end, and a similar, though smaller, one on the distal nerve end. These bulbs are made up of a conglomeration of fibrous tissue and immature nerve fibers. Before a satisfactory nerve suture can be made these bulbous extremities must be removed until normal-looking nerve bundles appear on the transverse section of the nerve ends. Some writers have reported satisfactory regeneration when only a portion of these bulbs was removed and end-to-end anastomosis between the remainder of the bulbs accomplished, but this method seems less likely to give satisfactory results than the other.

Sherren states that in secondary sutures it is not worth while to remove any more than the fibrous end of the peripheral stump, as the whole thing is nothing but fibrous tissue. However, many times, in cases several years after the incidence of the paralysis, I have been able to get to good-looking fasciculi by resecting a generous piece from the end of the peripheral stump. It is my custom to take small cross-sections until the fasciculi appear in the stump. This seems to me to improve the prospects of a satisfactory result.

**Neuroplasty.**—Neuroplasty is the plastic bridging of defects so as again to connect damaged peripheral nerves with the central nervous system. It includes several different procedures.

NERVE ANASTOMOSIS.—This procedure is accomplished in one of several different ways. In the first place, the peripheral portion of the paralyzed nerve may be connected with the neighboring sound nerve by 1 of 3 methods. In the sound nerve there may be made simply a longitudinal slit into which the end of the peripheral segment of paralyzed nerve is inserted and held fast by sutures (Fig. 5). A certain number of fibers of the sound nerve are always divided by this longitudinal incision and insure union with the paralyzed nerve, with return of function. This procedure reaches its best success when the paralyzed nerve is small in size and, therefore, needs but comparatively few fibers from the sound nerve to cause its regeneration.

Another way consists in making an oblique transverse incision through a

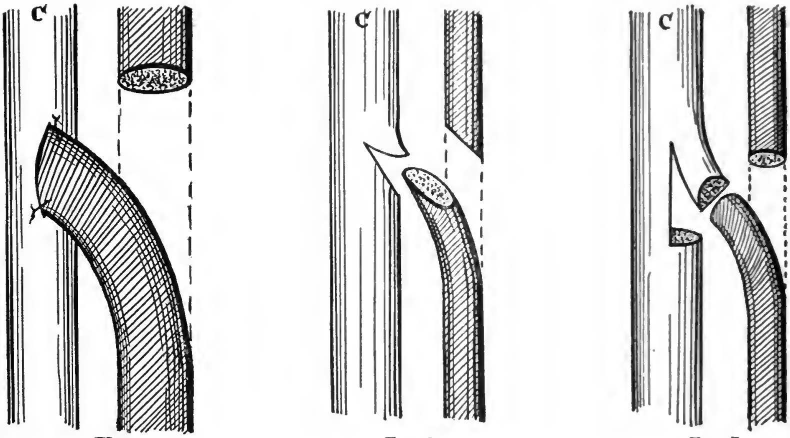



Fig. 5. Fig. 6. Fig. 7.

Figs. 5, 6, and 7.—Phases of Nerve Anastomosis. In each figure the dark nerve is the paralyzed and the light nerve is the sound one. C represents the central end of the sound nerve. 5 shows the implantation of the peripheral stump of the paralyzed nerve into a longitudinal slit in the sound nerve. 6 shows implantation into an oblique transverse slit in the sound nerve thus giving more definite end-to-end apposition of the nerve-fibers in the two. 7 shows end-to-end suture between the paralyzed nerve and a portion of the sound nerve elevated after transverse section. It is a slight modification of 6.

portion of the sound nerve and the insertion of the peripheral paralyzed nerve into this transverse slit (Fig. 6). This insures a considerably greater number of divided nerve fibers for the regeneration of the paralyzed nerve. The third method consists in transverse section of a portion of the sound nerve and the dissection upward of the portion of nerve thus divided (Fig. 7) and the use of this central reflected stump for the purpose of end-to-end suture with the paralyzed peripheral nerve stump.

With the same 2 nerves 3 other procedures are possible, reversing the 2 things done to the paralyzed and peripheral nerves. For instance, the longitudinal slit, the transverse section, or the reflection of the portion of nerve trunk may be applied to the paralyzed nerve on the peripheral end and a portion or the whole of the central end of the sound nerve may be used for anastomosis. These last 3 types are rarely of service.

Where the entire peripheral stump of the paralyzed nerve is implanted into the neighboring sound nerve, in cases where injury or disease has destroyed too much nerve to permit end-to-end suture with itself, it has sometimes been advised to implant the central stump of the paralyzed nerve also into the same sound nerve at a higher level, with the hope that its fibers will grow down along the sound nerve and reunite with its own peripheral stump. Since, however, it has been shown that the axis cylinders in the central end of the divided nerve have no preference for those of its own peripheral end, the results would probably be better if the central end were not used, as the consequent confusion of axis cylinders might well interfere with coördination later on.

NERVE CROSSING.—Nerve crossing refers to the procedure where the central end of the sound nerve, divided completely transversely, is sutured to the peripheral end of the paralyzed nerve, also divided transversely.

NERVE BRIDGING.—Nerve bridging refers to the attempt to cause nerve regeneration over the gap which exists between the ends of a divided nerve in cases where nerve stretching, combined with the most favorable position of the extremity, still fails to overcome the gap. **The rather frequently pictured and recommended method of making plastic flaps from each of the 2 ends of the divided nerve should be most vigorously condemned.** No flaps thus obtained can do more than form a conducting pathway for the fibers which may regenerate between the two nerve ends. To divide, transversely, half of the central stump considerably above its end and then to turn this flap downward does serious additional damage to the nerve. It is sure to cause considerable formation of connective tissue and also to form many adhesions with surrounding structures and, as a rule, gives nothing but disappointment. When this method is applied to both nerve ends the difficulty is doubled.

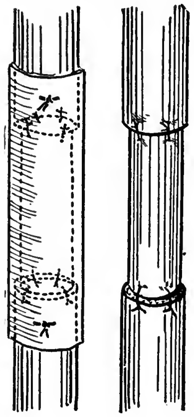


FIG. 8.—BRIDGE BETWEEN TWO ENDS OF DAMAGED NERVE. This bridge is made by taking a segment from some other nerve in the same patient's body and suturing it into the gap. The bridged area is wrapped with Cargile membrane which is fastened at each end to the epineurium by a few fine catgut sutures.

NERVE TRANSPLANTATIONS.—The best method of nerve bridging consists in autotransplantation, i. e. the use of a nerve trunk from the same individual to fill in the gap. It is perfectly possible to use a sensory nerve for the purpose of filling in a gap of motor nerve, inasmuch as the transplant acts only as the most favorable framework for the downgrowth of the nerve. Instead of using a single transplanted section of nerve, it may be possible to dissect out a considerable length of some nerve—for instance, the long saphenous—which may be cut into lengths sufficient to bridge the gap, a bundle of these segments being made equal in circumference to the trunk of the nerve to be repaired. These pieces are sutured end to end with the 2 ends of the nerve to be repaired. After the end-to-end suture is complete, the whole transplant and the 2 nerve sutures are wrapped in Cargile membrane to prevent the formation of adhesions to surrounding structures and to prevent the ingrowth of connective tissue into the nerve joints, the 2 things which will most of all prevent the return of function (Fig. 8).

The next best procedure consists in the use of a transplant from another human being, closely related to the patient if possible. A transplant taken from animals—"heterogeneous transplant"—has given exceedingly few satisfactory results, and this method should not be used.

TUBULIZATION.—Of the many other methods which have been described, that of tubulization is next best to autotransplantation. The method of tubulization consists in making a framework of catgut strands between the 2 ends of the divided nerve and then surrounding this framework by some structure which acts as a tube for the direction of the regenerating nerve fibers and for the prevention of interference with regeneration by adhesions with, or connective tissue ingrowth from, surrounding structures. (Fig. 9.) Cargile membrane is one of the most satisfactory materials to use. It can be wrapped around the catgut strands and the 2 ends of the divided nerve to make a satisfactory tube. Other materials which have been tried are sterilized preserved arteries from animals, gelatin tubes, and paraffin wax tubes, but these are difficult to get on short notice and have no advantages over the Cargile membrane.

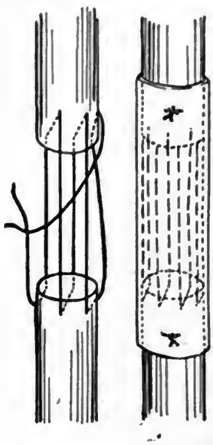


FIG. 9.—GAP BETWEEN NERVE ENDS BRIDGED BY MEANS OF CHROMIC CATGUT LOOPS; CARGILE MEMBRANE USED TO COMPLETE TUBULIZATION.

NERVE BRIDGING BY USE OF A VEIN.—Another method consists in dissecting a vein from the patient, slipping it up over one end of the nerve until the bridging sutures have been placed, and then sliding the vein down so as to form a protective tube covering in both the bridging sutures and the respective ends of the nerve, to which it is fixed by 1 or 2 fine catgut sutures at each end. This procedure is by no means so easy as it sounds, for the vein shrinks and is very difficult to manipulate.

The longest distance which has been satisfactorily bridged has been 4 in., but as a rule, regeneration over so long a distance should not be expected. There is much more hope of bridging over any space less than 3 in.

BONE RESECTION.—Another procedure, which can scarcely be called a neuroplasty, but which is a plastic operation done in order to approximate the 2 ends of the nerve, consists in the resection of sufficient length of bone so that the nerve will come together when the ends of the bone are again fastened together. Direct end-to-end suture of the nerve is then possible. The level of bone section should be as far away from that of the line of nerve suture as possible, so as to have the minimum amount of reaction in the neighborhood of the nerve junction. This method would be permissible only where no other method of bridging would offer any chance of success.

CHOICE OF NEUROPLASTIC METHOD.—In dealing with divided nerves, the procedures just described should be chosen in the following order of preference:

(1) end-to-end suture; (2) nerve bridging, if end-to-end suture is impossible and if the distance is not more than 2 in.; (3) (a) lateral anastomosis with a neighboring nerve, or (b) nerve crossing, if nerve bridging fails after a proper interval has elapsed—3 to 12 months, according to the length of the gap.

It is an interesting fact that about 1/3 of a nerve trunk may be divided transversely without causing obvious motor or sensory disturbance, so that one might do a lateral anastomosis and get new power in the injured nerve with very little obvious interference with the function of the nerve used for the anastomosis.

Nerve crossing, which involves the entire transverse section of a sound nerve, of course causes permanent paralysis of the muscles supplied by the sound nerve so divided, and this process is justifiable only where the damaged nerve is of much more vital importance than the sound nerve thus used for crossing.

Resection of bone, so as to shorten the extremity until end-to-end anastomosis between the ends of the nerves can be accomplished, is only to be chosen where the other methods promise no success.

**Neurolysis.**—Neurolysis consists in the freeing of the nerve trunk from pressure by surrounding structures, such as scar tissue, as, for example, in Volkman's ischemic paralysis, or callus, as seen in fractures of the middle of the humerus, where the callus involves the musculospiral nerve. Sometimes the compressed nerve will also have new connective-tissue formation within its own epineurium, and in this case it is often desirable to split the external nerve sheath and to separate from one another the various fasciculi composing the nerve trunk.

**General Considerations in Operations for Relief of Paralysis.**—In all these operations perfect asepsis and hemostasis are essential. Infection not only interferes with the immediate healing of the nerve, but causes an excessive amount of scar tissue both around and within the nerve joint, and so leads to permanent interference with the return of function. Hemorrhage, to a less degree, gives rise to the same disturbance.

In these operations the handling of the nerve structures must be most careful. No pinching, pulling, bruising, or unnecessary manipulation is ever permissible. The nerve sheath must be removed by methods previously mentioned, from the ends of the nerves to be joined, so as to minimize the possibility of connective-tissue ingrowth in the space between the nerve ends.

## Nerve Injuries in General

In dealing with injuries of nerves, where there is also a division of skin and neighboring muscles or tendons, primary nerve suture should be the rule. Not a few instances have occurred where a divided nerve trunk has been mistaken for a tendon and sutured end to end with another tendon. Where the damage to the nerve has been subcutaneous, many surgeons prefer to wait for the development of certain symptoms diagnostic of lasting injury to the nerve structure. When the nerve is completely divided either anatomically or physiologically, there is complete loss of function and there soon develops complete degeneration of the peripheral segment of the nerve. This degeneration begins very soon after the receipt of the injury and is complete by the end of the tenth day, at which time, as a rule, there is a "reaction of degeneration" present if the nerve has been completely divided. When this reaction is present, it is wise to expose the nerve at the damaged site and to do such repair work as is indicated by the findings on exposure.

**Reaction of Degeneration.**—A brief description of the reaction of degeneration will perhaps be helpful. Muscles in their normal relation to the central nervous system react quickly when stimulated with the faradic current and also with the galvanic current. With the faradic current the muscle stays contracted during the application of the current; with the galvanic current a sharp contraction occurs when the circuit is closed or opened, but there is no reaction while the current is passing through the muscle. Less current is required to obtain a contraction when the cathode is used or is applied to a muscle point than when the anode is used. Also the contraction is more evident when the current is closed than when it is opened. After its motor nerve is divided, the muscle ceases to respond to the faradic current after the lapse of from 4 to 7 days. After the tenth day the usual contraction from the application of the galvanic current may be very hard to get. Instead, this galvanic current will induce a slow vermicular contraction, originating in the muscle where the electrode is applied to it, and a stronger current must be used to start this contraction than is necessary to get contraction on the sound side. Also the muscular contraction comes with the closing of the circuit when the anode is applied to the muscle instead of the cathode. This failure of the faradic current to cause muscle contraction, with the change in response to the application of the galvanic current, is a condition to which the term "reaction of degeneration" (R. D.) is applied.

The length of time after division of the motor nerve that the muscles will still react to the galvanic current is variable and seems to depend mostly upon whether or not the contractile substance of the muscle still exists, in which case the response will come, or whether the muscle substance has undergone fatty and fibrous degeneration, so that no contractile substance remains, in which case there will be no response to any current. Often there will seem to be no response to the galvanic current at one time, and at a later time it will be present. This is accounted for on the basis that at times the resistance to the current in the skin and subcutaneous tissues, which varies from time to time, prevents the stimulus from reaching the muscular substance. Some authors state that it is not safe to depend entirely upon the stimulation through the intact skin when the question of treatment depends largely upon the findings. In cases where great issues depend upon the decision it is safer to cut down to the muscular substance and to apply the electrode direct. Cases are on record where, after 23 years from the time of nerve division, the muscles would still respond to the galvanic current.

**Deformity Due to Nerve Injuries and the Resulting Paralysis.**—It must be remembered that, in many of these subcutaneous divisions of nerves, the external nerve sheath may appear to be perfectly normal, but the nerve structures within may be completely divided and so damaged as to prevent reunion, regeneration and return of function, so that, in all cases, the nerve sheath should be split longitudinally and the nerve structures themselves examined for evidence of injury. With the damage to the nerve there appears paralysis of the muscles innervated by it. Muscles which are so paralyzed lose their tone and may readily be overstretched. On the other hand, the non-paralyzed antagonists of these muscles contract without opposition and before long undergo a process of organic shortening which will eventually hold the extremity in a deformed position.

With the joints thus held for a long period in a fixed position, the ligamentous structures of the joint also become more or less fixed in such a way that, if power should return to the muscles, there would be mechanical fixation of the joints which would seriously interfere with the proper functioning of the extremity. In very young children there is an additional element of disadvantage, because the bones of the paralyzed extremity neither grow to their proper size, nor do the joint ends develop as they would in a limb undergoing its proper range of motion and usefulness. It is, then, self-evident that, whenever groups of muscles are paralyzed, the extremity involved should be put up in some form of retention apparatus, whether it be a plaster-of-Paris cast, orthopedic brace, or bandaging, which shall prevent the non-paralyzed antagonists from shortening through overaction, and at the same time prevent the paralyzed muscles from being overstretched by their antagonists. If the paralyzed muscle is thus overstretched for a long time, it may refuse permanently to fulfill its proper function and return to its normal length, even after the motor supply to the muscle is perfectly regenerated. Even if the muscle does finally regain its normal length and function, the time of recovery is greatly lengthened. In addition to using some method of fixation, the extremity should be taken out of the fixation apparatus once or twice a day and given massage, passive motion, and, if possible, electric stimulation. By these means the development of deformity will be prevented, the nutrition of the muscles will be kept at its best, and, when once regeneration has occurred, the muscular and bone apparatus will be in normal condition to functionate properly.

This scheme of treatment should not only start at once after the incidence of the paralysis, but should be continued until voluntary motor power has returned sufficiently to prevent the development of deformities and overstretching of the still partially paralyzed muscles. Operation may be looked upon merely as an incident between the onset of the paralysis and the return of voluntary motor power, and these means of physical therapeutics should cease only for a sufficient length of time to allow wound healing, and then be continued postoperatively till recovery has ensued. Provided the extremity is thus cared for, the determination of the question as to whether operation should or should not be done need not be decided with undue haste. However, it should be remembered that on general principles the earlier nerve repair is accomplished, the more prompt and more satisfactory will be the result.

**Return of Function after Operation.**—One other thing, also, needs emphasizing—that after operation with suture, as a rule, a considerable period of time must elapse before there will be any evidence of returning function in the damaged nerve. This period is rarely shorter than 3 months with regard to motor return and oftentimes may be as long as 12 months, depending upon the conditions and the success of the suture in the individual case. The return of sensory power is apt to start earlier—from 6 to 16 weeks, but the complete return of sensation as well as of motor power may not occur for as long an interval as 2 or 3 years, during which time the system of treatment previously outlined must be persisted in.

A few cases have been reported in which motor power was said to have returned in muscles after "primary nerve suture" within a few days after operation. "Primary suture" may be considered as a nerve suture done before the onset of symptoms of degeneration of the peripheral end of the stump, i. e. 7 to 10 days. Most of these cases have been open to question, but recently, in conversation, Professor Foerster mentioned a case seen by him both before and immediately after operation, in which there was an undoubted return of motor power in the field of the sutured nerve within 2 or 3 days. This is a very rare occurrence, but it must be accepted as a fact.

**Causes of Failure in Operation.**—The chief causes of failure in nerve operations lie in rough handling of the nerve structures, improper choice of suture material and method, the failure to get good apposition, the failure to prevent connective-tissue ingrowth, and the failure to avoid infection. If infection occurs in the wound, failure is practically sure, because infection not only causes an infectious neuritis, but also results in the production of so much scar tissue as to prohibit the return of function in the nerve.

**Results of Operation.**—The results depend upon the careful following of technical details at the time of operation and also very largely upon the persistent systematic use of the various methods of treatment both before and after operation. In cases of nerve crossing or nerve anastomosis, to these methods of physical therapeutics must be added reëducation of the new cortical centers in the control of the muscles which have been previously paralyzed. In the majority of cases one must not expect a theoretically perfect anatomical and physiological result, especially in cases of anastomosis and nerve crossing. In end-to-end suture of the 2 parts of a divided nerve the final result may be so nearly perfect as to avoid detection of any defect except by most careful observation.

## Common Types of Nerve Injury

**Brachial Plexus Lesions.**—The traumatic Erb's paralysis in the adult and the brachial birth paralysis of Erb's type so-called, in new-born infants, are essentially the same kind of lesion. This lesion results from the overstretching and more or less tearing of the primary nerve trunks of the brachial plexus. It is practically always brought about by the separation of the head and neck from the shoulder on the side in which the nerves are damaged. Figures 10, 11 and 12 will indicate the slant of the nerves running from the spine to the arm and also indicate why pulling the shoulder away from the head and neck will damage the upper nerve trunk first, and why it is only in the more severe cases that the lower nerve trunks are also damaged. The lesions, both in the birth paralysis and the traumatic Erb's paralysis in the adult, are of very common occurrence. The lesion involves one or more of the roots from above downward. It may consist of a single mass of scar tissue, or there may be several scattered areas of scar tissue which interfere with the function of the nerve trunk or trunks in which they are situated. These lesions may be situated anywhere between the surface of the spinal cord and the ultimate nerve trunks which pass off from the brachial plexus into the axilla. The lesions, especially in the upper roots, are very apt to be severe enough to persist permanently and interfere with nerve function. In a few cases the plexus is torn completely across and there results one large mass of scar tissue which prohibits any function whatever in the roots of the brachial plexus.

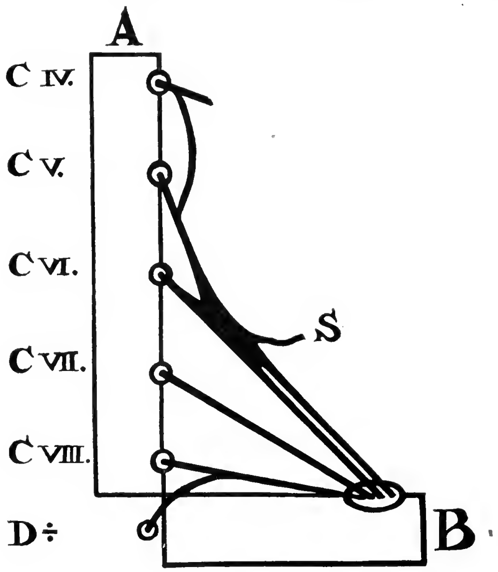



Fig. 10.—Schematic Representation of Brachial Plexus. A is the spinal column from which pass the various roots which go to make up the plexus. These roots come together in the axilla a little to the inner side of the shoulder B. S is the suprascapular nerve which comes off from the outer edge of the junction of the C v and C vi roots. It is obvious that any force that would increase the distance between A and B would put these nerves on the stretch, with the maximum strain coming on the upper root. Inasmuch as the suprascapular nerve comes from the outer edge of the nerve which first bears the maximum strain it is easy to understand why this nerve is always involved.

Many text-books say that these lesions, more particularly those of newborn infants, as a rule, get well spontaneously, but this, I am sure, from observation in many cases, is far from the fact. On the contrary, only a small proportion of the cases get completely well spontaneously. All of them, after a time, show some degree of recovery of function in the lower roots of the brachial plexus, but in the great majority of them there will be a persistent defect in the fifth or in the fifth and sixth roots. In those few cases which do recover entirely spontaneously the return of function will begin very promptly, i. e. within a few days of birth, and be complete in 3 months.

As a rule, if the lower roots as well as the upper are involved at first, one may feel confident that the upper roots have been so seriously damaged that they will show a permanent interference with function. In these infants the testing of the muscles for the reaction of degeneration is of very little service and can be accomplished only under anesthesia and after the child is 3 months old. The test is therefore inadvisable. Sensory disturbances are not very extensive, nor are they of much moment. In case the fifth root alone is permanently damaged, while there will be very obvious muscular paralysis, there will be no evidence of sensory disturbance, because the fifth root carries no exclusive sensory supply to the skin. Where the sixth nerve is also permanently damaged, there may be a small area of diminished sensibility over the deltoid region. In children, if these cases are neglected, there is failure of proper development in the muscles, ligaments, and the joint ends of the bones,

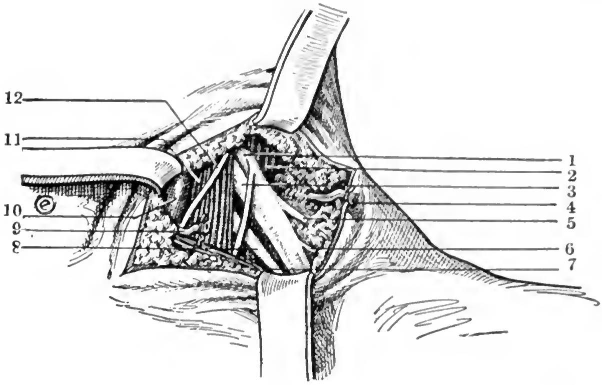



Fig. 11.—Plexus Exposed by Means of Oblique Incision Across Base of Neck and Almost at Right Angles to Course of Nerves. This wound heals with less scar. 1, C v; 2, scalenus medius muscle; 3, C vi; 4, transversalis colli artery ligated and divided; 5, suprascapular nerve; 6, external anterior thoracic nerve; 7, omohyoid muscle; 8, C vii; 9, transversalis colli artery; 10, internal jugular vein; 11, scalenus anticus muscle; 12, phrenic nerve.

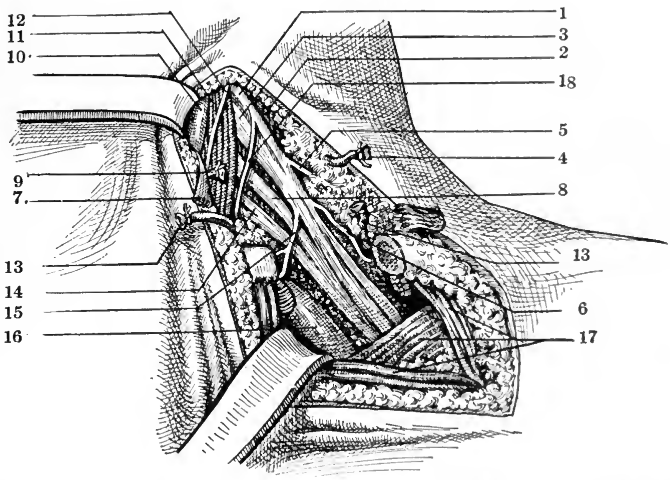



Fig. 12.—Brachial Plexus Exposed by an Oblique Incision from Junction of Middle and Lower Thirds of the Sternomastoid Muscle Down and Out to Junction of Middle and Outer Third of Clavicle. In this dissection a segment of the clavicle is removed to give a more distal exposure of the plexus. The structures 1 to 12 are the same as in Fig. 11. 13, Suprascapular artery; 14, C viii and D i nerves; 15, nerve to subclavius muscle; 16, subclavian artery; 17, pectoralis major and minor muscles; 18, muscular branch.

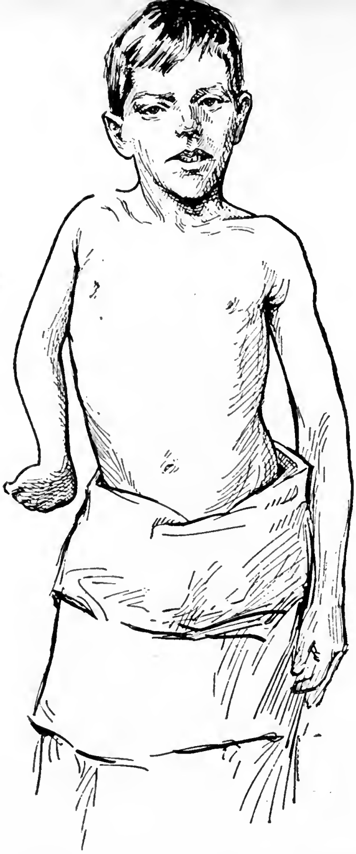


Fig. 13.—Right Arm Shows Typical Deformity of an Old Neglected Severe Brachial Birth Palsy. This boy is ten years old. Note the smaller size of the shoulder girdle and extremity on the right side, the flattened shoulder, the inward rotation of the entire extremity, the flexure of the elbow, and the marked flexion and ulnar adduction of the wrist.

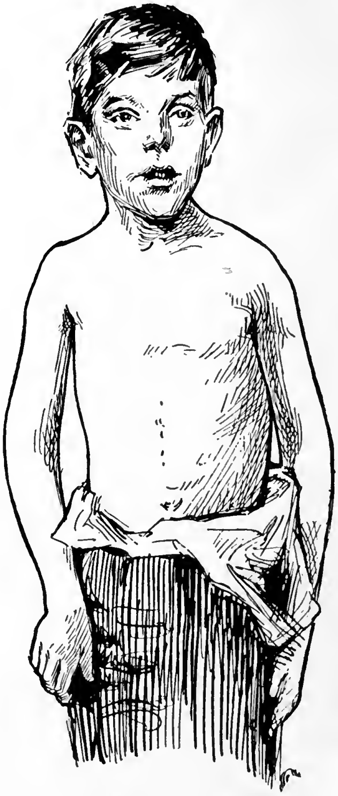


Fig. 15.—Nine Months After Operation—Note Improvement in Size and Position of Right Upper Extremity, Especially of Hand.

Fig. 14.—This Shows Maximum Power of Elevating Hand Toward Mouth Before Operation.

Fig. 16.—Two Years and Seven Months After Operation Patient Could Raise Right Hand to His Mouth.

and deformities result from the contracture of the antagonists of the paralyzed muscles, which, in turn, are apt to be overstretched. These conditions under neglect give attitudes characteristic of this type of paralysis, as indicated in Figures 13 to 21 inclusive.

In the adult these contractures do not give the same degree of deformity, because the extremity has been fully developed before the incidence of the nerve paralysis. (Figs. 24 and 25.)

Fig. 17.—Typical Deformity in a Child Less Than Two Years Old.

The muscles paralyzed fall into groups which correspond with the motor fibers located in the different anterior motor roots (see Fig. 26, from Kocher).

TREATMENT PRECEDING OPERATION.—The principles of treatment from the time of onset of paralysis until the time of operation have been outlined in the preceding section. The arm or extremity should be put up in a support which shall entirely relax the muscles paralyzed in a given case, so as to prevent their being overstretched. If the hand on the paralyzed side be placed on the back of the patient's head and held there, the relaxation of the paralyzed muscles is almost perfectly attained. Massage and electricity should not be applied to these cases for the

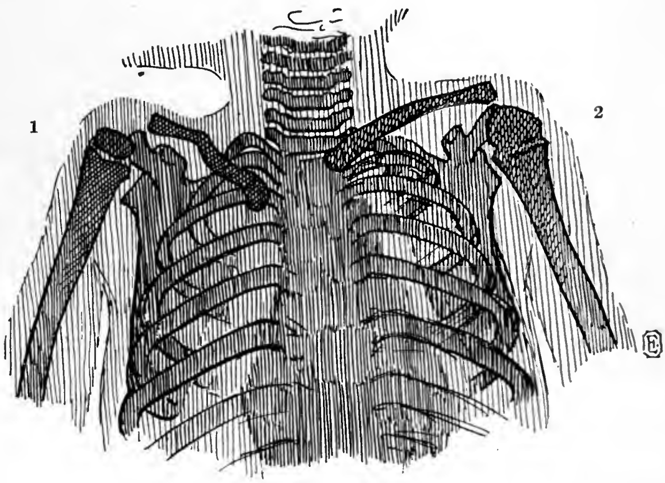



Fig. 18.—X-ray Picture Showing Shoulder Girdle in a Four-year-old Boy who had Suffered a Right-sided Brachial Birth Palsy. Note the interference with the growth of the bones in the right side of the shoulder girdle, and the infantile type of the shoulder joint.

first 3 weeks after the injury, inasmuch as a traumatic neuritis, which is apt to be aggravated by these procedures, occurs in the brachial plexus.

EARLY OPERATION IN INFANTS.—In infants operation is indicated in those cases which show serious damage to the brachial plexus and should be done

Fig. 19.—Deformity Following Complete Rupture of Left Brachial Plexus. Instead of resembling the typical one as shown in Fig. 17, the deformity is that of a complete flaccid paralysis of the extremity. Child, 11 months old.

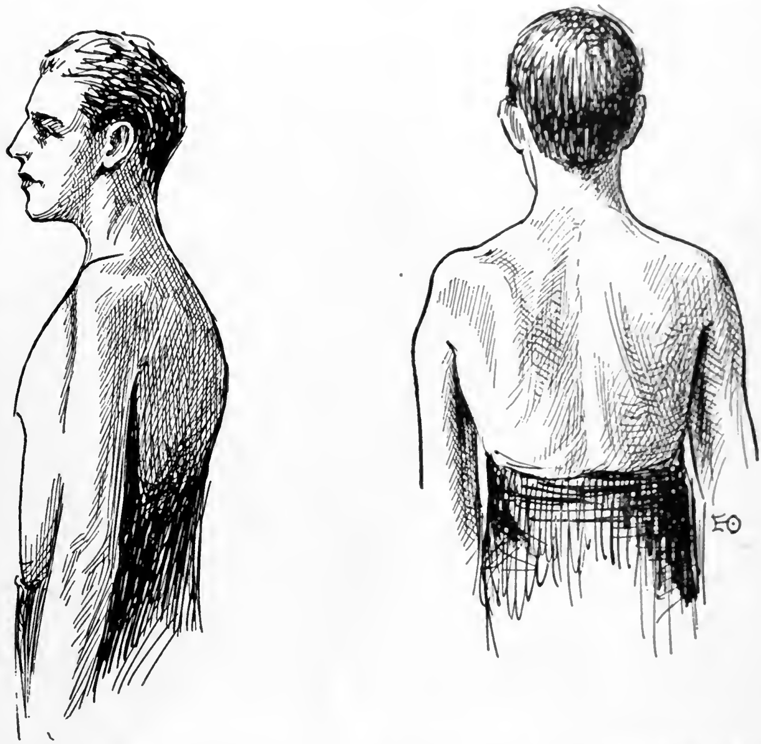
as soon as the general condition will warrant the use of an anesthetic, whether this be after 10 days or 3 months from the time of birth and the receipt of the injury.

In those cases where no injury sufficient to demand nerve resection and suture is found, the operation results practically in a simple exploration, with merely a division of the skin and subcutaneous fat, practically no loss of blood, and a perfectly clear view of all the nerves of the brachial plexus so that the surgeon may know just what he is dealing with and just what has to be done. This procedure involves practically no risk beyond that of the anesthetic. If damage is found its early repair gives the patient the best prospect of satisfactory regeneration and there has been no undue loss of time. In the cases of moderate severity at the time of injury, it may be legitimate to wait for 3 months, provided the care of the extremity and muscles, as previously described, is properly followed up.

Fig. 20.—Three Years After Repair of Plexus Child Was Able to Play with Left Arm and to Support a Heavy Doll with it.

Fig. 21.—Three Years After Repair of Plexus Child Could Also Grasp a Light-weight Doll with Her Fingers and Hold it out in Front of Her.

EXPLORATORY OPERATION IN ADULTS.—In adults, exploration should be done within a few days of the receipt of the injury, sufficient time being given for the tissues at the base of the neck to have regained their normal resistance against operative attack and the possibility of infection. In these cases there is no risk involved and no time should be wasted in waiting for the development of the electrical reaction of degeneration, inasmuch as the operation consists



**Figs. 22 and 23.—Traumatic Erb's Paralysis in Adult.** This is the same, etiologically and pathologically, as birth palsy, but as the extremity has attained full growth before the nerve damage occurs, the symptoms are chiefly those of paralysis and atrophy of the muscles involved. Note the atrophy in the deltoid and supraspinatus and infraspinatus.

merely in the skin incision, followed by palpation and inspection of the plexus and the opportunity for immediate repair of any discoverable damage. These procedures with a minimum loss of time will give the maximum result.

OPERATIVE TREATMENT.—The patient is placed supine on the operating table, with a sand-bag under the neck and shoulders of such a size and so placed as to just catch the occipital protuberance when the head is turned to the opposite side from the lesion and retracted somewhat so as to put the skin and muscles of the operative area somewhat on the stretch.

The plexus may be exposed by either of 2 incisions. One starts just above the insertion of the sternomastoid muscle and passes outward and slightly upward across the base of the neck, following the natural wrinkles of the skin.

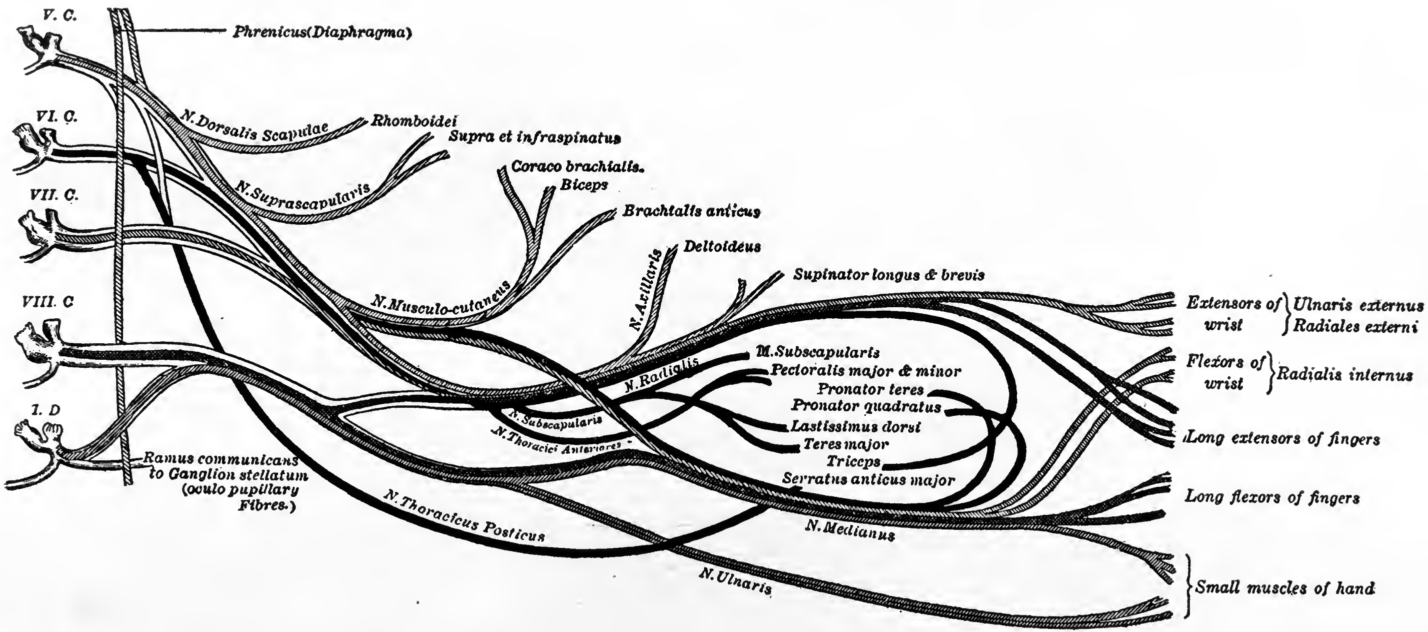



Fig. 24.—Schematic Brachial Plexus Showing Relation of Nerve Roots to Nerve Supply of Peripheral Muscles. (After Kocher.)

The skin and underlying fat pad are divided in the same line. Usually the external jugular vein, the transversalis colli, and suprascapular vessels are tied and divided. With proper retraction the nerves are pretty well exposed. This wound falls together naturally and heals without any tendency in the scar to spread. Its disadvantage is that in widespread damage to the plexus it does not give complete exposure, especially in adults.

The other incision starts at the level of the transverse process of the sixth cervical vertebra and runs obliquely downward and outward to the junction of the outer and middle thirds of the clavicle and divides practically the same

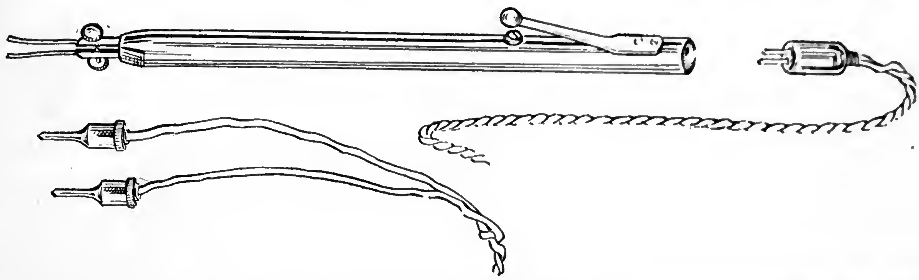


FIG. 25.—AN ELECTRODE WHICH CAN BE STERILIZED BY BOILING. It has flexible copper wire terminals.

structures as in the preceding case, although at a different angle (Figs. 11 and 12).

After retraction of the wound in either incision, the deep layer of cervical fascia normally lying just in front of the plexus is found thickened and adherent to the underlying nerves. This is dissected away, thus exposing the roots and plexus, which are examined by sight, touch, and, if necessary, by a tiny electrode (Fig. 25), to detect the presence of cicatrices which prevent nerve regeneration and the passage of nerve impulses.

The cicatrices are removed by transverse section of the nerves above and below at such levels as expose normal looking nerve bundles in the divided nerve ends. It is sometimes necessary to make several sections before getting a satisfactory looking end. It is wise to take off fairly thin segments until good fasciculi are exposed, so as to save as much nerve length as possible for the approximation. In the distal nerve trunk one can always get a satisfactory looking end by going far enough. In the proximal end, however, the cicatrix sometimes extends up into the intervertebral foramen. These exceptional cases will be considered later.

When the nerves have been properly prepared, end-to-end suture should follow. The best suture material in adults is fine, strong silk, because it is dependable. On opposite sides of the nerve, about ½ cm. from its freshened end, are passed 2 sutures transversely to the long axis of the nerve, and including mostly nerve sheath. Each suture is tied so as to get a firm hold, and the ends are left long. The other freshened nerve end is treated in similar fashion and the 2 are approximated by tying the lateral sutures of the one to the other. One

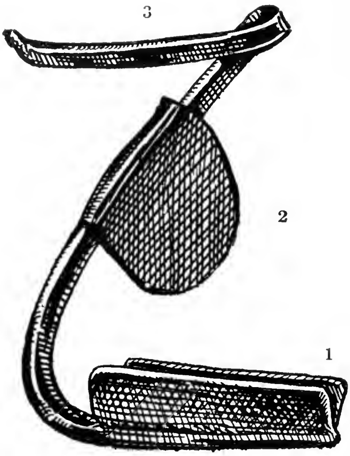



Fig. 26.—Leather-covered Steel Brace Made for Each Operative Case 1 is a channel to hold the forearm and hand. 2 is a shoulder pad which fits over the scapula and prevents the shoulder from being displaced backward and so causing strain on the nerve sutures. 3 is a band which encircles the head and to which a cloth skull cap is sewed so as to hold the head down where it belongs. A chin-strap prevents the child from wriggling out from under the head-piece. The arm and forearm are fixed in the brace by roller bandage.

or 2 fine catgut sutures at the periphery will complete the apposition.

Another method of suture which is satisfactory, especially where there is not too much tension, consists in passing a loop of chromic catgut through both nerve ends and tying them together. This is quicker and simpler, but has the disadvantage of perforating the nerves as well as not being quite so dependable. This, however, is the only feasible method in infants.

While the nerve sutures are being tied the neck and shoulder are approximated. The fat pad is allowed to fall into place, and the skin wound is sutured with silk. No drainage is used.

The approximation of the neck and shoulder is maintained by means of a steel brace especially designed for these cases and fitted previous to operation so that it can be slipped on just after the nerve sutures have been tied and thus prevent any chance of tearing them out.

This brace (Fig. 22) is worn continuously, without a moment's intermission, for 6 to 12 weeks, according to the individual case.

In those cases where the cicatrix extends up into the intervertebral foramen, a modified procedure is necessary. The cicatrized root may be split longitudinally up into the foramen, and if good nerve bundles are exposed above, the distal end of the nerve may be sutured into the cleft, with the hope that good union will occur. If the split cicatrix does not reveal good bundles above, the only thing left to do is lateral anastomosis of the distal nerve trunk into a neighboring sound root.

Fig. 27.—Head, Neck and Shoulder Held in Close Approximation During Healing, so Preventing any Strain on Nerve Sutures.

In those cases where the roots have been torn from the cord, lateral anastomosis is the only thing to be done, if any of the neighboring roots are still functionating.

Where considerable lengths of nerve roots must be resected to get beyond the cicatrices and the ends cannot be closely approximated, it will be found necessary to resort to nerve bridging or the procedure next mentioned.

When the entire plexus is badly torn, and the freshened nerve ends cannot be brought together, a subperiosteal resection of the middle third of the clavicle will permit very greatly increased approximation of the nerve ends. This would greatly increase the chances of regeneration, and certainly an extremity with a damaged clavicle, which will, nevertheless, move, is very much to be preferred to an anatomically complete extremity which is permanently paralyzed (Fig. 12).

POSTOPERATIVE TREATMENT.—When the proper time for the removal of the brace has arrived, the extremity may be placed in an ordinary triangular sling supported by the sound shoulder, and so adjusted as to elevate the paralyzed shoulder. The brace and sling not only prevent the paralyzed extremity from dragging on the nerve suture, but also prevent the weight of the extremity from overstretching the paralyzed muscles and thus prolonging their period of inactivity even after nerve repair has occurred.

When the change from brace to sling has been made, the extremity may be given massage, passive motion, electricity, etc., every day, being taken from the sling for that purpose. Procedures which would pull the shoulder away from the neck on the operated side should be avoided for many months.

At any time after 3 months from operation, voluntary motion may begin to appear in the paralyzed muscles, and as they regain their tone, the sling may be discarded. With the return of voluntary motion, the patient should be encouraged to take systematic exercises for the development of the muscles.

INJURIES BELOW THE CLAVICLE.—Injuries to the brachial plexus at a level below the clavicle are most frequently due to dislocations of the shoulder with traumatism by the head of the humerus to the nerve trunks in the axilla, to pressure from the arm pieces of crutches, or to the injudicious use of the foot in the axilla in the process of reducing a dislocated shoulder. As a rule, these injuries undergo spontaneous recovery after a greater or less length of time, and only the methods of tentative physical therapeutics are indicated.

**Injuries to the Suprascapular Nerve.**—The suprascapular nerve is injured in all of the brachial birth palsies and in all of the brachial paralyses of Erb's type in adults. Its fibers run on the outer edge of the fifth cervical nerve and therefore in all of the stretching injuries it is the first to bear the brunt of the injury which causes paralysis of the spinati. This paralysis has much to do with the peculiar deformity at the shoulder on attempts to raise the arm and with the inability to place the hand upon the head because of the loss of external rotation of the humerus.

Falls upon the shoulder suffered by many laboring men past middle life result in inability to use the shoulder and show paralysis of the deltoid. A careful examination will usually show that the suprascapular nerve has also been damaged. Such injuries are almost always due to damage of the upper nerve root of the brachial plexus rather than to injuries of the shoulder joint itself, although there may be complicating joint adhesions after some little time. If the paralysis persists, the upper portion of the brachial plexus should be explored and if the suprascapular has suffered damage, it should be repaired in the manner already described in brachial birth palsy, i. e., either by end-to-end suture or anastomosis with a neighboring nerve. (Figs. 24 and 25.)

The circumflex nerve also derives its fibers from the fifth root and most of the deltoid paralyses which are attributed to damage of the nerve in its peripheral distribution, are really due to a stretching injury to the fifth cervical root. In these cases, the patient is usually beyond middle life and not in good condition for operation in other respects, and it is not desirable to operate upon the nerve unless exceptional circumstances demand it. Often neighboring muscles can be trained to give sufficient abduction to fulfill most of the patient's needs.

**Injuries to the Musculospiral Nerve.**—The musculospiral nerve is more frequently injured in fractures than any other nerve, and the site of the injury is most frequently near the lower part of the humerus, as the nerve winds obliquely around the bone. These injuries are usually of the type of contusions, although the nerve is sometimes lacerated by the bone fragments and may very rarely be torn across. The nerve may be injured at the time of the fracture, or during the first few weeks afterward from pressure, though involvement in the bony callus thrown out.

If the nerve is injured in the lower portion of the arm below its external cutaneous branch, there will be no sensory disturbances, because below this point the musculospiral furnishes no exclusive sensory supply to the skin, but there always occurs a more or less complete drop wrist (Fig. 28). This nerve is also the one which suffers from what is known as "anesthesia paralysis" when the arm is carelessly allowed to hang over the edge of the operating table and the nerve suffers paralysis from direct pressure continued for some time. It is also the nerve which is involved in the so-called "Saturday-night paralysis," or paralysis due to sleeping with the arm folded under the neck. This nerve is frequently paralyzed, also, by the pressure of a crutch in the axilla.

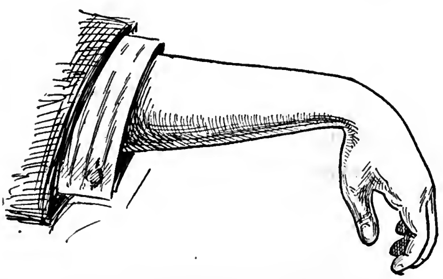


Fig. 28.—Characteristic Wrist-drop Resulting from Musculospiral Paralysis.

The prognosis in these cases is usually good. Many of the injuries are of such moderate degree as to undergo spontaneous regeneration and return of function. In a case where the nerve is more severely injured and nerve suture is indicated, the results are good in a larger proportion of cases than in the suture of the other nerves of the arm, perhaps largely because the muscles supplied by this nerve do not perform the finer movements of the hand as do the muscles supplied by the median and ulnar.

If at the time of fracture there is an open wound—in other words, a compound fracture—the nerve should be explored and, if found sufficiently injured, should at once be sutured, end to end, after resecting the damaged segment.

Otherwise it may be surrounded by Cargile membrane to avoid adhesions and left alone. If the fracture is simple and there are evidences of serious interference with nerve function in the musculospiral, it is advisable to explore the nerve after allowing a few days to elapse so that the tissues may regain their resistance against infection. Some men advise waiting for 10 to 14 days and are then guided by the presence or absence of the reaction of degeneration. If the reaction of degeneration develops, exploration is essential. If the muscles do not show the reaction of degeneration, tentative treatment for a longer period may be justified. Sometimes the nerve is not sufficiently damaged to cause reaction degeneration, but is so lacerated that later scar formation will prevent a large portion of it from functionating properly, so that operation is necessary later. In any case, the bony fragments should be carefully aligned and the extremity put up so as to avoid overstretching of the paralyzed muscles.

OPERATIVE TREATMENT.—When operation is necessary, posterior longitudinal incision is made through the muscle down to the site of the fracture and the nerve is explored. If there is evidence of much damage, the damaged portion of the nerve is resected and end-to-end suture done. If the nerve seems to be in fairly good shape, but is being compressed by a bone fragment or inflammatory infiltration, the bone fragment may be trimmed and the nerve protected by Cargile membrane.

In many cases the paralysis occurs gradually some little time after the fracture. This always indicates compression and usually this compression is due to involvement of the nerve in the callus. As soon as symptoms of this difficulty appear the nerve should be exposed and freed from pressure, protected by Cargile membrane and, if necessary, transplanted a short distance away from its original site, to avoid the recurrence of pressure. It usually takes about a year for the return of function.

**Injuries to the Ulnar Nerve.**—JUST ABOVE THE WRIST.—The ulnar nerve is most frequently injured just above the wrist joint, very frequently as a result of a broken window pane or other accidents of this type. Usually the wound is a ragged gash which involves not only the ulnar nerve, but also most of the tendons on the ulnar side of the wrist, as well as the ulnar artery. The ulnar nerve is never divided alone, but always in conjunction with some of the tendons. Not infrequently these wounds are closed without an appreciation of the fact that the nerve has been divided, consequently there is no union and a permanent paralysis of the portion of the ulnar nerve beyond the section. This leads to atrophy of the intrinsic muscles of the hand and gives a characteristic deformity (Fig. 29).

FIG. 29.—TYPICAL DEFORMITY RESULTING FROM ULNAR PARALYSIS.

In all such injuries, the nerve should be carefully sought out and when divided should be most carefully sutured end-to-end. In primary sutures, the results are usually pretty good, and the return of function may be expected to occur in from 1 to 2 years. In secondary suture the operation is much more difficult and the chances of success are greatly diminished, although here, even if motor power does not return, the sensory disturbances, and particularly the trophic disturbances, will be greatly lessened as a result of the secondary suture.

AT THE ELBOW.—Another site at which the ulnar nerve is frequently injured is at the elbow, where it passes behind the inner condyle of the humerus. At this site, the nerve may be dislocated from its groove by excessive muscular action in people with an exaggerated valgus angle at the elbow. Full flexion is apt to cause a dislocation or a partial dislocation of the nerve trunk. If this happens frequently, it may lead to irritation of the nerve and to a chronic productive neuritis.

Often a fall upon the elbow, or an occupation which involves continuous pressure upon the inner aspect of the elbow, will cause a similar productive neuritis. In many patients who have suffered fracture of the internal condyle followed by persistent valgus deformity, the nerve may be injured and develop a chronic interstitial neuritis. In all of these instances, the symptoms consist of tingling and paresthesia, with a greater or less amount of pain and a greater or less amount of disturbance of the motor function of the nerve below the elbow. In cases of fractures of the internal condyle, a number of cases are on record where the injury occurred during childhood, but the symptoms of ulnar neuritis at the elbow did not develop for many years, sometimes 25 or 30 years after the original injury. In these cases the muscular atrophy and paresis resembled pretty closely those due to progressive muscular atrophy, and these cases are usually mistaken for that disease. Another curious thing, which has been noted by Spiller and others, is that occasionally in these cases there will also be an atrophy of the corresponding intrinsic muscles of the opposite hand. This is not easily accounted for, but has been observed to exist, and with the repair of the damaged ulnar nerve, both hands have shown improvement.

Of course, such a bilateral involvement is very apt to lead one astray in the diagnosis, and this is more particularly so as the evidence of nerve impairment begins so many years after the receipt of the injury.

One might, also, in this connection, refer to the interference with ulnar function in the case of cervical ribs. Here, also, the evidence of nerve disturbance does not appear for many years, although the cervical rib has, of course, been present during the entire life of the patient.

In all of these cases of interference with ulnar function at the elbow, the nerve should be exposed there by a longitudinal incision over its course, the aponeurotic wall over the canal should be divided, and the nerve elevated for inspection and palpation. As a rule, in these cases, there will be found a distinct bulbous thickening of the nerve, usually just behind and a little below the inner condyle, which bulb is due to a chronic interstitial neuritis. It may contain more or less nerve fibers or the trouble may have progressed to a point where the bulbous mass is almost entirely connective tissue. Of course, the symptoms in the individual case will depend upon the stage to which the neuritis has developed. With complete replacement of nerve by fibrous tissue, there will be complete loss of function. In the cases with very marked impairment of function and, of course, in all cases with complete loss of function, the bulbous mass should be entirely resected. In the case of fractures with a resulting prominent internal condyle, or where the internal condyle is naturally overprominent, the groove for the ulnar in the bone should be deepened and carefully smoothed, and the ulnar nerve wrapped in Cargile membrane and laid back in the groove. The aponeurotic covering of the canal is then sutured over it and the limb is put up in a splint in complete extension, in order to relax the drag on the nerve suture.

In cases where the interstitial process has not advanced very far and where there is only a beginning interference with motor control and a moderate paresthesia, the bony canal should be deepened, the nerve sheath split longitudinally to relieve tension, Cargile membrane wrapped around it, and the nerve replaced in its deepened canal and treated as above.

**Injuries to the Median Nerve.**—The median nerve, like the ulnar, is most frequently injured just above the wrist by broken glass, incised wounds, etc. The symptoms are generally sensory and confined to the palm of the hand, but there is also a paralysis in the abductor opponens group of muscles and the outer 2 lumbricales.

With a section of this nerve just above the wrist, there is usually combined a section of some of the tendons, although this nerve is so superficial that it may occasionally be the only structure divided in addition to the skin and subcutaneous tissues. After the diagnosis is made, primary suture should be done in all cases. After primary suture the prognosis is good and the return of power should be expected in about 10 months. After secondary suture, it is likely that sensibility will not become perfect, but the return of power in the muscles involved is apt to be good.

Another site at which the median is sometimes damaged is just above the elbow, where it is likely to be injured by one or the other of the fragments in a supracondylar fracture of the humerus. The types of injury are quite similar to those in the musculospiral nerve and if the symptoms of damage persist long enough for reaction of degeneration to occur, exploration and repair are indicated.

**Injuries Affecting the Median and Ulnar Nerves.**—The median and ulnar nerves are very apt to be injured simultaneously, especially in injuries just above the wrist, in which most frequently the ulnar is completely divided and the median only partially divided. The symptoms are a combination of those resulting from the 2 individual lesions previously described. The treatment should be along the lines there laid down.

Another type of injury in which these two nerves are both interfered with, is that known as *Volkmann's ischemic paralysis.* This condition usually follows fractures near the elbow, either of the humerus or of the bones of the forearm, and is essentially a condition of muscular damage, presumably as a result of splints which are too firmly applied and possibly, also, because of some inherent lack of resistance in the patient. The muscles undergo an acute degenerative process which results in their transformation into hard, fibrous tissue, giving the peculiar deformity of this type of injury (Fig. 30).

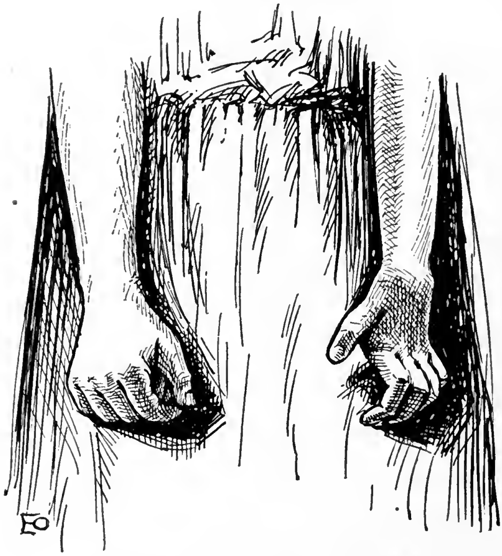


FIG. 30.—TYPICAL DEFORMITY IN VOLKMANN'S ISCHEMIC PARALYSIS (LEFT HAND). Note the different position of the thumb as compared with Fig. 29.

In many of the cases there develops evidence of damage to the nerves which, as a rule, is observed only after some few weeks and is probably the result of external compression by the cicatrized muscle tissue, although the nerve damage may be primary and in that case should have been noted at the time of the original injury. With stretching of the muscles and the use of hot baths and massage, frequently the firm fibrous mass may be made to become softer and more pliable, so that the fingers can be extended. With this improvement, there will usually result a disappearance of the symptoms of nerve pressure. If the nerve symptoms do not improve, it may be necessary to cut down upon the nerves in the upper portion of the forearm, free them from surrounding compression, and protect them from a recurrence.

**Injuries to the Cauda Equina.**—ANATOMICAL CONSIDERATIONS.—The spinal cord ends in the adult at the lower level of the first lumbar vertebra. The portion of the cord below the twelfth dorsal vertebra is known as the conus medullaris. The lumbar and sacral roots arise from the sides of the lower end of the cord close together, then pass downward and make their exit from the dural canal considerably below the level of their origins. The third sacral root leaves the cord just at the upper end of the conus. The ganglia of the posterior roots of these nerves lie extradurally, therefore intradural damage of the posterior roots leads to permanent degeneration.

CAUSES.—The cauda equina is injured, as a rule, by fractures or fracture dislocations of the lumbar or dorsolumbar spine. Below the level of the first lumbar vertebra, the injury usually involves the cauda alone. Above that level the conus medullaris is also very likely to suffer injury, although it is possible that an injury as high as the eleventh dorsal vertebra may involve only the nerves of the cauda. Occasionally there will result evidences of injury to the cauda equina without any obtainable evidence of bone injury, although this is a rare occurrence. These cases practically all make a spontaneous recovery.

RESULTS.—In injuries of the cauda alone, sensory symptoms are developed in the area of the third sacral roots and those below. This gives a saddle-shaped area of sensory disturbances involving the buttocks and perineum (Fig. 31).

There is paralysis of muscle groups according to the anterior roots damaged, and the paralysis is of the peripheral type. Often the paralysis is asymmetrically distributed on the 2 sides.

In injuries both of the cauda alone and of the conus alone, there is paralysis of the bladder and rectum, resulting in retention of urine and incontinence of feces. In injuries involving the conus alone there is a small area of anesthesia over the coccyx, in addition to the paralysis of the bladder and rectum. After a few months, lesions involving the cauda will show improvement, especially in the motor disturbances. If the posterior roots have been damaged sufficiently to cause degeneration, the sensory disturbances will be permanent because the injury has occurred between the trophic center, which is the ganglion of the posterior root, and the spinal cord. On the whole, prognosis is not very good. While the majority of cases of pure caudal injury show improvement, they very seldom progress to complete recovery. When the conus has been damaged, the symptoms are apt to remain permanent.

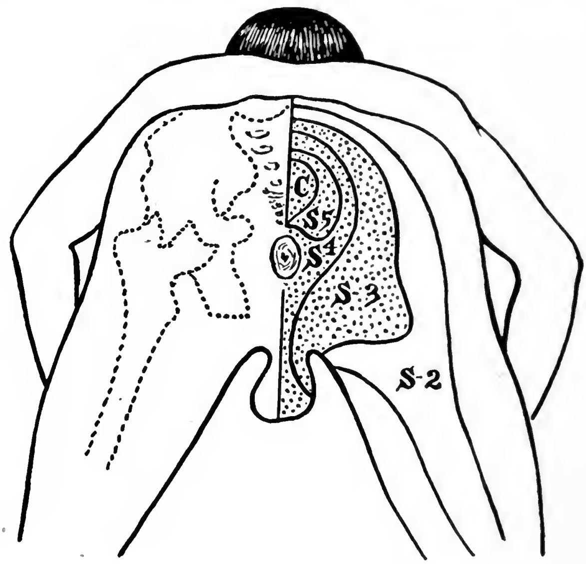


FIG. 31.—SENSORY SUPPLY OF PERINEAL REGION. (After Cushing.)

TREATMENT.—In those cases with symptoms of caudal and combined conus and caudal lesions, where the X-ray pictures show injury to the bony spine, laminectomy should be done at once, and such damage as is found, repaired, i. e., by end-to-end suture of divided or crushed motor roots, release from bony pressure, etc. Delay in the presence of continuing pressure may cause complete and permanent degeneration of the posterior roots, with corresponding permanent sensory disturbances.

In these cases, bilateral laminectomy is to be preferred, as the injury is bilateral and the manipulations require extra space. In late cases, when paralysis of the bladder and rectum have persisted, it is feasible to do intraspinal anastomosis, using a root or roots from above the site of injury, dissected for some distance extraspinally and pulled back within the dura (this to get the additional length of nerve necessary), and then anastomosed end to end with the third and fourth sacral roots, which have been divided at their exit from the cord and raised to meet the sound roots. One successful case by the use of this procedure has been reported by Frazier (11).

The suggestion has also been made of using this sort of nerve anastomosis for getting around transverse injuries of the cord. One of the chief difficulties in this type of nerve anastomosis is the very great tendency toward connective-tissue formation within the dura and resulting interference with proper regeneration in the 2 nerves sutured.

**Injuries to the Great Sciatic Nerve.**—Injuries to this nerve are infrequent, except in war, where they are very common. It may be injured in fractures of the pelvis, during manipulations for reducing a dislocated hip and especially in the manipulations for reducing congenital dislocations of the hip. Usually these injuries are only partial, and spontaneous recovery ensues after a considerable interval of time.

The great sciatic divides into the external and internal popliteal nerves just above the popliteal space. It is an interesting fact, however, that the 2 nerves run entirely separate right up to the sacral plexus and are simply bound together by an external sheath. Although there is no known reason for it, it is a fact that the external popliteal nerve suffers damage far more often than the internal popliteal. In gunshot wounds it is the portion of the great sciatic damaged in about 90 per cent. of the cases. The symptoms will depend upon the extent of the damage and will, of course, involve paralysis of the muscles whose nerve supply has been cut off; they will vary in the degree of loss of sensibility with the amount of nerve damaged, and also according to the site of the nerve damaged. Where the damaged portion of nerve is resected and end-to-end suture done, the first muscular return occurs, as a rule, in the hamstring muscles, in about a year. In 2 years, the leg muscles begin to show voluntary power, and complete recovery may occur after 3 years. In general, the return of function in the great sciatic is very much less prompt and less perfect than in cases of nerve damage in the upper extremity. For this reason the greatest care should be exercised to follow all the details of perfect technic, both at the time of operation and in the after-care, in order to get the best result possible in the individual case.

The internal popliteal nerve is seldom damaged, but when it is damaged and then repaired, its recovery is more prompt and more satisfactory than is that of the external popliteal.

The external popliteal nerve is usually injured just as it winds around the neck of the fibula. It often suffers from pressure damage as a result of ill-adjusted leggings or from falls into holes, where the leg is jammed, etc. In these cases, the damage is usually one of severe pressure, often accompanied by laceration of the nerve trunk. This type of injury is very apt not to undergo spontaneous regeneration. The paralysis may be complete or may involve only a portion of the muscle supply, according to the extent of injury to the nerve. In these cases the indication is always to do immediate exploration on discovery of the paralysis. As a rule this can be done readily under local anesthesia, the condition of the nerve determined and the proper means of repair adopted.

The other nerves of the lower extremity are rarely damaged, except in gunshot or stab wounds, in which case the wound should be enlarged and the nerve sutured.

See also Operations for Relief of Pain.

## OPERATIONS FOR TUMORS OF NERVES

**False Neuromata.**—The nerve sheaths are often, either inside or out, the seat of fibroma, sarcoma, or other new growth, which may seem to be a part of the nerve, although in reality the fibers pass through the tumor or beneath it and get around it, so that these growths are, therefore, not essentially tumors of the nerve tissue. These are known as false neuromata because they do not contain nerve cells or nerve fibers. They may cause nerve symptoms as a result of the pressure of the tumor causing secondary degeneration of the nerve. The symptoms will be those resulting from compression of the nerve.

Fig. 32.—Multiple Neuromata. (After Starr.)

**True Neuromata.**—True tumors of the nerves, known as neuromas, consist of nerve fibers which may be medullary or, more often, non-medullary, and are without nerve cells. In many of the tumors there is so much fibrous tissue that they are called neurofibromata. Neurofibromata are very apt to be multiple and in the majority of cases may run up into the hundreds. In one case, reported by Prudden, there were 1,000 tumors. As a rule, the tumors are small—about ½ cm. in diameter—but occasionally they grow to be of a diameter of 10 cm. Sometimes they appear on the sensory nerves of the skin and in these cases may be readily felt and are usually tender. These tumors are often designated as *fibroma mollusca,* or *tubercula dolorosa.*

Another form of nerve tumor is what is known as *plexiform neuroma,* this type being found most frequently about the head, face and neck. It consists of a great enlargement and plexiform arrangement of nerve fibers, which are not painful nor sensitive to touch.

**Treatment.**—In most cases the multiple neuromata cause no symptoms unless they become large enough to cause pressure, in which case pain and, possibly, motor disturbances result. These neuromata cannot be removed because they are so numerous. Occasionally neuromata of large size are removed to prevent the mechanical disturbances arising from their size and situation.

In removing *false neuromata* the nerve sheath should be split longitudinally, the tumor grasped and the nerve bundles dissected away from it very carefully, so as to cause minimum damage to them. In *true neuromata* involving the nerve tissue proper, where removal is necessitated because of pain or motor paralysis due to pressure, transverse section above and below the tumor should be followed by immediate end-to-end suture.

In some of the neurofibromata there may occur myxomatous, cystic or sarcomatous degeneration. With the development of sarcoma, pain and paralysis are apt to appear from pressure. Of course, sarcoma must be removed, but is very apt to recur elsewhere.

The neuroma which develops at the end of a divided nerve in an amputation stump is usually the result of long-continued moderate irritation. These neuromata are usually painful and very tender to the touch. If nerves at the time of amputation were resected sufficiently high, neuromata would not form. Once painful neuroma has occurred, the only treatment is incision down to and excision of it and as much of the nerve trunk as is feasible.

## OPERATIONS ON THE CRANIAL NERVES

Surgical interference is indicated in disturbances of the cranial nerves resulting in great pain, as in trigeminal neuralgia; in motor disturbance, as in facial palsy; and in certain other functional disturbances, as in persistent tinnitus aurium, and in a certain small number of cases in which the gastric crises of tabes seem to have their origin in pneumogastric disorder.

The first four cranial nerves will not be considered here inasmuch as their disturbances are either non-surgical or result indirectly from the pressure of neighboring lesions, the treatment of which will be considered under the section on the skull and brain.

### FIFTH CRANIAL NERVE

#### *Trigeminal Nerve*

The fifth cranial nerve, or trigeminal, as it is frequently called, has stimulated more surgical interest and the development of more ingenious technic than any other nerve in the human anatomy.

The indication for surgical interference is always intractable unbearable neuralgia, and this has usually existed, either persistently or in attacks which occur more frequently as time goes on, over long periods of time.

**Anatomical Considerations.**—The nerve arises by a small anterior motor and a large posterior sensory root, which emerge close together from the pons above its center, run forward to the upper edge of the petrous bone, where they pass through an opening in the dura above the internal auditory meatus, and then between the dura and petrous bone to the depression near the apex of the petrous bone in which the Gasserian ganglion is ensconced, and which is usually just internal to the entrance of the middle meningeal artery to the skull. Only the sensory root enters the ganglion. The motor root lies under the ganglion, passes out of the skull, and then joins the inferior maxillary branch from the ganglion.

The dura splits so as to ensheath the ganglion, which is said also to have another thin envelope in immediate contact with its surface. The blood supply to the ganglion comes chiefly from beneath.

From the ganglion arise 3 sensory trunks.

THE OPHTHALMIC.—The upper or ophthalmic trunk runs forward along the cavernous sinus and divides into 3 branches which enter the orbit through the sphenoidal fissure. The lachrymal branch has no surgical interest. The frontal branch emerges from the orbit in 2 parts, the supra-orbital, which passes through the foramen of the same name, and the supratrochlear, which emerges nearer the median line. These 2 between them supply sensation to the integument of the forehead and cranium as far back as the occiput. The nasal branch enters the cranial cavity from the orbit through the anterior ethmoidal foramen and then passes into the nasal cavity through the cribriform plate. It supplies sensation to the upper anterior mucous membrane of the nose and to the tip and ala of the nose externally.

THE SUPERIOR MAXILLARY.—The superior maxillary, or second division, passes forward through the foramen rotundum, across the sphenomaxillary fossa, through the sphenomaxillary fissure into the infra-orbital canal, from which its terminal branches emerge at the infra-orbital foramen. In its course it gives off branches which supply sensation to the mucous membrane of the cheek, palate, pharynx, and nose, to the teeth of the upper jaw, and to the skin of the nose, cheek and temporomalar region.

THE INFERIOR MAXILLARY.—The inferior maxillary, or third division, passes downward through the foramen ovale and is joined just outside the skull by the motor root. This combined nerve then divides into an anterior branch, almost entirely motor, which innervates the muscles of mastication, and a posterior branch, almost entirely sensory, which supplies sensation to the auriculotemporal region, the lower face, the tongue and floor of the mouth through the lingual nerve, the teeth and integuments of the chin through the inferior dental.

**Indications for Treatment.**—Concerning the choice of methods in treatment, there will always be discussion, but there is unanimity in the feeling that medical treatment should always be given first chance, and that with it should always be combined careful attention to the mouth (especially to the teeth, with regard to erosion of the enamel or the presence of pyorrhea), to the nasal cavity and accessory sinuses, and to the contents of the orbit, to eliminate any causes of reflex disturbances and pain.

Such treatment should be reasonably prompt and durable in its effect. If, in spite of it, the attacks of pain become more frequent or more severe or both, then some further means of relief should be given while the patient is still in good general condition, and before any of the disastrous drug habits, of which these patients are so commonly the victims, have been fixed.

When the time for surgical interference has arrived a variety of methods is presented for choice. These methods vary inversely as to the risk involved and the prospect of permanency of relief from pain.

### Peripheral Operation

When the pain is distinctly peripheral and is confined to one branch of the nerve, many men, notably Moschcowitz, believe that permanent relief may be given by a properly performed peripheral operation. In general the steps of the peripheral operation consist in the exposure of the nerve at its foramen of exit, its slow avulsion by the Thiersch method, and then the interposition of some obstruction to the reunion of the central and distal ends of the nerve if regeneration occurs.

Fig. 33.—Silver Rivets. (After Moschcowitz.)

The avulsion method consists in freeing the nerve, at its foramen of exit, from surrounding connective tissues, then grasping it with a curved clamp, and then very slowly twisting it about the clamp so as to put the central end on the stretch. After this slow, steadily increasing strain is applied for some minutes, the nerve breaks centrally and some few centimeters come away. The twist is now reversed, and the peripheral portion of the nerve removed in similar fashion. The fifth nerve is notoriously inclined to regenerate and cause a return of pain so that this removal of a long stretch of nerve is important if a permanent result is to be hoped for.

In addition to the avulsion, regeneration may be further prevented by plugging the foramina of exit with a foreign body, of which the most satisfactory seems to be the silver rivet of Moschcowitz, made in different sizes and with a malleable head which can be moulded to fit the bone surrounding the foramen (Fig. 33). The soft tissues are closed over the rivet with layer sutures and the wound dressed without drainage.

**On the Supra-orbital.**—The first division of the nerve is very rarely the seat of neuralgia, which is fortunate, since this method is not well adapted to the supra-orbital, which is the only important accessible branch, since its exit is through a notch rather than a foramen and there is no satisfactory method of preventing reunion. When this nerve is to be exposed for any reason, the incision is made in the eyebrow, parallel to its long axis, just above the supra-orbital notch, which is easily felt. The incision carried through the soft tissues exposes the nerve lying upon the bone and running at right angles to the line of incision (Fig. 34).

This is avulsed in the manner previously described, and the wound closed without drainage.

**On the Superior Maxillary.**—The second branch from the ganglion, the superior maxillary, is often the primary seat of neuralgia. When the pain is distinctly peripheral, avulsion at the infra-orbital foramen may be indicated. When the pain primarily involves the molars of the upper jaw, it indicates that the disease is well back in the main trunk of the second branch and that, therefore, avulsion of the infra-orbital is not likely to stop the pain.

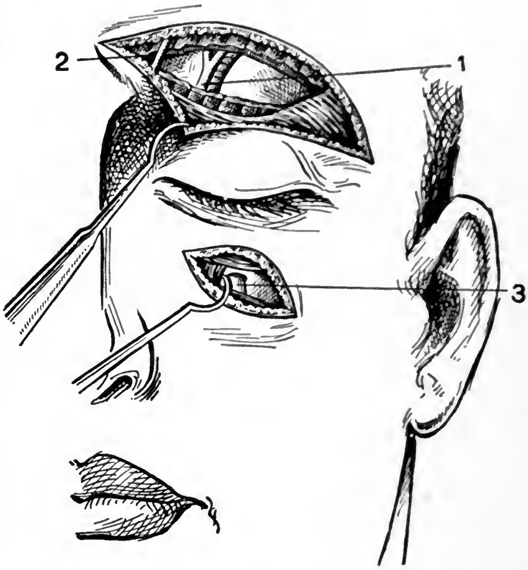


FIG. 34.—1, SUPRA-ORBITAL NERVE AND ARTERY; 2, SUPRATROCHLEAR NERVE; 3, INFRA-ORBITAL NERVE EMERGING FROM THE INFRA-ORBITAL FORAMEN.

In those cases where the peripheral operation is indicated, the patient is placed supine on the table with the head slightly raised. When the foramen cannot be located by touch, it may be satisfactorily indicated as follows: Draw a line from the supra-orbital notch, which can always be felt, down between the bicuspids of the upper jaw and also those of the lower jaw. This line passes through the supra-orbital notch, the infra-orbital foramen, and the inferior dental foramen (Fig. 36). If, now, another line be drawn parallel to and about 8 to 12 mm. (according to size of face) below the inferior margin of the orbit, it will cross the preceding line over the infra-orbital foramen. The line of incision should be about 2.5 cm. long, should begin to the inner side of the foramen, and should run down and outward so as to avoid damage to the fibers of the facial as they enter the orbicularis muscle. If local anesthesia is to be used, and it frequently suffices, the tissues in the preceding line are infiltrated and after an interval of 5 minutes the incision is carried through skin, fat, and orbicularis muscle down to bone. The foramen is usually found at the bottom of a small depression filled with fat, and from it radiate the terminal branches of the infra-orbital nerve. (Figs. 34 and 35.)

If avulsion is to be practiced, a long slender needle must be passed as far backward along the nerve as possible and some local anesthetic must be injected to prevent the pain that would otherwise be caused. This step would not be necessary if general anesthesia were used unless one were practicing anoci-association as described by Crile.

The whole nerve, after being freed from fat and connective tissue, is grasped with the curved clamp and avulsed by the method previously described. A

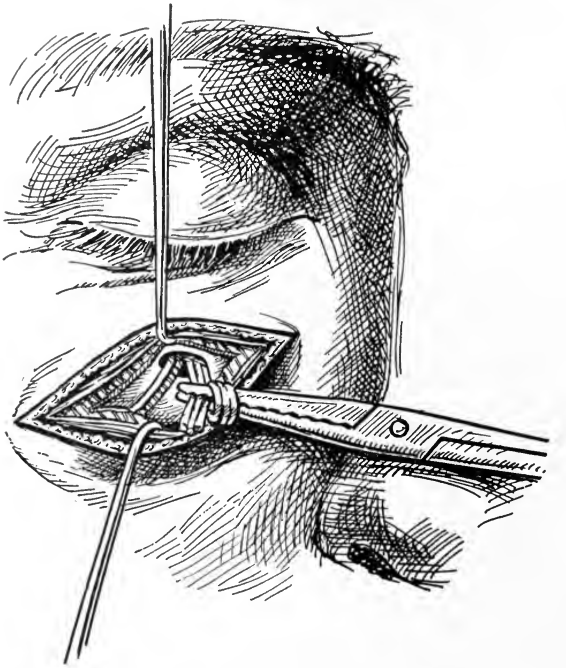


Fig. 35.—Avulsion of Central End of Infra-orbital Nerve.

silver rivet of a size to fit snugly is driven into the foramen, and the malleable flange is accurately moulded to the surrounding bone. The soft tissues are closed by catgut layer sutures, the skin by fine silk. No drainage is used. The scar lies in the line of natural wrinkles and will be scarcely noticeable.

Another method which avoids an external scar consists in making a longitudinal incision in the gingivolabial fold of mucous membrane over the canine fossa down to the bone and then stripping up all the soft tissues until the foramen and nerve branches are exposed. While this method does not leave a visible scar, the working space and illumination are much less satisfactory, and the chances of infection from the mouth are considerable.

**On the Inferior Dental.**—The inferior dental nerve is the one most frequently involved with neuralgia. It makes its peripheral exit from the mental foramen. This foramen lies on the line previously mentioned, at a point about midway between the alveolar and inferior borders of the jaw. This point will be found to be nearly submucous.

A longitudinal incision is made in the gingivolabial fold just below the two bicuspids down to bone, from which the soft tissues are separated until the foramen and the nerve coming from it are exposed. The lower lip can be retracted downward readily and good light and working room obtained. After the nerve is avulsed and the foramen plugged, the wound may be closed with

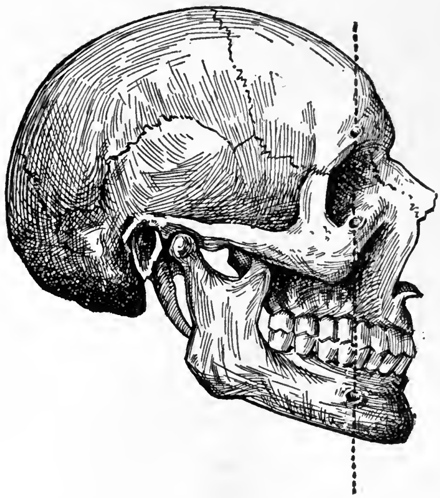


Fig. 36.—A Straight Line Running from Supra-orbital Notch and Passing Between the Two Bicuspid Teeth Will also Run Through Infra-orbital and Mental Foramina.

a few sutures of silk through the mucous membrane, or the tissue may be allowed to fall into natural apposition without any sutures.

**Results of Peripheral Operation.**—These peripheral operations are easy, simple, and free from danger. They sometimes give permanent relief, often give relief for 1 or 2 years, but, as a rule, in the majority of cases have proven unsatisfactory in the long run.

When the neuralgic process involves the nerve trunks back near the base of the skull so that operation of the peripheral type is contra-indicated, three modes of procedure are open to consideration:

1. Resection of the nerve trunks at their exit from the base of the skull.
2. Alcohol injections into the nerve trunks.
3. Intracranial operation on the Gasserian ganglion.

## 1. Resection of the Nerve Trunks at Their Exit from the Base of the Skull

The various procedures devised for this purpose are all mutilating, bloody, tedious, and difficult. They involve as much intrinsic risk as the intracranial attack upon the Gasserian ganglion and in addition give no guarantee of permanent relief from the neuralgia for which they are done, because these nerves show a surprising power of regeneration, and this regeneration is usually followed by a recurrence of the pain. For these reasons such operations are not worth while and will not be described.

## 2. Alcohol Injections into the Nerve Trunks

Alcohol injections into the nerve trunks at their exit from the skull have had a considerable vogue for several years and have many enthusiastic advocates.

**Advantages.**—The advantage of the method lies in the fact that by an operation which is simple and comparatively free from danger, immediate relief can be given to these sufferers without their being incapacitated for work for more than a few hours.

**Disadvantages.**—The disadvantages are several: The procedure is carried out in the dark, the operator feeling about in the tissues with the point of the needle until he strikes the nerve trunk. It not infrequently happens that even an experienced man will fail to find the trunk itself and have to satisfy himself with injecting the alcohol into what he conceives to be close proximity to the nerve.

At best the injection, even when put into the nerve itself, gives relief only temporarily (6 to 12 months), and must be repeated when the pain recurs. If injections are repeated too frequently, the muscles of mastication are apt to become indurated and so interfere with the free mobility of the lower jaw. When, in difficult cases, the nerve itself is not found, but the alcohol is injected into the tissues in the region of the nerve, the relief is not so durable, and the surrounding tissues are more indurated.

**Instruments.**—The instruments used consist of a needle 12 cm. long and 1.75 mm. in diameter, rather blunt-pointed, and fitted with a stylet which comes out flush with the needle tip. This needle is graduated in centimeters. The proximal end of this needle is constructed to make a tight joint with the threadless nozzle of a glass syringe, which will hold 2 c. c. or more (Fig. 37).

Where much induration of the soft tissues has occurred, it is sometimes necessary to use a slenderer and sharper needle in order to penetrate to the nerve. Such a needle is more apt to cause injury to vessels, is more flexible, and so less under control for prodding in different directions in the depth, and is less apt to give the characteristic pain upon piercing the nerve.

**Solution for Injection.**—The solution used varies with different writers. The one used by Patrick (59) in his large series was:

| | gm. or c. c. | |
|---|---|---|
| Cocain muriat .................... | | 1 (gr. ii) |
| Alcohol ............................ | 13 | 5 (dr. iiiss.) |
| Aq. dest. q.s.ad..................... | 15 | 5 (oz. ss.) |

M.

Sig. Usually about 2 c. c. at an injection.

**Anesthesia.**—Usually a general anesthetic is unnecessary and undesirable, for the conscious patient is able to help very decidedly in determining whether the needle is in the nerve or not.

**Contra-indications.**—The first or ophthalmic division of the nerve should never be injected, since its close proximity to very important vessels and nerves renders the procedure too hazardous. For analogous reasons the injections of the Gasserian ganglion through the basal foramina do not seem justifiable.

**Technic.**[1]—GENERAL CONSIDERATIONS.—The needle penetrates the skin somewhat more easily if the stylet is slightly withdrawn until the subcutaneous tissues are reached, when it is fully inserted to give better protection to the vessels of the deeper structures. The needle is pushed steadily and slowly in the direction where the nerve trunk should be, until it has reached the depth at which the nerve is usually found. If the needle, during its progress, enters the nerve sheath, the fact is made known by a pain in a part or the whole of the peripheral distribution of the nerve. This pain varies greatly in degree, and is sometimes only a "pins and needles" sensation.

If the needle has been inserted in the proper direction and to the proper depth without eliciting any of these sensory disturbances, the point should be

[1] After Hugh T. Patrick.

pressed upward, downward, forward, and backward to see if in some one of these directions it will not elicit the nerve pain and indicate in what direction it should be then inserted. The needle is partially withdrawn and re-inserted in the indicated direction. When the attempts thus far have failed, one must systematically try to feel out the nerve by pushing the needle point in various directions in the zone in which the nerve must be located.

When the characteristic pain indicates that the needle has entered the nerve sheath, the stylet is withdrawn, and the syringe with the solution is fitted into the needle. Two c. c. are injected steadily into the nerve. Too sudden or forceful injection of the alcohol causes unnecessary pain.

In case none of these various attempts have elicited the characteristic pain, the needle should be inserted to where the nerve ought to be and a little alcohol solution injected with a spurt. This will sometimes elicit the pain when the point of the needle has failed to do so. If the pain is thus elicited, the regular dose of alcohol should be injected with the feeling that it is in the nerve or in close proximity to it. If all of these methods have failed to discover the nerve trunk, the patient should be asked to return a day or two later, when a second attempt may be more successful.

After the alcohol has been injected, the syringe is detached and the stylet replaced in the needle, which is then left in situ for a few minutes to permit hemostasis along the track of the needle, which is then slowly withdrawn. After a few moments of pressure over the skin puncture a little collodion is used to seal it and the procedure is finished.

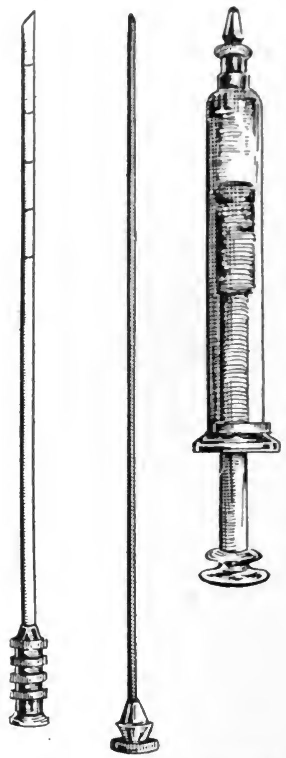
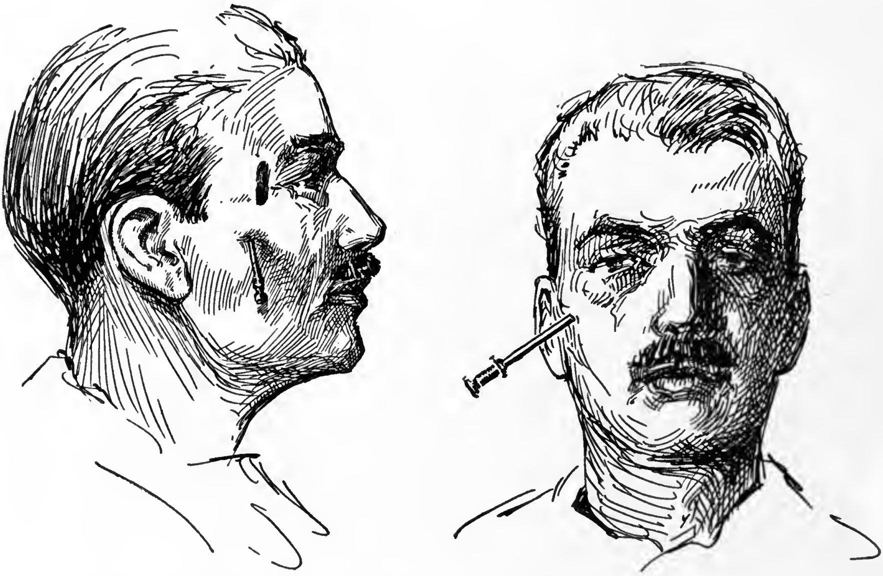


Fig. 37.—Glass Syringe, Needle and Stylet for Alcoholic Injection of Fifth Cranial Nerve.

In the interval between the injection of the alcohol and the withdrawal of the needle sensory tests should be made of the skin area supplied by the nerve supposedly injected. If deep pin pricks over the whole area supplied cause no pain at all, the injection has been perfectly successful. If there is only partial analgesia, or if the analgesia is delayed in appearing, the injection has been near rather than into the nerve, and it may be expected that the relief from pain will be of short duration.

It frequently happens in these tic douloureux cases that sensory stimulation of a surface supplied by one branch of the nerve will cause spasms of pain in an entirely different branch. Patrick calls the field in which stimulation starts the distant pain the "dolor-genetic zone," and states that the nerve supplying this zone must be injected before the distant pain can be stopped.

INJECTION OF THE SUPERIOR MAXILLARY NERVE.—The point of entrance for the needle is at the lower border of the zygoma, 0.5 cm. behind the line of the posterior edge of the orbital process of the malar bone (Figs. 38 and 39). This edge is easily felt. The needle is inserted in the sagittal plane and slanted upward so that at a depth of 5 cm. the point would be about on the level of the lower end of the nasal bones. At this point the needle is supposed to



FIGS. 38 AND 39.—SIDE AND FRONT VIEW OF POSITION OF NEEDLE FOR INJECTION OF SECOND DIVISION OF FIFTH NERVE.

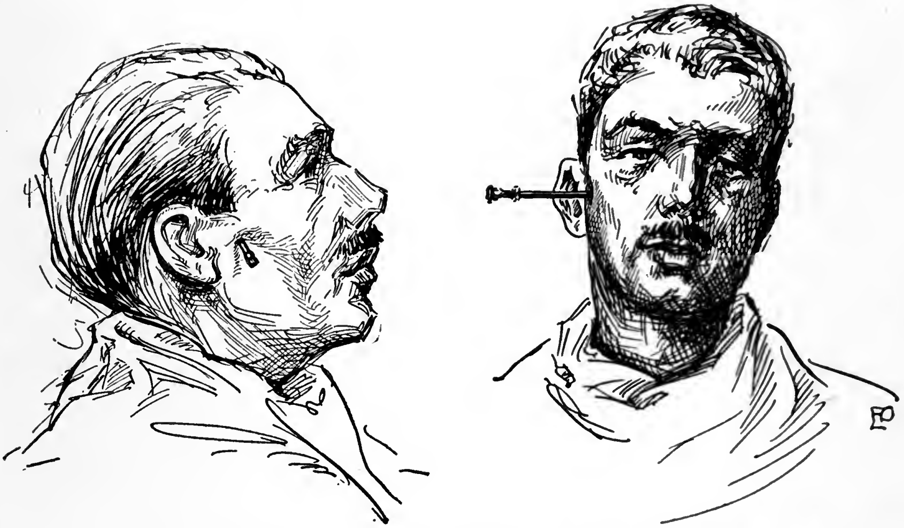
enter the nerve as it comes into the sphenomaxillary fossa from the foramen rotundum.

Variations in the bony contour of different skulls make it necessary to modify the procedure in certain cases. The zygomatic arch is sometimes high, sometimes low, and sometimes the anterior end of it slants downward at a fairly sharp angle. The width of the orbital process of the malar bone varies considerably. These factors influence the entrance and slant of the needle. The coronoid process of the lower jaw may be so far forward of its usual position as tc necessitate the entrance of the needle well in front of and below the site above mentioned. In these cases the needle may strike the posterior edge of the superior maxilla if it be well rounded and prominent, and it may then be necessary to pass the needle through the coronoid notch in the attempt to reach the nerve.

In cases with atypical bony conformation the operator, to be successful, must be able to visualize the relation of the nerve to the bony processes, choose the modification of the approach, and then strike it in the dark so to speak.

In general, the needle should be inserted about 5 cm. to reach this nerve, although the distance will be slightly less in patients who are narrow in the interzygomatic diameter, and slightly more in those with a wide diameter.

Two dangers are inherent to this injection: (1) entrance into the orbit through the sphenomaxillary fissure, which comes from slanting the needle too far forward and can always be avoided by attention to this detail; (2) paralysis of the sixth nerve, which lies deeper than the nerve under consideration but in the line of progress of the needle. To avoid this latter trouble, when the needle is in position for the injection, the alcohol is sent in a few minims at a time, and the power of external rotation of the eye constantly tested. On the first sign of weakness in this motion, the injection is stopped



FIGS. 40 AND 41.—POSITION OF NEEDLE FOR INJECTION OF THIRD BRANCH OF FIFTH NERVE.

and the point of the needle is made to seek out another part of the nerve farther away from the sixth, when the injection may be completed. With these precautions, damage to the sixth, if it occurs at all, will be slight and transient.

INJECTION OF THE INFERIOR MAXILLARY NERVE.—The point of entrance for the needle selected by Levy and Baudoine is just below the zygoma and 2.5 cm. in front of the anterior root of the zygoma, which runs just in front of the external auditory canal (Figs. 40 and 41). In patients with long narrow heads this distance is satisfactory, but in short wide heads it is too great. As a matter of practice, the point will be found to be on the lower border of the zygoma about halfway between perpendiculars from the anterior root of the zygoma and the posterior edge of the orbital process of the malar bone. The needle is inserted inward, somewhat backward, and slightly upward, for a distance of about 4 cm., when it should be close to the nerve. The depth of the nerve from the surface varies from 4 to 5.5 cm., according to the size and shape of the head.

A helpful landmark is the external pterygoid plate, which lies at about the same depth but a little anterior to the nerve. If the needle be made to strike the pterygoid plate at the start, it can be worked backward at about the same depth and made to strike the nerve with more certainty than by methods having no fixed landmarks. When the sigmoid notch is very shallow it may be necessary to have the patient open the mouth to permit the needle to pass. If the needle passes too close to the inferior maxillary joint, this is apt to become stiff and painful for a time. When the nerve is pierced there is usually pain in the lip, jaw or tongue.

**Results.**—From the foregoing it is obviously more or less a matter of chance as to whether the needle point enters the nerve sheath or not, and when it does not the results are sure to be unsatisfactory.

Following the injection there is always considerable swelling of the soft parts, which usually subsides quickly. Occasionally there will be a very unfortunate sequel. One woman who had had several injections for a severe neuralgia of the inferior branch with relief for several months at a time, after her last injection had immediate marked swelling, discoloration, and pain in the whole side of the face and head. This was soon followed by sloughing of the skin and subcutaneous tissues from the midline of the vertex, down along the front of the ear to the lower border of the lower jaw, forward to the angle of the mouth, upward to the bridge of the nose, outward under the eye, and upward across the temple to the vertex. Several other such cases have been reported, but fortunately the percentage of such complications is not high.

If it is necessary to give several injections, especially if the intervals be short, there is a tendency for the muscles of mastication to become infiltrated, with resulting interference with the free mobility of the lower jaw.

The results of this procedure are at best temporary, the relief lasting from 6 to 12 months (rarely 4 years), according to the severity of the disease and the accuracy with which the alcohol was placed in the nerve trunk. There is no mortality connected with the procedure, and the percentage of serious complications is low.

From its temporary effect and the uncertainty involved in its application, it would seem to be best reserved for those cases unable, for one reason or another, to obtain the permanent relief afforded by the Gasserian operation and also for the temporary relief of patients who wish to get into condition to have the Gasserian operation done.

### 3. Intracranial Procedures for Tic Douloureux

It is generally conceded, even by those who are enthusiastic about the alcohol injection treatment, that the only sure and permanent relief from tic douloureux lies in a properly performed intracranial operation upon the Gasserian ganglion or its posterior root.

Many authors and the profession at large, who constantly refer to the great danger and high mortality of this operation, have gained their entirely erroneous impressions from the statistics made up before the operation had been brought to its present high stage of perfection.

Frazier, quoting 230 cases reported by Horsley, Lexer, Döllinger, Cushing and himself, places the mortality at the astonishingly low figure of 3.7 per cent. Moreover, since the technic has been improved, injury to the eye, either motor or trophic, is very unusual, and the sequelæ resulting from traumatism to the brain substance are almost unknown.

Such being the case, this operation must be removed from the category of extrahazardous procedures when properly performed. This removes the chief prop from the support of those who advocate the trial of the various temporizing measures until such time as the sufferer has developed a fixed drug habit or is physically exhausted or both. In spite of the fact that this type of patient has furnished the majority of operative cases, the refinements of technic have reduced the mortality to the very low figure quoted above. When patients, properly selected, are operated upon early in the course of the disease, this mortality will be still further reduced and they will be saved an enormous amount of unnecessary suffering.

**Indications.**—A case should be considered appropriate for intracranial operation under the following conditions:

1. When prompt and definite relief has not followed:
   - Measures for the improvement of the general health, especially the regulation of the digestive tract and diet;
   - Proper dental care of the mouth, especially with regard to enamel erosion and the presence of pyorrhea alveolaris;
   - Appropriate treatment of abnormalities or infections within the nose or its accessory sinuses, which might be the cause of reflex irritation.
2. When the tic involves the ophthalmic branch. This is the least frequent type, but is also the least amenable to any of the various forms of peripheral treatment.
3. When the tic involves two of the branches of the ganglion, thus indicating a deep origin of the irritation.
4. When the attacks are becoming more severe and more frequent in spite of tentative treatment.
5. When, in borderline cases, satisfactory relief has failed to follow the use of one or more of the peripheral forms of treatment previously outlined.

**Anatomical Considerations.**—The large sensory and relatively small motor root of the ganglion pass from the pons forward beneath the tentorium cerebelli, through a small aperture in the attachment of the tentorium at the upper edge of the petrous bone, and then forward and a little downward to the cavum Meckelii near the tip of the petrous bone. Here the ganglion lies inclosed in a special fibrous sheath known as the *dura propria,* outside of which is an envelope from the regular dura. The blood supply consists of numerous small vessels which enter the ganglion from beneath, which accounts for its firm fixation to the underlying structures and for the sharp bleeding which follows attempts to raise it from its bed. It gives off 3 branches, the first running along the cavernous sinus in intimate relation with it, and the third, fourth, and sixth cranial nerves; the second entering the foramen rotundum; and the third and largest entering the foramen ovale. The motor root does not enter the ganglion but runs beneath it and out through the foramen ovale with the third branch, which it joins soon after leaving the cranial cavity. All of these branches are surrounded by extensions of the dural sheath which envelops the ganglion.

The depth of the ganglion from the surface varies somewhat with the shape of the skull, being deeper in broad skulls and more superficial in narrow skulls.

The relation of the middle meningeal artery is of importance. This vessel enters the middle fossa through the foramen spinosum, which is quite variable in its relation to the ganglion. It usually lies external to the ganglion. It may lie between the foramen rotundum and ovale, or it may lie on a plane posterior to the latter, in which case it obscures the third branch and also the posterior root, and should then be doubly ligated and divided.

The upper branch of the facial nerve runs obliquely upward and forward, crossing the zygoma on a line running from the external auditory meatus to the external angular process of the frontal bone. This nerve supplies the orbicularis muscle, the integrity of which is so important in the prevention of the keratitis which is so apt to develop with the sensory and trophic disturbances which follow the extirpation of the ganglion. The incision should be so planned as to avoid injury to this nerve.

**Technic.**—GENERAL CONSIDERATIONS.—The methods of entering the skull and the instruments used have already been described in another section.

A brief review of the stages leading up to the present best method of handling the ganglion itself will be worth while. Upon what is to be done to the ganglion will depend largely the choice as to the method of its exposure.

Primarily, when it was thought necessary to remove the ganglion complete, if a radical cure was to be obtained, the ganglion was exposed by one of the various methods, the posterior root divided, the ganglion grasped with a strong clamp, and, after division of the middle and inferior branches, was avulsed. This crude technic resulted frequently in the incomplete removal of the ganglion and in serious damage to the cavernous sinus and the cranial nerves running along its wall in close proximity to the ganglion. It was this type of operation that gave such a bad reputation for danger, mortality, and serious complications to the intracranial method of relief for tic douloureux. The prejudice so originated has remained firmly fixed in the mind of the profession, to this day, in spite of the immensely improved results which refinements in technic have demonstrated in a large series of cases.

Later it was noted that pain in the ophthalmic branch was unusual and, inasmuch as the difficulties and dangers of the operation were chiefly related to the removal of this branch, the procedure was simplified by removing only the second and third branches with the corresponding part of the ganglion. This technic gave as much relief from pain and, in the avoidance of operative difficulties and dangerous sequelæ, was infinitely superior.

Then Spiller demonstrated that division of the posterior root of the ganglion would cause permanent degeneration of the sensory portion between the ganglion and the pons. In 1901 Frazier first applied this modification of the technic and divided the posterior root instead of attempting to remove the ganglion. Various operators now expose the posterior root, pass a small hook beneath it, and avulse the root from the pons, leaving it or excising it just proximal to the ganglion. There are objections to this process of avulsion. It has been demonstrated repeatedly that simple section of a posterior sensory root between its ganglion and the central nervous system causes permanent degeneration and loss of function of the divided nerves. This holds true, not only of the spinal, but also of the fifth and seventh cranial nerves. If simple section of the root will cause permanent relief from pain, which it has repeatedly done, there can be no valid reason for the added traumatism caused by avulsing the root with the chance of causing superficial hemorrhage on or in the pons.

No cases have been reported in which symptoms of damage to the pons have followed avulsion of the root, so possibly this objection is chiefly theoretical. Nevertheless, the surgical maxim should hold, "gain the required result with the least amount of traumatism."

Another consideration is of real significance. The motor root of the ganglion is smaller than the sensory and is covered by it, so that it is practically impossible in most cases to separate them and divide only the sensory root. In avulsing the root the motor is torn away with the sensory portion and permanent paralysis of the muscles of mastication results, including the temporal on the side of operation. This causes not only defective jaw action, but also marked deformity resulting from atrophy of temporal muscle.

If, on the other hand, the sensory and motor roots are simply divided proximal to the ganglion, the sensory root undergoes permanent degeneration with loss of function, while the motor root, being divided distal to its trophic center, which lies in the central system, will undergo regeneration with return of function after several months. This sequence of events has followed this technic in 2 cases in my hands, and has also followed in the seventh nerve case reported elsewhere.

Therefore, the simplest and best technic lies in exposure of the combined roots of the ganglion, followed by simple section, leaving the cut ends approximated so as to favor motor regeneration. In the very small percentage of cases in which the sensory root can be separated from the motor root and alone divided, this, of course, should be done.

Another advantage of the root section method lies in the almost complete elimination of danger to the cavernous sinus and the third, fourth and sixth nerves, and the great saving in time of operation, as the removal of the ganglion was always the most bloody and tedious part of the procedure.

For the purpose of root section, not nearly so large an opening in the skull is necessary. The Hartley-Krause osteoplastic flap gives ample room, and, with the Hartley-Kenyon motor saw, can be quickly and accurately turned down.

For the extirpation of the ganglion it gives very satisfactory results. The one objection lies in the wide exposure of the brain cortex to pressure by the retractors, although trouble from this source almost never occurred in the hands of Dr. Hartley. The method is described elsewhere.

For the root operation the auriculotemporal exposure, as described by Frazier, and the infratemporal exposure, as described by Cushing, are undoubtedly the best.

THE SPILLER-FRAZIER METHOD (DIVISION OF THE SENSORY ROOT BY THE AURICULOTEMPORAL ROUTE).—From ½ hour to 1 hour before operation the patient is given morphin, gr. 1/6, and atropin, gr. 1/100. Nitrous-oxid-ether anesthesia is induced, the patient placed in the sitting posture, and a horse-shoe-shaped flap made, beginning at the middle of the zygoma and ending behind and a little below the helix of the ear. The musculocutaneous flap is reflected, and bone over an area 3 cm. in diameter is removed. The center of this hole will be about on the level of the entrance of the posterior root into the ganglion. This opening is enlarged downward by the rongeur as far as the infratemporal crest, which is on a level with the base of the skull. The dura is separated from the base of the fossa and from the anterior surface of the petrous bone. When the middle meningeal artery, coming up through the foramen spinosum, is encountered, it is ligated and divided. Instead of using the ordinary ligature, I have found the silver clip devised by Cushing more convenient for the occlusion of this vessel. Elevation of the dura for a slight distance further toward the median line will expose the region of the ganglion as it lies surrounded by its dural envelope in the cavum Meckelii near the inner end of the petrous bone. The inferior dental branch is easily identified as it runs through the foramen ovale. Just in front of this branch the dural sheath is incised and the incision is carried backward over the upper surface of the ganglion until the posterior root is exposed. One can usually see the small foramen through which the root crosses the ridge of the petrous bone to pass beneath the tentorium to the pons.

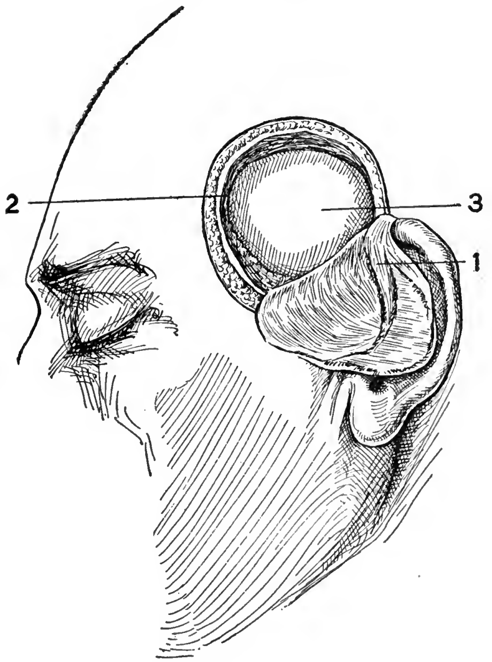


FIG. 42.—AURICULOTEMPORAL APPROACH TO THE GASSERIAN GANGLION (1). 1, Musculocutaneous flap; 2, skull trephined; 3, dura. (After Frazier.)

The root is gently hooked up and divided with scissors, or it may be avulsed.

For reasons previously given, the simple division is much to be preferred. The motor root should be avoided when possible. During the course of the operation hemorrhage is controlled by means of narrow strips of gauze passed in on either side beneath the elevated dura, in such a manner as not to interfere with operative progress.

When the sensory root has been divided, the anesthetic can be stopped, be-

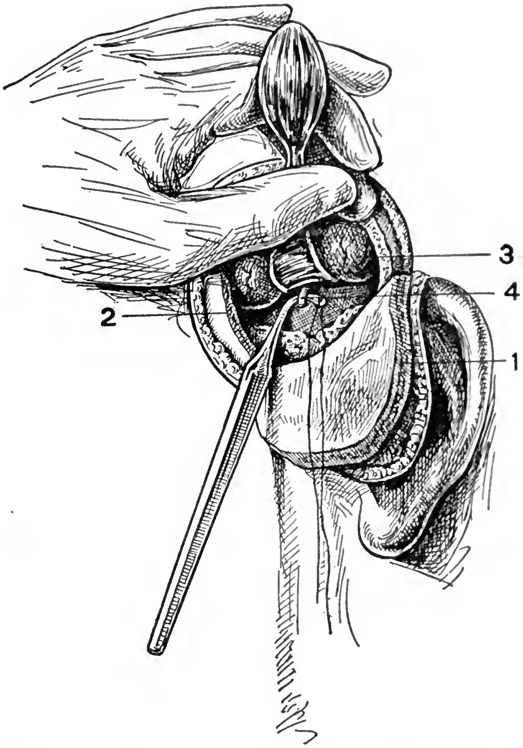



Fig. 43.—Auriculotemporal Approach to the Gasserian Ganglion (2). 1, 2, and 3 are the same as in Fig. 42; 4, middle meningeal artery coming up through foramen spinosum with a ligature carrier passed around it. (After Frazier.)

cause the operative field has now been rendered insensitive. The wound is carefully closed by suture in layers, using catgut for the deeper structures and silk for the skin. Frazier advises a rubber tissue drain for 24 hours in the posterior angle of the wound, but my experience without any drainage would indicate that it is not necessary, as a rule.

When the patient has recovered consciousness the reflexes and sensation in the operated side of the face should be tested to see if all of the sensory root has been divided.

The eye on the operated side should be protected from dust and air currents for about a week. If, by some mischance, the branch of the facial nerve to the orbicularis has been paralyzed, the eye must be carefully watched and cared for over a long period of time until the orbicularis has recovered.

The protection may consist of gauze pads wrung out of boric acid solution, or of an automobile goggle, which gives protection and at the same time allows free inspection of the eye.

THE CUSHING OPERATION (INFRATEMPORAL).—The incision runs from the temporal root of the zygoma (slightly in front of the ear) upward and then forward, so that the vertex of the incision is at or slightly above the level of the upper border of the pinna, and then forward and downward, terminating at

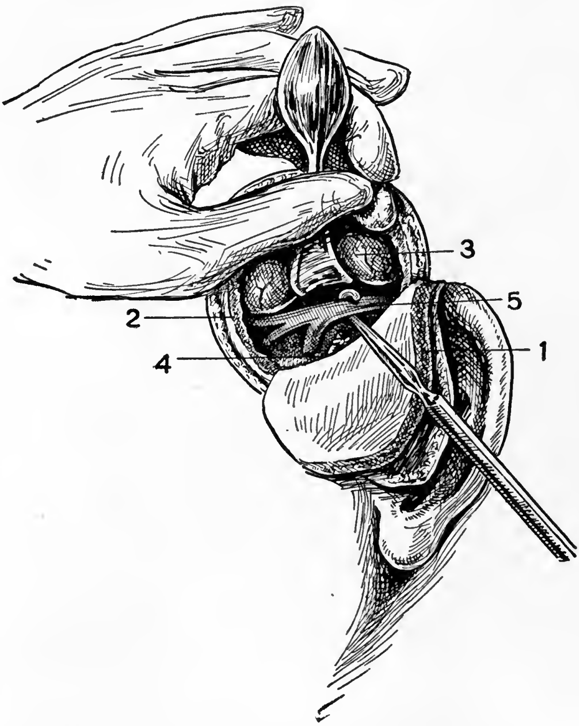



FIG. 44.—AURICULOTEMPORAL APPROACH TO THE GASSERIAN GANGLION 1, 2, 3, and 4, same as Fig. 43; 5, nerve hook passed under and around the posterior root of the Gasserian ganglion. (After Frazier.)

least 1 cm. from the posterior border of the frontal process of the malar bone. This modification of the original incision and its termination at the above point are designed to avoid injury to the upper twigs of the facial nerve which supply the frontalis and the orbicularis. This skin flap is reflected until the zygoma is well exposed. Subperiosteal resection of the zygoma is done, avoiding injury to the branches of the facial nerve as they cross the zygoma. Incision is then made through the temporal fascia and muscle concentric with, but slightly within, the skin incision, down to the bone. The muscle flap is elevated from the bone, to which it is but loosely attached, and retracted downward into the space previously occupied by the zygoma.

The bone is trephined and the hole enlarged by rongeur to a diameter of about 3 cm., with the lower edge at or involving the infratemporal crest. The

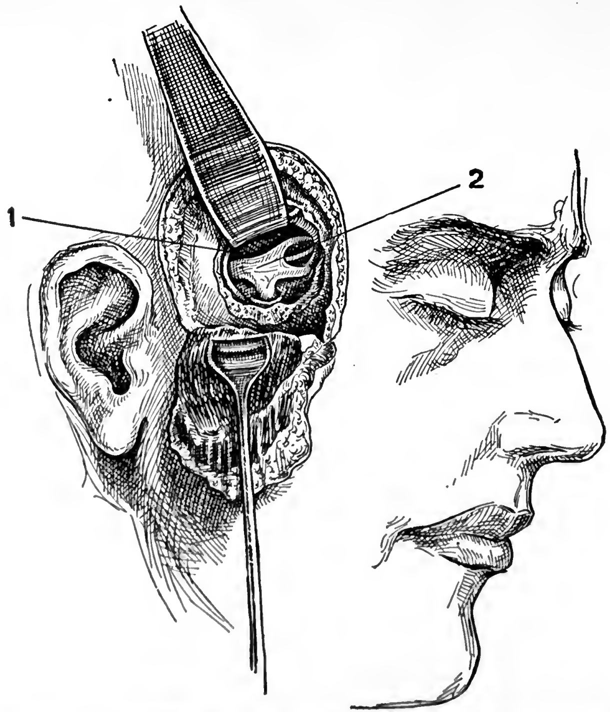



Fig. 45.—Infratemporal Approach to the Gasserian Ganglion (1). 1, Middle meningeal artery; 2, Gasserian ganglion exposed by elevating the dura beneath the artery without damage to the artery. (After Cushing.)

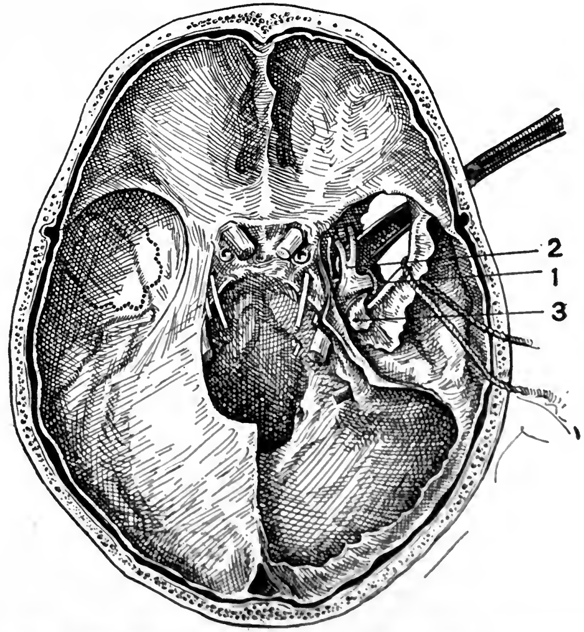



Fig. 46.—Infratemporal Approach to the Gasserian Ganglion (2). A view from above showing the relations of the approach to the ganglion and the artery. 1, Middle meningeal artery; 2, Gasserian ganglion; 3, Dura propria of the ganglion reflected back. (After Cushing.)

dura is thus exposed with the middle meningeal artery running across the hole obliquely upward and forward from its entrance into the skull through the foramen spinosum to the arterial sulcus in the anterior inferior angle of the parietal bone.

With a blunt elevator the dura beneath the arterial arch is raised from the bone, and a short distance inward the inframaxillary branch of the ganglion is exposed as it passes into the foramen ovale. Further elevation of the dura forward exposes the second branch entering the foramen rotundum. Between the 2 the dural envelope of ganglion is easily incised, and this incision is carried backward along the upper surface of the ganglion until the posterior root is exposed. The posterior root may then be either avulsed or simply divided, according to the preference of the operator, avoiding injury to the motor root when it is possible to isolate it. Hemorrhage is controlled as in the previous operation.

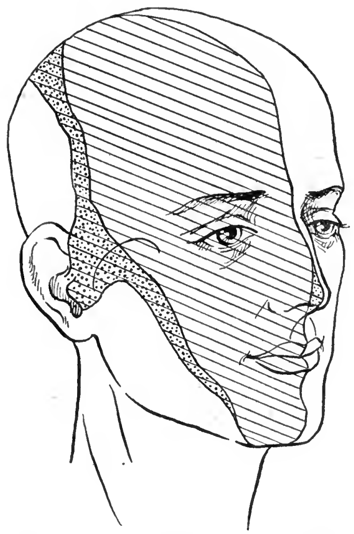


FIG. 47.—INFRATEMPORAL APPROACH TO THE GASSERIAN GANGLION (3). After complete section of the posterior root of the ganglion there will be an area of complete anesthesia, indicated by the oblique lines, and, at its posterior border, an irregular area of incomplete anesthesia indicated by the stippled area. (After Cushing.)

The wound is most carefully closed with layer sutures, Cushing using fine silk, while most operators prefer absorbable catgut, except for the skin suture.

When the posterior root has been completely divided, there is total loss of sensation in the peripheral field of the corresponding ganglion, except for a narrow, irregular zone at its posterior and inferior borders where the fibers of the upper cervical nerves overlap those of the fifth nerve and maintain some sensibility (Fig. 47).

When the motor root has also been divided, as is usually the case, there is paralysis of the muscles of mastication, of which the temporal is the most obvious. If the root has been avulsed, the paralysis will be permanent and there will be marked atrophy of the paralyzed muscles. If, on the other hand, the root has simply been divided and the ends left in approximation, it will, in many cases, regenerate and give return of function in the paralyzed muscles in from 6 to 12 months.

The skin sutures are removed in from 3 to 5 days; the patient is allowed to sit up as soon after 3 days as his condition will permit, and may leave the hospital any time after a week.

**Advantages of Posterior Root Section.**—By the use of this method of posterior root section, practically all of the difficulties, dangers and complications of the older operation of excision of the Gasserian ganglion are avoided. Disturbances of the eye on the operated side are less frequent in occurrence and less severe when they do occur. This is believed by Spiller to be due to the favorable trophic influence of the ganglion which is left in situ. The brain is retracted much less, so there is little likelihood of disturbance of its function. Failure to obtain relief must be due to either missing the posterior root or not completely dividing it. In either case there will not be the typical complete anesthesia of the face on the operated side which is usual. Only in rare cases will hemorrhage be such as to necessitate a two-stage operation.

**Results.**—Complete section of the posterior root gives permanent relief from the pain and causes permanent loss of sensation in the field supplied by the fifth root, except for a slight increase of function previously mentioned, which sometimes appears after a number of months in the upper cervical nerves.

When the motor root is permanently paralyzed, there appears a marked atrophy of the muscles of mastication, of which the temporal is especially noticeable. The zygoma stands out very prominently and accents the deformity due to the atrophy. For this reason, Cushing does subperiosteal resection of the zygoma and discards it. As a result, he reports that the muscular atrophy causes a much less noticeable deformity.

The eye on the operated side is apt to be sensitive to strong winds or to cold, and the patients often complain that that side of the face feels boardlike. Nevertheless, they regain their weight and color and are again able to take up their proper duties in life unless a fixed opium habit prevents.

## SEVENTH CRANIAL NERVE

**Indications.**—Surgical interference is directed toward the seventh cranial nerve for 3 different types of disturbance:

1. Facial spasm.
2. Facial paralysis.
3. Neuralgia of the sensory portion of the nerve.

**Anatomical Considerations.**—For the sake of brevity, the seventh and eighth nerves and the pars intermedia will all be considered together. Superficially they arise from the upper part of the medulla, external to the olivary body and pass forward and outward and slightly upward to the internal auditory meatus, which is in the posterior surface of the petrous bone about ⅔ of the way in toward its tip. This meatus lies almost directly above the posterior lacerated foramen, through which pass the ninth, tenth, and eleventh cranial nerves. This close relation of the 2 foramina and the 2 sets of nerves may be confusing in an operative field often obscured by hemorrhage.

As they enter the internal meatus, the seventh lies above the eighth, with the pars intermedia between the two (Fig. 48). At the depth of the internal auditory canal the seventh enters the aqueductus Fallopii, along which it passes outward to the geniculate ganglion. It then passes abruptly backward along the inner wall of the tympanic cavity just above the fenestra ovalis, and then straight downward through the mastoid portion to the stylomastoid foramen, from which it passes downward and forward, crossing the styloid process obliquely on its outer surface, to enter the parotid gland, just before doing which it divides into its 2 main branches.

The landmark for locating the exit of the nerve is the receding angle between the anterior border of the mastoid and the posterior border of the vaginal process of the temporal bone, which lies just below the bony external meatus. At a slightly greater depth than these bony processes lies the upper part of the styloid process, behind the base of which, and at a slightly higher level than the receding bony angle previously mentioned, is the stylomastoid foramen, from which the nerve makes its exit.

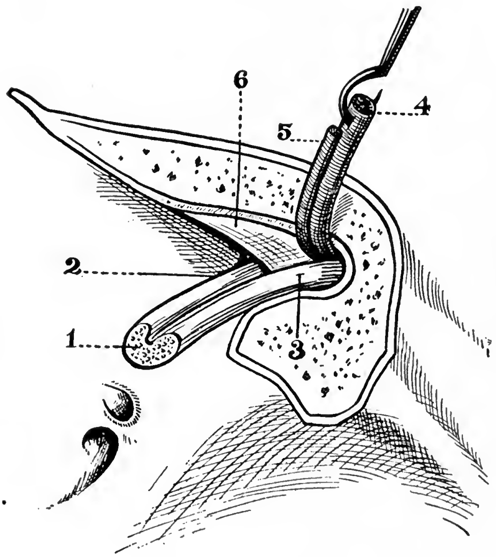



Fig. 48.—Relations of the Facial Nerve. 1, Auditory nerve; 2, cochlear branch; 3, vestibular branch; 4, facial nerve; 5, nerve of Wrisberg or pars intermedia. This shows how the facial and pars intermedia may rest in a groove in the auditory nerve. (After Testut.)

The pars intermedia runs outward in the aqueductus Fallopii to the geniculate ganglion, into which its fibers enter. From this ganglion communicating fibers pass forward, and others pass outward to supply sensation to part of the tympanic membrane and a portion of the external auditory meatus. This nerve and ganglion are now pretty well proved to be the sensory portion of the seventh cranial nerve and may be the seat of very severe neuralgia, quite comparable to that in the fifth nerve, as will be seen later.

The eighth nerve passes into the internal meatus, and at the end of the internal auditory canal sends its terminal branches through the various foramina in the lamina cribrosa to the structures of the internal ear. The eighth nerve leaves the medulla in the form of a number of small fasciculi, which run together just before they reach the internal meatus.

In a certain number of cases the seventh and pars intermedia may be nearly concealed by the eighth, which receives them in a groove in its upper mesial border. It may then be difficult or impossible to separate them for the purposes of operation.

### Operation for Facial Spasm

For facial spasm there are 2 methods of surgical treatment:

1. The injection of alcohol into the trunk of the nerve.
2. Transverse section of the nerve and the anastomosis of its distal stump into a neighboring motor nerve.

**Alcohol Injection.**—For the alcohol injection the same instruments are used as were described in the case of the fifth nerve.

The stiletted needle is pushed through the skin just below the receding angle between the anterior border of the mastoid and the posterior border of the vaginal process, which was described above, and carried straight in in the sagittal plane for from 1 to 2 cm., according to the size and shape of the skull and the amount of superficial fat. At from 1 to 2 cm. depth the styloid process should be sought with the point of the needle, and when found, the needle should be worked up and down for a short distance in the hope of striking the main trunk of the nerve, which crosses the styloid process obliquely at about this level. If the point of the needle pierces the nerve, there will be a spasm of the face on the same side, and the alcohol may be injected at once (0.5 to 1 c. c.—50 per cent.). If the needle does not locate the nerve at this level, its point must be made to follow up the styloid process to its base, and then, by a slight displacement backward, it can be inserted into the stylomastoid foramen, when the nerve can be easily located and injected.

When the nerve has been injected there follows immediate paralysis of the same side of the face, which lasts for a varying period of time (a few weeks up to several months). When the nerve regenerates, voluntary motion usually returns without the presence of the spasm, which may never again develop. It may, however, recur a few months after the appearance of voluntary motion, or may accompany the return of voluntary motion in a modified degree. The injection may be repeated from time to time if necessary.

Facial tic, as contrasted with facial spasm, is a habit grimace, a physiologic perversion, and can usually be corrected by proper educational measures. In severe cases of even this type the alcohol injection may be given in order to give temporary relief from the habit and to give the patient a better opportunity to regain control of the muscle groups as voluntary power returns with the regeneration of the nerve.

**Section of the Facial Nerve and Anastomosis with a Motor Nerve.**—When the injection of alcohol has failed to give satisfactory relief from facial spasm, section of the facial nerve at its exit from the stylomastoid foramen, followed by anastomosis with a neighboring motor nerve, should be done. Naturally, only those patients suffering from a severe and uncontrollable facial spasm would consider this radical treatment.

This method removes the control of the facial muscles from a perverted set of cortical cells and gives it to another set of cells, reached through the nerve with which the facial is anastomosed. Moreover, the period of paralysis gives the muscles a prolonged rest from the spasm.

The technic of this procedure will be described under the treatment of facial paralysis.

### Operation for Facial Paralysis

Facial paralysis may result from a lesion in the central system, from a lesion of the peripheral portion of the nerve between the medulla and the stylomastoid foramen, and from a lesion of the peripheral portion of the nerve distal to the foramen.

In this last case, if the paralysis is the result of a stab or gunshot wound, the wound should be enlarged, the ends of the nerve identified, freshened, and united by end-to-end suture. When the lesion involves the main trunk or the two primary branches of the nerve, this procedure may not be hopelessly difficult, but when the lesion involves the pes anserinus, there is little likelihood of success, and the most one can do is to avoid infection in the wound and thus favor prompt healing with a chance of spontaneous union of the divided fibers.

Where the paralysis results from infection or new growth in the parotid, there is nothing to do beyond the ordinary surgical treatment of the primary condition.

**Anastomosis of the Peripheral Portion of the Nerve with a Neighboring Motor Nerve.**—In paralysis resulting from lesions proximal to the stylomastoid foramen, relief may be had by anastomosing the peripheral portion of the facial with some neighboring motor nerve. As this operation is done largely for cosmetic reasons, and as the results are not fully developed for 2 years or more after operation, it should not be done in cases where the expectation of life is short or where the general health is so affected as to add greatly to the risk of operation. In cases following mastoid operations the wound should be healed and the region free from infection before the nerve work is attempted.

In cases where these contra-indications are absent, operation should be done as soon as it is evident that spontaneous regeneration and return of function will not occur. The determination of this factor is still the chief bone of contention. Some are so conservative that they insist on waiting 2 years because an occasional case has been reported in which some spontaneous return of power has occurred after this interval. This, however, is not the rule. Others advise 1 year and those who are called radical are willing to operate after 6 months from the onset of paralysis if no spontaneous return of power has occurred. Between these different periods one must choose, and the surgeon should always associate a competent neurologist with him in the decision of this question. If the reaction of degeneration persists in the paralyzed muscles up to 6 months, it is more than likely that spontaneous regeneration will not occur. Some men feel that if no regeneration has occurred at the end of 3 months and the reaction of degeneration still persists, operation may be advised at once. It must be remembered that, on general principles, the earlier the operation is done after paralysis, the better is the prognosis. The care of the paralyzed muscles before and after operation should follow the principles laid down in another section.

Spontaneous regeneration is less likely to occur when the nerve trunk has been completely divided, as by gunshot, or chisel during mastoid operation, etc., than when it is simply involved in a non-suppurative inflammation, as in Bell's palsy, so that in the former cases operation would be justified at an earlier period.

The two nerves to choose between for the anastomosis are the spinal accessory and the hypoglossal. The spinal accessory was first used, but the majority of later operators have chosen the hypoglossal because of the more intimate association of the cortical centers, the spinal centers, and the peripheral muscle groups of the facial and hypoglossal nerves (Fig. 49).

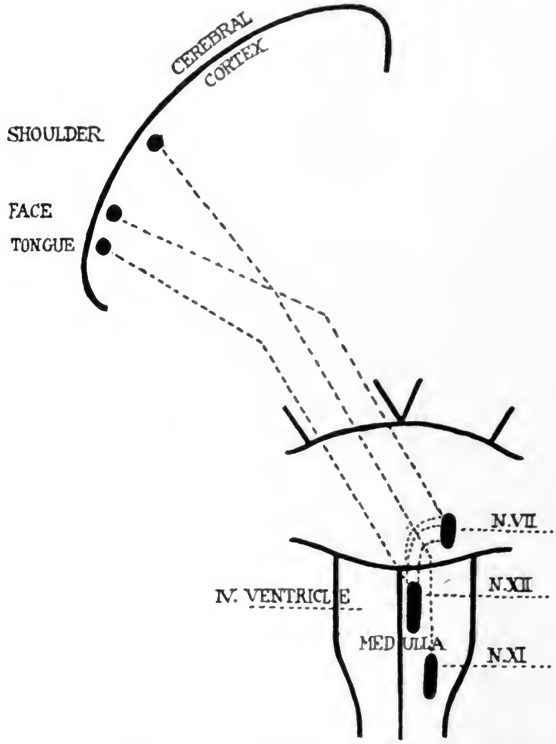



Fig. 49.—Schema Showing Relations of Nuclei of vii, xi, and xii Cranial Nerves in Cortex and Medulla. It is obvious that the vii and xii are much more intimately associated than vii and xi.

METHODS OF ANASTOMOSIS.—Two methods of anastomosis have been used; one a lateral slit in the hypoglossal with implantation of the peripheral stump of the facial. The other partial or complete transverse section of the hypoglossal with end-to-end suture between the peripheral end of the facial and the central end of the hypoglossal nerves. The opinion of the majority favors the second method because of the belief that regeneration in the facial nerve is more prompt and more complete. This method causes complete permanent paralysis in the muscles supplied by the portion of hypoglossal divided. The patients soon learn to accommodate themselves to this loss of hypoglossal power and do not suffer much discomfort. It has been advised that the distal portion of the hypoglossal nerve so divided should be implanted into one of the neighboring cervical roots. My own cases, 12 in number, have been done by the lateral implantation method, and the results, as far as indicated by the published pictures, compare very favorably with those done by the transverse section method, and there is less permanent disturbance of the hypoglossal.

TECHNIC.—Faciohypoglossal Anastomosis.—The operation involves the following steps: (1) the incision; (2) the isolation and section of the facial nerve; (3) the exposure of the hypoglossal nerve; (4) the implantation; (5) the closure of the wound; (6) the after-treatment.

*1. Incision.*—The patient is etherized; a firm cushion is placed behind the head and neck; the head is turned slightly to the opposite side and extended a little upon the neck; the operative field is thoroughly cleansed. The incision involving the skin and subcutaneous tissues passes along the anterior margin of the mastoid process and the sternomastoid muscle for about 5 cm. (2 in.), starting at the level of the external auditory meatus. The temporofacial veins may or may not be disturbed.

*2. Isolation and Section of Facial Nerve.*—The deep fascia is divided in the same line, with special care to keep close to the anterior border of the mastoid process to avoid damage to the parotid gland. This gland, covered by its capsule, is separated from the mastoid by an elevator and held forward by a blunt retractor, exposing the posterior belly of the digastric muscle, which is then pulled downward and backward. When the digastric is large, it may be necessary to divide its upper border transversely to its long axis to allow the retractor to give a proper exposure of the field.

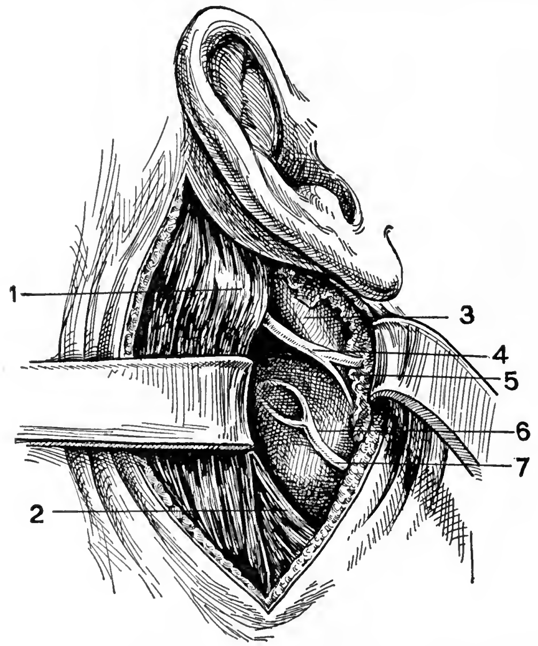



Fig. 50.—Anatomy and Relations of the Facial Nerve. 1, Tip of the mastoid process covered by sternomastoid muscle; 2, posterior belly of the digastric muscle; 3, Styloid process; 4, facial nerve showing bifurcation just before entering; 5, parotid gland; 6, prominence of the transverse process of the second cervical vertebra; 7, occipital artery.

The index finger, pushed into the depth of the wound and slightly forward, readily identifies the styloid process. Near the base of this process the trunk of the facial nerve passes almost directly forward to enter the parotid gland, and it can usually be felt to roll as a distinct small cord, surrounded by connective tissue, between the finger and the styloid process (Fig. 50). When there is difficulty in identifying it in this manner, one should remember that it emerges from the stylomastoid foramen, which is just behind the base of the styloid process.

The nerve, once identified, is enucleated from the surrounding connective tissue, and is divided as far up the stylomastoid foramen as a narrow-bladed sharp knife will allow. Usually one can get from 1 to 2 cm. (½ to 1 in.) of free nerve trunk.

Where the facial trunk is very short, an extra ½ cm. can be gotten by removing the outer bony wall of the canal at the stylomastoid foramen and divid-

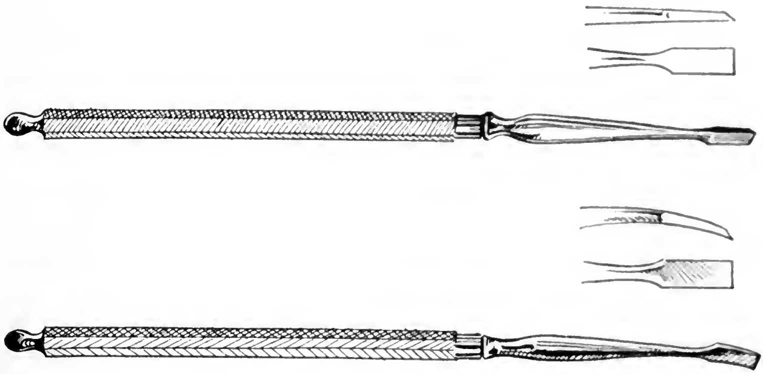


FIG. 51.—CHISELS CONVENIENT FOR REMOVING LOWER PART OF CANAL IN WHICH FACIAL NERVE RUNS SO AS TO OBTAIN A SLIGHTLY LONGER PERIPHERAL FACIAL STUMP FOR ANASTOMOSIS.

ing the nerve just so much higher up. I have done this several times with advantage. (Figs. 51, 52, 53.)

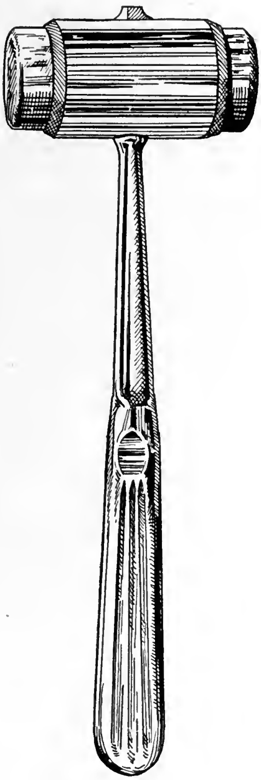


FIG. 52.—MALLET.

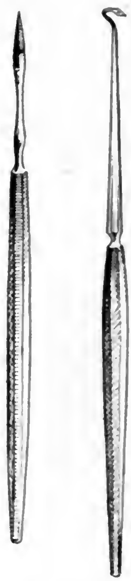


FIG. 53. — SLENDER KNIFE FOR SPLITTING THE HYPOGLOSSAL, AND SPECIAL NEEDLE WITH A FIXED HANDLE FOR PASSING SUTURES THROUGH HYPOGLOSSAL SHEATH.

At this point it is desirable to prepare the nerve for the final suture. About 1/4 cm. (1/8 in.) from its free end 2 fine silk sutures are passed through the nerve sheath on opposite sides of the nerve, and each is tied in a square knot. The ends are left long (15 to 20 cm., 6 to 8 in.) (Fig. 54). The nerve end is trimmed to a wedge shape with a sharp scalpel. The sutures and nerves are protected from damage during the next step.

In cases in which the mastoid has previously been operated upon, the bony landmarks are often confused and the scar tissue interferes somewhat with the easy performance of the first stage of the operation. Under such circumstances, the incision is made along the anterior border of the bony remnant of the mastoid, and, keeping just behind the parotid gland, the dissection is carried through the scar tissue till the deeper landmarks (the digastric muscle and the styloid process) are identified, when the operation proceeds as before.

*3. Exposure of Hypoglossal Nerve.*—The isolation of the hypoglossal nerve is the most difficult and tedious step, and involves whatever danger there is in the operation. The finger in the wound readily identifies the prominent, smooth, transverse process of the atlas (Fig. 50). Not infrequently the occipital artery runs upward and outward across the anterior surface of this prominence. It should always be looked for, and when present, either displaced outward, or divided between 2 ligatures, as an unexpected division of it gives rise to annoying hemorrhage and blurs the anatomical field.


Fig. 54.—Stages in Technic of Facio-hypoglossal Anastomosis. The small special needle (Fig. 53) may be used instead of the needle shown in the drawings which would require a holder. The working space is small and a needle holder is clumsy.

Lest they be inadvertently damaged in the following steps of the operation, it should also be remembered that over this same transverse process, but more toward the median line, the spinal accessory nerve runs obliquely downward and outward (sometimes in front of, sometimes behind the internal jugular vein), while the internal jugular vein runs vertically in front of it. These 2 structures are covered by a layer of deep cervical fascia, through which a vertical incision is made over the outer border of the transverse process and is continued upward and downward till it is about 4 cm. (1½ in.) long. Through this slit in the fascia the internal jugular vein is exposed and is separated posteriorly by blunt dissection. The spinal accessory nerve should not be disturbed during the operation. The fascia and vein are then retracted forward and inward by a blunt retractor. Imbedded in the connective tissue thus exposed in the depth of the wound are seen 2 white cords, the hypoglossal and pneumogastric nerves, with the internal carotid artery pulsating just to their inner side (Fig. 51).

Usually the more superficial of the 2 nerves is the one sought. It must be positively identified, however. Mechanical or electrical stimulation will cause its proper muscles to contract (styloglossus, hypoglossus, geniohyoid, geniohyoglossus, thyrohyoid, sternothyroid, sternohyoid) or one may follow its course anatomically downward to the point where it turns forward, around the occipital artery and gives off the descendens hypoglossi nerve.

Once identified, it is dissected upward till the stump of the facial nerve can be approximated to it without tension. This must be done with care not to divide the communicating branches from the pneumogastric, upper ganglion of the sympathetic and the 2 upper cervical nerves, all of which are in the immediate neighborhood.

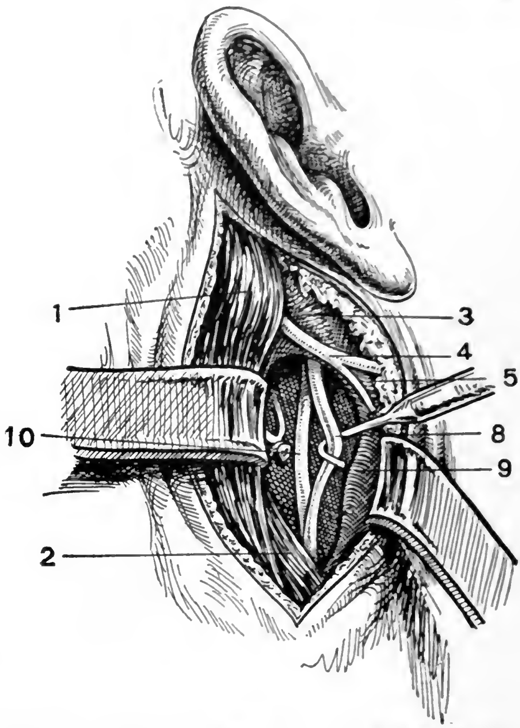



FIG. 55.—NERVE ANASTOMOSIS. 1 to 7 same as Fig. 50; 8, hypoglossal nerve held up on blunt hook; 9, internal jugular vein; 10, vagus nerve.

*4. Implantation.*—While the nerve is supported on a blunt hook, a longitudinal slit ½ cm. (¼ in.) long is made well into the nerve trunk. A fine, curved needle is threaded on to one of each pair of long silk ends previously left tied to the stump of the facial nerve. One suture is passed through the inner and the other through the outer margin of the wound in the hypoglossal nerve. When the sutures are tied, the wedge-shaped end of the facial is snugly held in the cleft in the hypoglossal nerve and is usually best turned slightly upward by means of a probe, a procedure suggested by Dr. Weir. These sutures must not be tied too tightly lest they injure the fibers of the hypoglossal nerve, a few of which are almost surely included in their grasp (Fig. 53, B and C).

If one elects to do a transverse section of the hypoglossal nerve, in part or in whole, and then do end-to-end suture, the site for transverse section is chosen at a point sufficiently low so that when the hypoglossal segment is dissected free upward it will allow approximation between the ends of the hypoglossal and facial without tension upon the sutures. A single suture is passed through the center of the ends of both nerves and tied sufficiently tight to give good approximation. With nerves as small as these it is scarcely worth while to attempt perineural suture where there will be no tension whatever.

To prevent the ingrowth of connective tissue elements, Cargile membrane is wrapped about the nerve junction. The hypoglossal is dropped back to its normal position, and there is usually no tension on the sutures.

*5. Closure of the Wound.*—If the digastric muscle has been partly divided, it should be sutured with catgut. No other deep sutures are required, since the parts naturally fall back into position. The skin is closed with silk sutures. No drainage is used. Sterile dressings are applied. Fixation of the head and neck is, as a rule, not necessary.

6. *Postoperative Course.*—The temperature reaction is usually very moderate. There is a disturbance of phonation and deglutition. Care must be exercised when the patient drinks to put the liquid in on the sound side of the mouth, and the patient must learn the trick of swallowing with a more or less complete unilateral paralysis of the muscles of deglutition. There is a tendency at first for liquids to enter the larynx and trachea. The patients learn to swallow readily within a few days. The voice is husky, and the patient feels somewhat as though he had a laryngitis. These disturbances wear away in the course of a few weeks. The wound heals by primary union, and the skin sutures are removed on the third to the fifth day, after which no dressing is necessary.

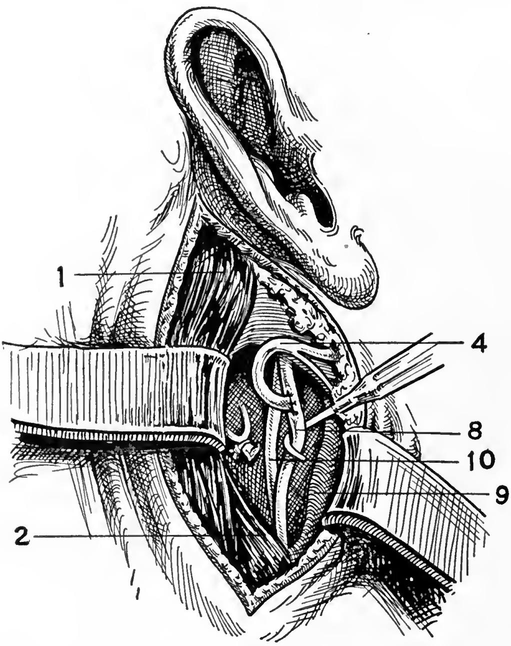



Fig. 56.—Nerve Anastomosis. Same as Fig. 55 except that it shows the facial sutured into a lateral slit in the hypoglossal.

The after-treatment is the most important factor in obtaining the desired result. Massage, electricity and, later, coördinated muscular movements must be persistently and systematically resorted to for months. It is now well recognized that after any nerve transplantation, the return of coördinated power involves a reëducation of the nerve centers, both in the spinal cord and in the cerebral cortex.

The education of the spinal centers progresses fairly rapidly, while that of the cortex requires long periods of time, often years, for its completion.

Experimental work on animals has shown steady progress in return of function for periods of 5 to 10 years.

As soon as voluntary power over the muscles begins to return the patient should be taught systematic exercises before a mirror for the development of muscle power and coördination. The cortical volitional impulses thus sent down far surpass in value either electricity or massage as a stimulus to nerve and muscle regeneration.

*Results.*—The result of the operation will depend upon a number of conditions.

1. The best results follow in those cases in which the cause of the paralysis

has been a traumatic division of the nerve. Less hopeful of complete recovery are those cases due to neuritis, especially when suppurative in character, i. e. in suppurative mastoiditis.

2. The longer the time between the paralysis and the anastomosis, the slower and less complete is apt to be the recovery. In cases of traumatic paralysis, anastomosis should be immediate. In interstitial neuritis (Bell's palsy) it is necessary to wait a few months for signs of spontaneous recovery, which so often occurs. At the end of 3 to 6 months of treatment the neurologist can decide as to the propriety of operating. In the suppurative forms operation should be done as soon as the danger of infection of the wound is passed, as there is small likelihood of spontaneous recovery.

3. The condition of the paralyzed muscles—flaccidity, contracture, spasm, changes in electrical reaction, and, most particularly, the degree of atrophy—is important. The more atrophy, the less hope. Therefore massage and electricity must be systematically used from the onset of the paralysis to keep the muscles in good condition in case either spontaneous regeneration of the nerve occurs, or operation becomes necessary.

4. The technic must be precise and delicate. The nerves must not be pinched or unduly handled, the sutures must be fine and involve only the nerve sheaths. The importance of these details is accentuated by the postoperative appearance of temporary interference with the functions of the hypoglossal nerve. The degree and duration of this interference are directly proportionate to the traumatism inflicted on the nerve during operation. There must be the least possible amount of scar tissue. Asepsis is essential, because suppuration, aside from being dangerous in itself, would reduce the probability of nerve union to the minimum, and there would later be pressure on the nerve due to contraction of the cicatrix.

5. The importance of the after-treatment has been indicated above. The first degree of recovery consists in symmetry of the face during quiescence, but without volitional control over the muscles. The next degree consists in the return of volitional control of the muscles, but with the paralyzed side of the face uninfluenced by the emotions (laughing, crying, etc.). The third and complete degree consists in the return of emotional control of the face.

This was acquired to a certain extent in Körte's case (43). The reasons for preferring the hypoglossal to the spinal accessory nerve as a medium for anastomosis are rendered more intelligible by Figure 49, which represents schematically the sharp contrast between the close relationship of the nuclei of the facial (seventh) and hypoglossal (twelfth) nerves, and the wide interval between the facial and spinal accessory nuclei. Again the face and tongue centers in the cortex are closely associated, indeed, overlap, while the face and shoulder centers are widely separated, a fact emphasized by Ballance and Stewart.

The physiological association of the 2 nuclei in the medulla is strikingly shown in the frequent affection of both in disease, as labioglossal palsy, and by the fact that the transverse fibers of the tongue and the orbicularis oris can contract only together. The close anatomical connection of all the cranial nerves through the posterior longitudinal bundle should be considered in the light of a rudimentary plexiform arrangement analogous to that of the cervical, brachial, and crural plexuses.

Fig. 57.—Complete Facial Paralysis Following Mastoid Operation.

This close association of the cortical and medullary centers of the facial and hypoglossal nerve renders the process of reëducation (previously discussed) shorter and simpler than in the case of the spinal accessory.

*Results.*—The immediate results are the disturbances of phonation and deglutition previously mentioned, plus a unilateral paralysis of the tongue on the same side as the operation, which is more or less complete, according to whether the hypoglossal nerve has been partially or completely divided. This paralysis of the tongue persists for a number of weeks and gradually disappears if the hypoglossal nerve has not been divided but has been used for lateral implantation. Even after the tongue, in these cases, has regained its full range of mobility, there persists permanently a diminution in size of that side of the tongue.

Fig. 58.—Same Boy, Three Years After Faciohypoglossal Anastomosis, Showing Ability to Laugh Almost Symmetrically.

*Remote Results.*—Frequently 6 weeks after operation the face at rest will have regained its symmetry, and the patient will say that the paralyzed side has lost its boardlike feeling, but there will be no evidence of voluntary motion, nor will there be any change in the electrical reaction of the muscles. At any time from 3 months on, according to the individual case, a beginning of voluntary motion may be expected. This practically always appears first in the muscles about the chin, then at the corner of the mouth and cheek, then around the eye, and at last in the muscles of the forehead. The patients soon get so that they can control these groups of muscles independently of each other or can use them all at the same time. It is only after several years and after prolonged training on the part of the patient that symmetry in the expression of emotion, such as laughing and crying, may appear. Usually this spontaneous

Fig. 59.—Corrugator Supercilii Muscles Acting Equally Well on Both Sides.

emotional control does not develop, although the patient, if not caught unexpectedly, may simulate it so accurately as to escape detection, by voluntarily making the paralyzed side balance the normal side. (Figs. 57, 58 and 59.)

FACIOSPINAL-ACCESSORY ANASTOMOSIS.—The exposure and preparation of the facial nerve are the same as in the preceding operation. The spinal accessory will be found running downward and outward across the front of the second transverse process, coming either from in front or behind the internal jugular vein, passing beneath the posterior belly of the digastric, and entering the inner surface of the sternomastoid muscle about $1/3$ of its length downward from its mastoid origin. When the nerve has been exposed, the portion running to the sternomastoid muscle is divided transversely and dissected upward for end-to-end suture with the facial. Using this portion of the nerve avoids the disfiguring deformity of the drop-shoulder which often results from division of that portion of the spinal accessory which innervates the trapezius muscle. (Figs. 60 and 61.)

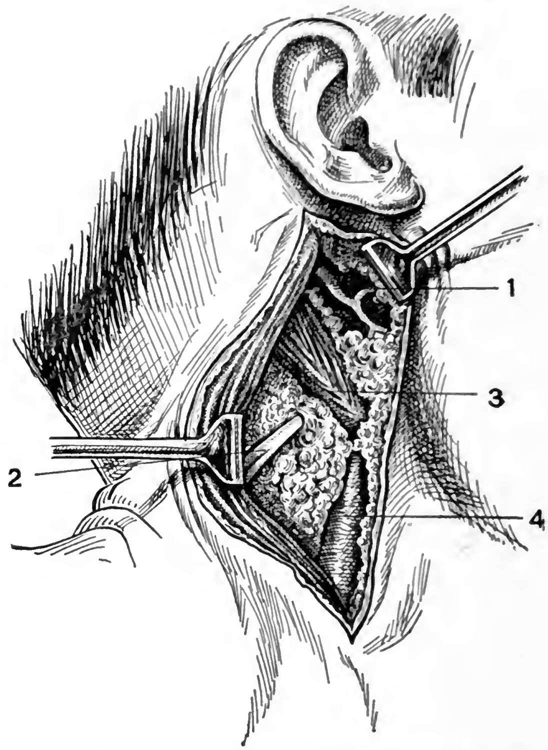



FIG. 60.—NERVE ANASTOMOSIS. 1, Facial nerve; 2, spinal accessory nerve; 3, posterior belly of the digastric muscle; 4, internal jugular vein. (After Cushing.)

The wound is closed as in the preceding operation.

Where the faciospinal-accessory anastomosis has been done, attempts to use the face, or attempts to use the muscles innervated by the spinal accessory nerve, result in associated movements of both groups of muscles. This leads to unexpected contortions and grimaces which are disagreeable. By training for a year or more, some patients are able to entirely dissociate these 2 groups of movements; others are not completely successful in this dissociation.

POSTOPERATIVE EXERCISES.—No matter which nerve has been used, the final results will not be attained until 2, and in some cases 3, years have elapsed from the time of operation, and during this time the patient must follow persistently a series of systematic progressive exercises for the development of control in the previously paralyzed muscles, as well as the systematic use of massage and electricity.

When regeneration begins in the facial nerve after such an anastomosis, the after-treatment really amounts to the education of an entirely new set of cortical cells in the control of the previously paralyzed muscles of one side of the face.

Briefly the progressive exercises may be outlined as follows: When voluntary motion first appears in the chin and at the angle of the mouth, it may be greatly intensified in faciohypoglossal cases if the patient will voluntarily cause excessive action of the muscles supplied by the hypoglossal on the sound side and as much of the hypoglossal as may remain undivided on the paralyzed side. Pushing the tongue firmly against the front teeth seems to be a particularly good adjuvant. This overactivity of the hypoglossals seems to cause a great overflow of nerve impulse into the anastomosed facial nerve with consequent increased activity in those muscles supplied with regenerated fibers. The rate of improvement is thus accelerated.

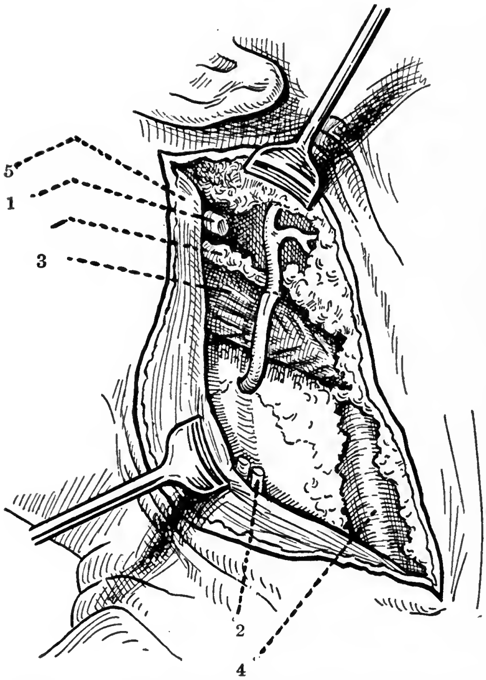


Fig. 61.—Nerve Anastomosis. Numbers same as in Fig. 60. (After Cushing.)

In the early period all the muscles which have regained any power contract together, with a resulting grimace. The training then aims at the control of individual muscles or small related groups before the mirror until the grimace is dissociated into its component parts, and the different small groups of muscles can be used freely and independently of all the other groups.

Then finally the attempt is made to regain emotional symmetry of the face. Standing before the mirror, the patient voluntarily makes the paralyzed side of the face symmetrical with the normal side during various expressions of emotion. After long practice, a very few patients can balance the face automatically, but the great majority of them, if caught unexpectedly, express the emotion only with the normal side of the face until they catch up and balance voluntarily.

It will thus be seen that no face resulting from a facial anastomosis will ever be as good as a perfectly normal face, but it is infinitely better than a permanently paralyzed one.

### NEURALGIA OF THE SENSORY PORTION OF THE SEVENTH CRANIAL NERVE

It has been pretty definitely proven that the pars intermedia, or nerve of Wrisberg, is the sensory root of the seventh cranial nerve, and runs out to the geniculate ganglion, which is its trophic center. This ganglion and its sensory root may be the seat of severe neuralgia analagous to that in the Gasserian ganglion and its nerves (Hunt, 42). (See anatomical relations previously described.)

The pain in neuralgia of this nerve is severe, sharp, and stabbing, and is referred to the external auditory canal and the upper posterior adjoining portion of the inner surface of the auricle. It may be associated with neuralgic pains in the Gasserian ganglion region, or with neuralgic pains in the distribution of the 2 upper cervical nerves. When this pain cannot be controlled by medical means, the only relief lies in surgical attack. Since some of the sensory filaments may be included in the motor part of the seventh or in the upper portion of the eighth cranial nerve, or in both, the only sure relief from pain consists in the division of the motor seventh, the pars intermedia, and the upper portion of the eighth. An operation for this purpose has been reported only once. (Clark and Taylor, 33.)

*Division of the Motor Seventh, Pars Intermedia, and the Eighth.*—The only feasible site of attack is in the posterior cranial fossa, where all 3 nerves converge to enter the internal auditory meatus. Section of the nerves just posterior to this meatus will cause facial paralysis through division of the motor seventh, and will cause temporary disturbance of hearing from division of the upper part of the eighth, but the pain is completely relieved. Inasmuch as the sensory fibers are divided between their trophic center (geniculate ganglion) and the central nervous system, there will be a permanent degeneration of the fibers and, therefore, permanent relief from pain. The motor fibers on the other hand being divided distal to the central nervous system and therefore distal to their trophic centers, will unite, regenerate, and again take up their function. This return of control of the face muscles started in the 1 case reported after about 6 months, and was nearly complete in a year. The patient was seen only at long intervals, so that the exact time of return of power in the face was not noted.

This is quite in line with the results obtained in section of the posterior roots in the Gasserian neuralgia, where motor power will return in the muscles of mastication if the roots are simply divided and not avulsed.

TECHNIC—Ether is used, and is administered through rubber tubes passed through the nares to the laryngeal entrance, so as to keep the etherizer out of the way of the operator.

The patient is placed prone on the table with cushions under the shoulders and the head hanging forward so as to give a good exposure of the operative field and still leave the chest free for respiratory movements. Some of the head-rests specially devised for operations on the posterior fossa are very useful.

(See chapter on Cerebellar Surgery.) An osteoplastic flap is turned down. Its outer edge lies just within the posterior border of the mastoid, the upper border about 2 cm. above the line of the lateral sinus, and the inner border just to the same side of the median line; the lower, or hinge border, well down toward the foramen magnum. A dural flap is cut with its base turned toward the median line, its upper edge just below the lateral sinus, its outer and inferior edges just within the corresponding bone edges. A flat blunt retractor is passed along the outer side of the cerebellum beneath the dura to the base of the petrous bone, along the posterior surface of which it is gently inserted, retracting the cerebellum, backward and toward the median line, until the cerebrospinal fluid at the base of the brain escapes in considerable quantity with a rush. Immediately the cerebellum retracts easily, and the nerve field is exposed. Care must be taken not to mistake the ninth, tenth, and eleventh nerves passing through the foramen lacerum posterius, for they lie directly beneath the internal auditory meatus, into which the 3 nerves sought enter. In the one case operated upon this happened at first, and only the jumping of the shoulder when the eleventh nerve was stimulated indicated which nerve was under inspection. Retraction, which exposed the space immediately above, readily brought into view the seventh and eighth nerves and the pars intermedia (Fig. 62). The seventh, the pars intermedia, and the upper fasciculus of the eighth nerve are cut. The retractor is slowly withdrawn, allowing the cerebellum to return to its proper space. The dura is closed by a continuous catgut suture. The bone flap is laid back in place. The periosteum is sutured with 20-day chromic catgut. The muscles are sutured with plain gut, and the skin with a continuous silk suture. No drainage is used. Sterile dressings are applied.

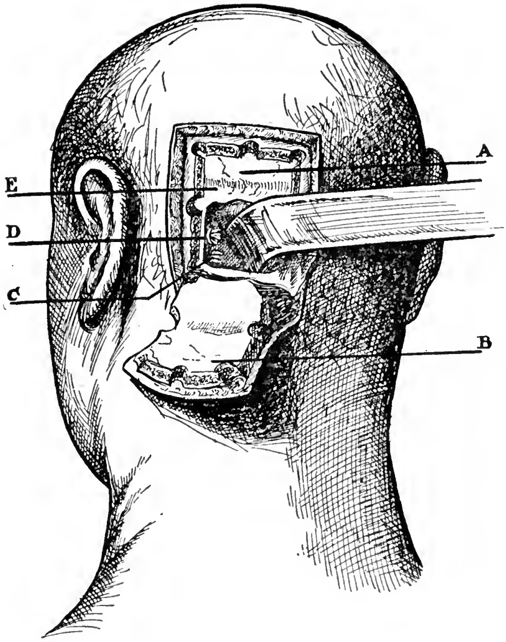


FIG. 62.—INTRACRANIAL NERVE SECTION. A, Dura covering occipital lobe; B, Osteoplastic flap; C, ix, x and xi cranial nerves entering foramen lacerum posterius exposed by retracting the cerebellum toward the median line; D, vii and viii cranial nerves and pars intermedia entering the internal auditory meatus; E, lateral sinus.

DISCUSSION OF TECHNIC.—The flap is made large so that the cerebellum may be retracted easily and without undue compression. It is carried well above the lateral sinus so as to get bone thick enough to bevel on 3 sides and thus enable one to lay the flap back without bone sutures and without danger of its pressing on the brain. The inferior portion of the occipital bone is quite thin. The bone flap is cut by the Hartley-Kenyon motor saw.

After the dural flap is made and the cerebellum retracted, 2 things are found very useful: a suction apparatus working on the principle of the Sprengel pump, which keeps the field free from cerebrospinal fluid and blood; and a small cystoscopic bulb-light on a flexible stem, so that the light can be placed right in the operative field.

When the internal auditory meatus is exposed, the nerves are seen entering it with an artery of moderate size—the auditory. This artery is carefully retracted, as it would be rather troublesome to tie in a wound of such depth. If it must be divided, the Cushing silver clips will be most convenient.

The seventh, the pars intermedia, and the upper fasciculus of the eighth cranial nerve are divided with a scalpel. The result is a complete facial palsy, some temporary disturbance of hearing, and complete disappearance of the characteristic pain.

This operation gives ample exposure for carrying out this division of the seventh and its associated nerves just posterior to the internal auditory meatus. If the bone flap is carried well out toward the mastoid, but little manipulation of the cerebellum is necessary, so that the removal of bone from behind both lobes of the cerebellum is not required. Hemorrhage is free while making the incision through the soft tissues down to the bone, but may be readily controlled by the usual means. With displacement of the cerebellar lobe, there usually escapes a considerable quantity of cerebrospinal fluid from the great posterior cistern, and then the cerebellum may be displaced with considerable freedom and the operative field opened up very satisfactorily.

RESULTS.—The wound heals by primary union and after a time the bone flap becomes solid with the rest of the skull, so that there is no ultimate defect. There is complete and permanent disappearance of the pain. There may be slight disturbance of the auditory sense on the side of the operation, but this disappears within a short time. The paralysis of the face gradually disappears in the course of the first year after the operation.

This type of case is by no means infrequent, and when it comes to be recognized, many cases of intractable otalgia will be relieved by surgical intervention.

Many operators do not use the osteoplastic flap, feeling that the thick layers of muscle and fascia give sufficient protection to the cerebellum, but the ease with which the operation just described was done and the perfect skull which resulted would lead me to attempt the same method a second time. Instead of doing the osteoplastic operation, they reflect the soft parts from the occipital bone on the side to be operated upon and remove all of the bone within the limits of the lateral and occipital sinuses, the posterior border of the mastoid externally, and the edge of the foramen magnum inferiorly. From this point on, the operation is the same as that previously described.

## EIGHTH CRANIAL NERVE

The eighth cranial nerve is attacked surgically in cases of persistent tinnitus aurium, incurable by other means, and also occasionally in cases of very persistent vertigo, due to derangement of the internal ear. Not many cases have been reported, but there has been an occasional complete success. Frazier reports complete success in a case of tinnitus aurium.

The operation is the same as that described for division of the facial nerves, except that only the auditory nerve, provided it can be isolated, need be divided after the group of nerves entering the internal auditory meatus has been exposed. With the division of the entire auditory nerve, there will, of course, result absolute loss of function of the nerve on that side forever.

Bryant says that those cases of persistent tinnitus aurium are most apt to get relief from section of the auditory nerve in which there is complete deafness to air-conducted sound but good appreciation of bone-conducted sound.

In aggravated vertigo of labyrinthine origin this operation has afforded marked relief in many cases, but has resulted in real cure in very few.

## TENTH CRANIAL NERVE

The tenth nerve is occasionally injured in the course of operations in the neck. Under these circumstances, immediate end-to-end suture of the nerve should be done. If the nerve is injured on only one side, there is seldom any serious resulting disturbance.

The tenth nerve is sometimes resected on one side of the neck in the course of block dissection for malignant growths without serious consequences resulting from this particular feature of the operation.

Operations on the tenth nerve, as such, are few and have not been sufficiently standardized to warrant detailed description. As a matter of interest, it may be stated that in one case (Byrne and Taylor, not yet published) the upper ganglion of the right pneumogastric nerve was removed in toto in a case of tabetic crises, in which pain was the minor symptom, but nausea and vomiting were constant. It is in this type of case that Professor Foerster of Breslau says the lesion is in the pneumogastric. The patient died on the third day, after delirium cordis, dyspnea, edema of the lungs, and coma had rapidly followed each other. During this time, however, he did not vomit at all, except once or twice during his recovery from the ether.

Another operation has been done several times in Germany for tabetic crises of the above type. It consists in resecting several inches of both the right and left pneumogastric nerves as they pass onto the stomach after passing through the diaphragm with the esophagus. The persistent vomiting is said to have ceased.

## ELEVENTH CRANIAL NERVE

**Anatomical Considerations.**—The eleventh nerve passes through the foramen lacerum posterius in company with the ninth and tenth nerves, passes downward and outward either in front of or behind the internal jugular vein, crosses the second transverse process and enters the deeper surface of the sternomastoid muscle at about the junction of its upper and middle thirds, gives motor branches to this muscle, and then the remainder passes through the muscle and leaves the posterior border at or just above its middle. It then runs obliquely downward and outward across the posterior cervical triangle to enter the trapezius muscle.

**Indications for Operation.**—This nerve is not infrequently divided during the excision of glands of the neck, either in the anterior or posterior triangle. If divided in the anterior triangle, both the sternomastoid and trapezius muscles are paralyzed; if in the posterior triangle, the trapezius muscle alone is paralyzed and there results a marked drop-shoulder with undue prominence of the upper angle of the scapula, and marked atrophy of the trapezius. While these combined factors cause marked deformity, there is surprisingly little loss in range of motion of the extremity. In some cases where the trapezius gets much of its motor supply from the upper cervical nerves (II, III and IV), division of the spinal accessory causes almost no symptoms. If the accidental division of the nerve is discovered at the time of operation, immediate end-to-end suture should be done, and the extremity should be sustained by a sling or brace to prevent undue traction on the paralyzed muscles until regeneration of the nerve and return of power have occurred.

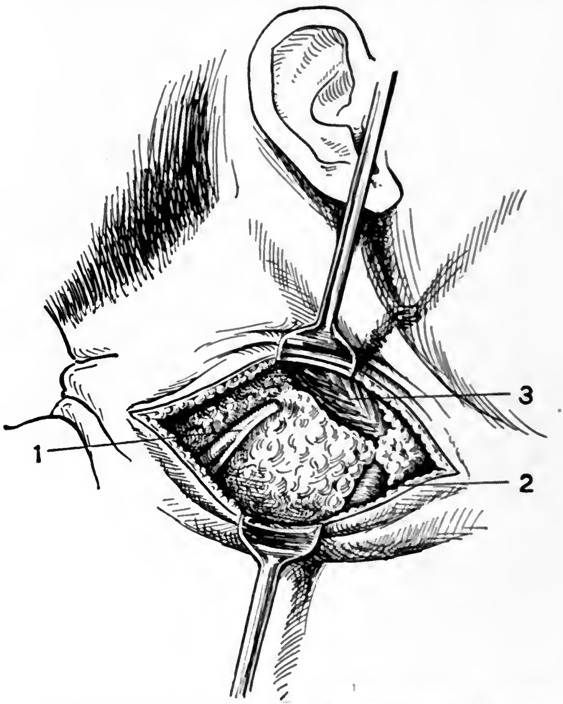



Fig. 63.—Exposure of Spinal Accessory by a Transverse Incision Following Natural Wrinkles of Skin of Neck. 1, Spinal accessory nerve; 2, internal jugular vein; 3, posterior belly of the digastric muscle.

If section of the nerve is discovered only by the appearance of the paralysis during convalescence, the wound should be promptly opened and the divided ends sought and sutured.

Even after years, it is worth while to seek the ends, freshen and suture them. The danger is practically nothing and the reward, in successful cases, is great. In these old cases, if in the posterior triangle, the downward displacement of the shoulder drags the distal stump far downward, so that the search must be made in the line which the nerve, thus pulled upon, would naturally follow. The shoulder, after the nerve is sutured, must be held well up toward the neck to relieve tension, both on the nerve and the paralyzed muscle, until function has returned.

Outside of its use for anastomosis with the facial nerve, which has previously been described, the only operation on the eleventh nerve consists in resection of it for wry-neck in conjunction with section of the upper cervical nerves.

**Technic.**—The best incision is parallel to the transverse creases in the cervical skin (Fig. 63). The incision should be about 3 to 5 cm. long and should be placed at the level of the junction of the upper and middle thirds of the sternomastoid muscle. The incision runs through the skin and subcutaneous tissues down through the layer of deep cervical fascia which surrounds the sternomastoid muscle. The edges of the wound are retracted and the anterior edge of the sternomastoid muscle is retracted outward and somewhat everted. After complete hemostasis, one will usually see the spinal accessory nerve coming downward and outward over the second transverse process and entering the deeper surface of the muscle. If the nerve is not thus easily located, one must seek upward and downward along the deeper surface of the muscle for a short distance until it is located. It may be tested by the electric current to positively identify it. Having been identified, as much of the nerve trunk as can be conveniently resected is removed. The space in the sternomastoid muscle is sutured over the buried distal nerve end and the proximal stump may also be buried in the cervical fascia in order to increase the security against regeneration and union of the nerve ends. The wound is closed without drainage (catgut for the fascia, silk for the skin) and the dressings are applied.

### TWELFTH CRANIAL NERVE

The twelfth nerve is not important as a surgical entity. It is used as described in facial anastomosis as a source of new nerve supply. It is often injured in cut-throat accidents and sometimes in surgical operations in its neighborhood. When so injured it should be sutured end to end.

## UNILATERAL LAMINECTOMY

**Indications.**—The indications for unilateral laminectomy are as follows:

For any exploration of the spinal canal.

For section of the posterior roots on either 1 or both sides.

For spinal decompression.

When a tumor is exposed by this method, if necessary for its safe removal, the laminæ of the opposite side may be readily removed and the operation converted into a bilateral laminectomy.

The method is scarcely applicable to work on fractures of the spine where the injury is bilateral.

**Anatomical Features.**—The anatomical features to be appreciated are the spinous processes, surmounted by the supraspinous ligament, and the row of

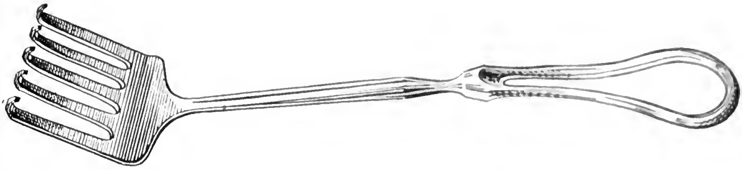


**Fig. 64.—Retractor Especially Designed for Laminectomy.** It has the advantage of holding the skin and superficial muscles well out of the way and so allowing plenty of light to get to the depth of the wound.

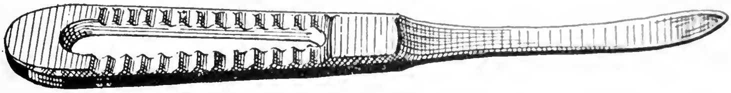


Fig. 65.—Periosteal Elevator.

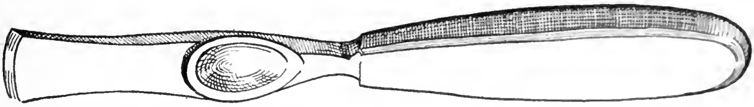


Fig. 66.—Periosteal Elevator for Lifting Muscles from Spinous Processes and Laminæ.

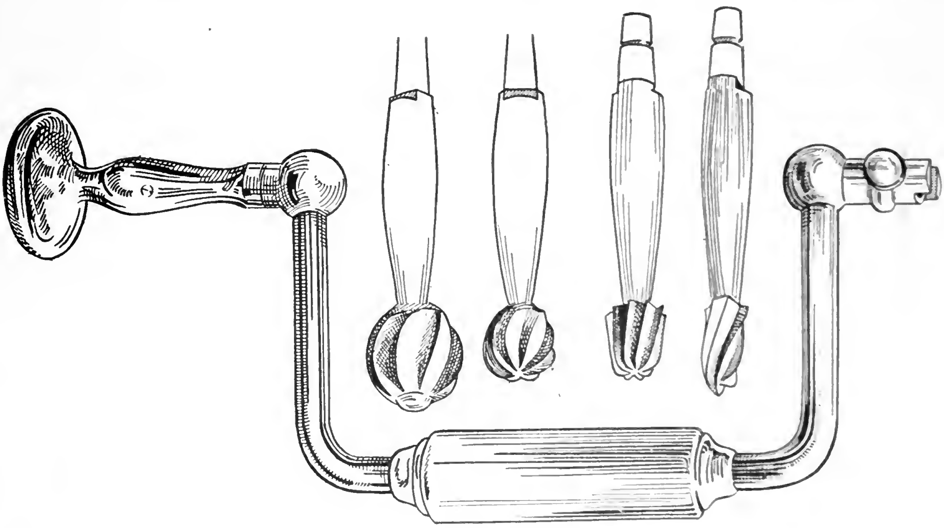


Fig. 67.—Hudson Set.

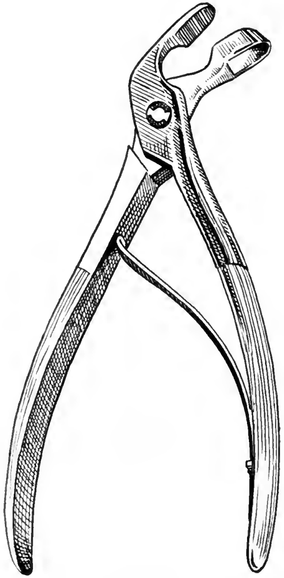


Fig. 68.

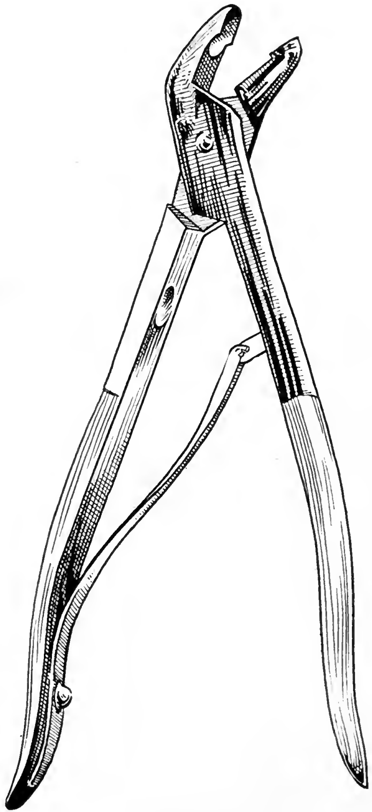


Fig. 69.

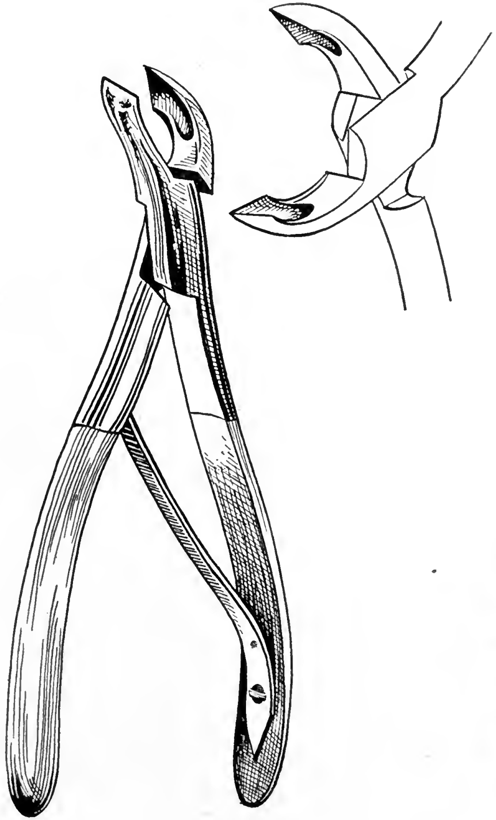


Fig. 70.

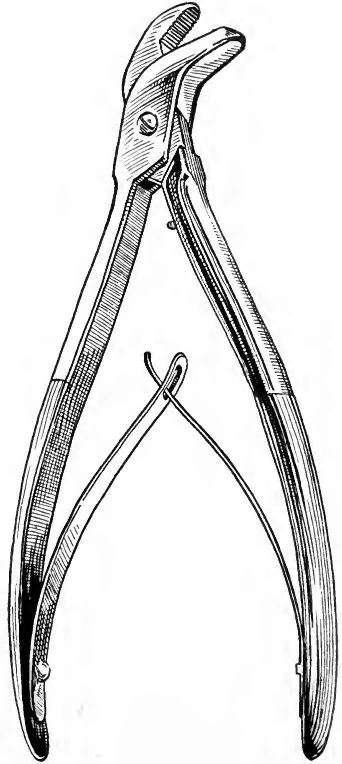


Fig. 71.

Figs. 68, 69, 70, and 71.—Rongeurs for Removing Bone in Unilateral Laminectomy.

articular processes on each side with the laminæ between. In the cervical region the groove formed by these bony elements is broad and somewhat shallow; in the dorsal region narrow and fairly deep; while in the lumbar region it is of medium width and considerable depth.

In the dorsal region the laminæ overlap each other so that there is no interlaminar space through which to enter the canal, while in both the cervical and lumbar regions there is a definite interval which may be increased by flexion of the spine. The laminæ are connected by strong ligamentous structures.

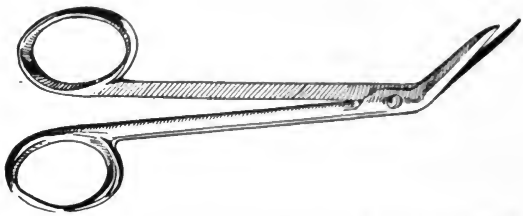


Fig. 72.—Scissors Designed to Allow Rapid Cutting of Dura Without Damage to Underlying Structures.

Between the inner wall of the bony canal and the dura is a layer of fat with a connective tissue framework carrying a freely anastomosing set of vessels. This layer is from 2 to 4 mm. thick.

Within the dura, which is somewhat less than 1 mm. thick, lies the cord suspended in a liberal amount of spinal fluid and anchored by the ligamentum denticulatum which runs down each side of the cord between the anterior and

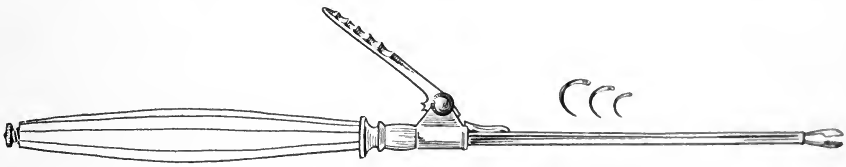


Fig. 73.—Lane Needle-holder and Needles. Very useful in closing the dura.

posterior roots as they pass downward and outward to perforate the dura and pass into the intervertebral foramina where the ganglion lies attached to the posterior root.

The cord ceases at the level of the second lumbar vertebra, and below this level are found only the conus and the nerves forming the cauda equina.

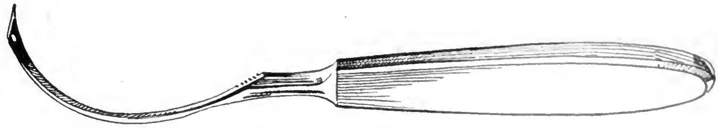


Fig. 74.—Peaslee Needle.

**Instruments.**—The instruments consist of a special set of retractors (Figs. 64 to 74), a periosteal elevator, a set of Hudson burrs, special rongeurs, special dura scissors, Lane's needle holder, Peaslee needle, in addition to the ordinary supply of knives, scissors, hemostats, thumb forceps, needles, ligatures, sutures, etc., which are used in all operations. Horsley's bone wax is occasionally useful when there is persistent bleeding from the divided bone.

**Technic.**—After it has been decided which laminæ are to be removed, an incision is made parallel to the spinous processes but just to the side from which the laminæ are to be taken, so as to preserve the supraspinous ligament. First the skin, then the deep aponeurosis, and finally the muscles along the sides of the spinous processes are divided, hugging close to the bone.

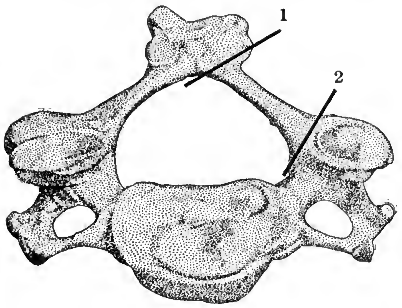



FIG. 75.—A CERVICAL VERTEBRA. 1 shows how beveling under the spinous process gives good exposure of the opposite side of the cord. 2 indicates how the removal of the lamina out to that line gives a good view of the dorsum and side of the cord, and, with very little elevation of the cord, a good view of at least half of the anterior surface of the cord.

With a broad periosteal elevator, the muscles are raised from the laminæ well out to the articular processes. Hemorrhage, which is often profuse at this stage, is controlled by packing the wound with sponge pads wrung out of hot saline solution, which are left in place for from 3 to 5 minutes. It is very rarely necessary to use a hemostatic forceps.

With the special retractors, the wound is held well open, exposing the denuded laminæ in the depth of the wound. These retractors with the obliquely placed prongs have the advantage of holding the skin and superficial layers of muscle well outward and making the wound a broad wedge-shaped one instead of the narrow deep one which is given by the usual right-angled retractors.

In the cervical and lumbar regions, where the laminæ are not closely apposed, the ligamentous structures attached to the lower edge of one of the laminæ, usually near the middle of the wound for convenience, are divided with the knife, and then the rongeur or punch (Fig. 66) is slipped under the lamina and is made to punch a groove upward through the various laminæ to the upper end of the wound. The punch is then reversed, and the lower laminæ punched out in like manner. The bone on each side of the groove is then removed as far as necessary by using the various rongeurs. Considerable increase in space and illumination is obtained by beveling under the base of the spinous process (Figs. 75 to 77), and still more by encroaching upon the articular processes when necessary (Fig. 77). In

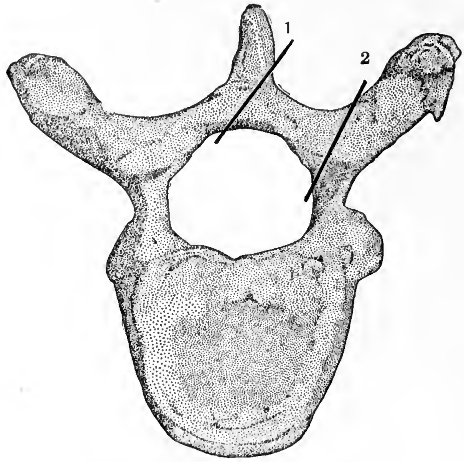



FIG. 76.—A DORSAL VERTEBRA.

the dorsal region, where the laminæ are closely imbricated, the start for the punch is obtained by boring through one or more of the laminæ with the Hudson burrs which make a hole large enough to give easy entrance to the punch.

When the laminæ have been satisfactorily removed, oozing from the bone surfaces is controlled by bone wax, and the other hemorrhage by hot saline sponge pads. The layer of fat between bone and dura is divided longitudinally, exposing the dura. (Fig. 78.)

With a sharp-pointed knife the dura in about the middle of the wound is punctured and the spinal fluid allowed to escape somewhat slowly. Then the snout of the special dura scissors (Fig. 72) is passed into the aperture, and the dura is divided the length of the wound. It will readily be seen that these scissors properly used give perfect protection to the subdural structures. (Fig. 72.)

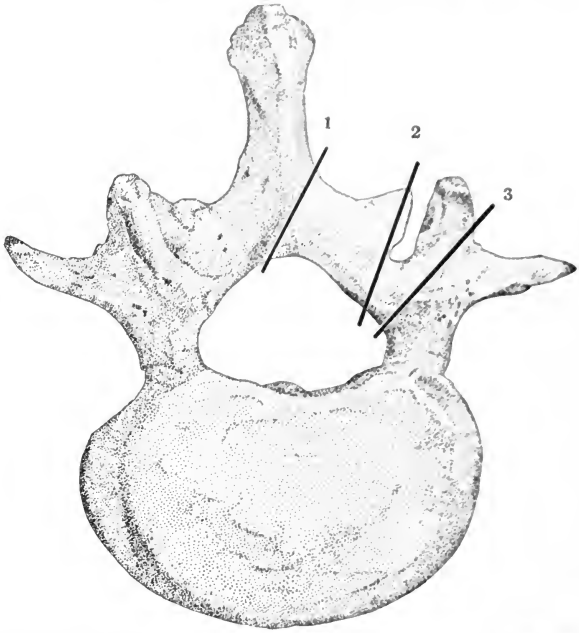



Fig. 77.—A Lumbar Vertebra. If the removal of bone between 1 and 2 does not give sufficient space, the removal may be carried out to line 3 including the articular process. This gives ample exposure and has no disagreeable sequelæ.

No special attention is paid during the course of the operation to the escape of spinal fluid.

After the object of the operation has been accomplished and hemorrhage within the dural canal stopped, the dura is closed tight by a continuous, fine catgut suture. This is best accomplished by means of the Lane holder and needles (Fig. 73).

By means of the Peaslee needle (Fig. 74), which is passed through the muscles previously separated from the spinous processes and laminæ, and then between the spinous processes and up through the muscles of the opposite side, chromic catgut sutures are passed at the rate of 1 for each vertebra. When these are tied (after all are in situ), the muscles are held snugly against the spinous processes where they belong, and oozing from the muscle is controlled. The deep aponeurosis is closed by a combination of interrupted and continuous chromic catgut sutures. The skin is closed by silk sutures.

No drainage is ever used. The dressing consists of sterile gauze pads fixed in place by adhesive plaster straps, over which cotton is held in place by a bandage or binder. No attempt is made at immobilizing the spine by plaster or other means of fixation.

Patients are kept in bed for 14 days and then allowed to get about gradually.

If at any time during the course of the operation it seems desirable to convert the procedure into a *bilateral laminectomy,* this is readily accomplished. The spinous

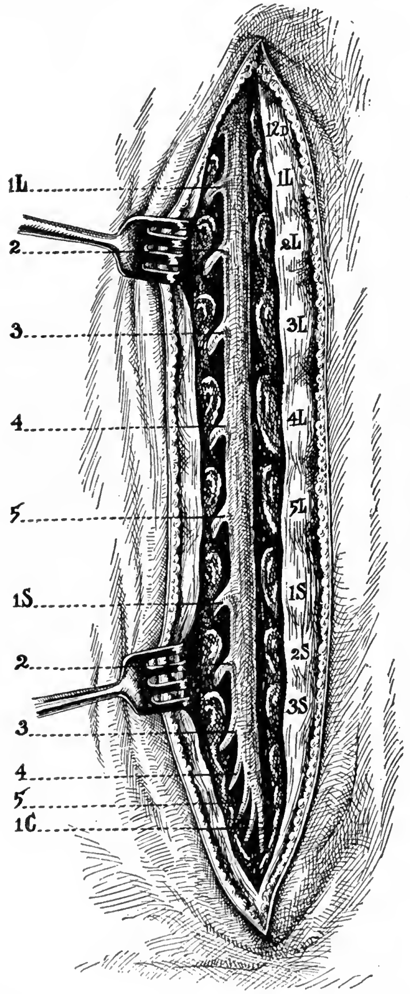



Fig. 78.—Unilateral Laminectomy from the D xii to S v. The nerves leave the spinal canal just about on a level with the spinous process of the corresponding vertebra.

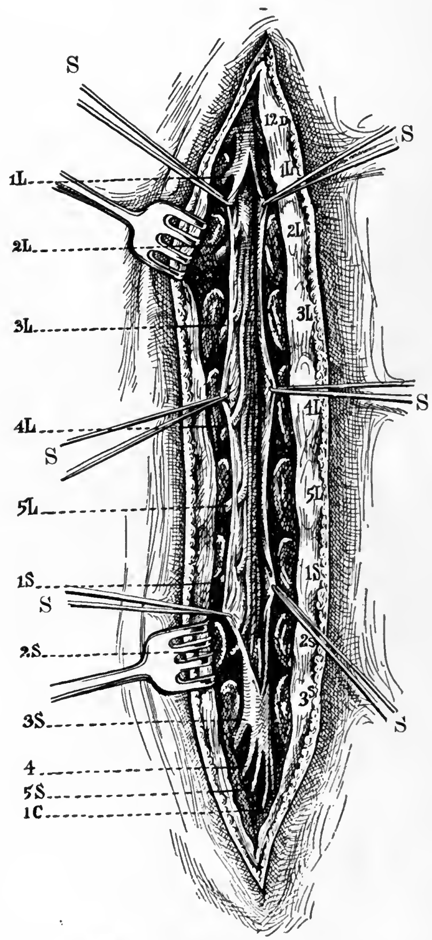



Fig. 79.—Same Dissection with Dura Split and Held Open by 6 Silk Suture Retractors Showing Cauda Equina.

processes may be clipped off at their bases by bone forceps or divided by saw, and then the spinous processes and the muscles are pushed over so as to expose the laminæ of the opposite side, which are removed by the rongeur as far as necessary.

**Advantages and Limitations.**—With the special tools devised for the purpose, this operation is but slightly more difficult and somewhat slower than the ordinary laminectomy. There is rather less hemorrhage and decidedly less damage to the bony protection of the cord. After healing has occurred, the anatomical conformation, the flexibility and the function of the spinal column are perfect.

The author has used the method in 45 cases, in all parts of the spine from the first cervical to the second sacral, and it gives a very satisfactory exposure. Its limitations are chiefly found in cases of tumor so large as not to be safely extractable through one side, and in cases of fracture of the spine involving laminæ of both sides.

For exploratory purposes, one can see the entire dorsum of the cord, the roots of both sides, and, with very slight manipulation of the cord, can expose the anterior half of the cord on the side of the operation.

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# CHAPTER XIV

## OPERATIONS UPON THE MUSCLES, TENDONS, BURSÆ AND FASCIÆ

ARTHUR SEYMOUR VOSBURGH

## THE MUSCLES

### INJURIES OF THE MUSCLES

Conditions calling for operative interference in diseases of the muscles are rare. The surgeon is more often called upon to treat wounds, subcutaneous injuries, hernia and ruptures of muscles.

**Subcutaneous Injuries of Muscles.**—Subcutaneous injuries of muscles result from external violence or from muscular action. The lesions vary from the tearing of a few fibers to the rupture of the entire muscle belly. The predisposing causes are degeneration of the muscle from any cause, such as typhoid, disuse, and chronic alcoholism. The lesser degrees of muscle tears are quite common, and aside from the pain and inconvenience experienced during the period of repair, cause no permanent disability. The sufferer from such an injury should have the part firmly strapped, and should be encouraged to use the injured member as much as possible. Prolonged rest of the part is the worst treatment that can be employed, as it greatly lengthens the period of convalescence. The amount of exercise to be employed each day should be measured by the surgeon. If not followed by pain, persisting for some time after discontinuance of the exercise, the limb has not been too much used. Repair takes place through organization of the blood clot filling the gap in the torn muscle.

**Hernia of Muscles.**—This is a rare lesion of muscles. It occurs most often in the recti and the adductors, their fascial sheaths having been torn by direct violence, by muscular action, or from some slight exertion in one suffering from disease, such as typhoid. The underlying muscle often shares in the injury. Recognition of the injury from the history and the presence of the characteristic physical signs is easy. Repair of the tear in the muscle should be made, as well as suturing the rent in the sheath.

**Rupture of Muscles in the Arm and Leg as the Result of Muscular Violence.**—Muscular violence is the most common cause of rupture of muscles in the extremities. The origin or insertion of a muscle may be torn loose, or the tear may extend across the belly of the muscle. Restoration of function is not possible without resort to operative measures.

The muscles most frequently ruptured *in the arm* are the biceps, its long or short head or its attachment to the tubercle of the radius; the coracobrachialis; and the long head of the triceps. If these injuries are not to be followed by marked weakness and loss of function, operative interference is imperative.

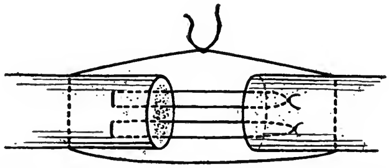

Fig. 1.—Relaxing Sutures: Distant and Mattress.

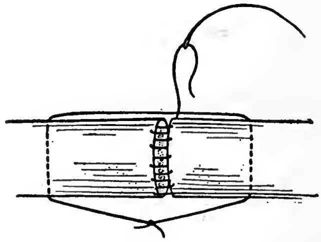

Fig. 2.—Distant Suture: Immediate Suture.

The procedure to be followed in a given case will be determined by the nature and location of the injury. Rupture of a muscle belly calls for suture. This is best done with chromic gut, using 2 varieties of suture: distant, for relaxation; and immediate, for accurate adjustment of the divided ends. The distant sutures, utilizing the fascial sheath, embrace large masses of muscle, thus offering better holding qualities; and are therefore used, wherever possible, for bringing the ends of the muscle together and holding the immediate line of suture relaxed. The mattress suture is the best for this purpose. The immediate suture, continuous or interrupted, secures close alignment of the muscle. Where the tendon of a muscle is torn from its origin or insertion, it is best secured by suturing it under a flap of periosteum, or securing it by 1 or 2 chromic gut sutures passed through holes drilled in the bone.

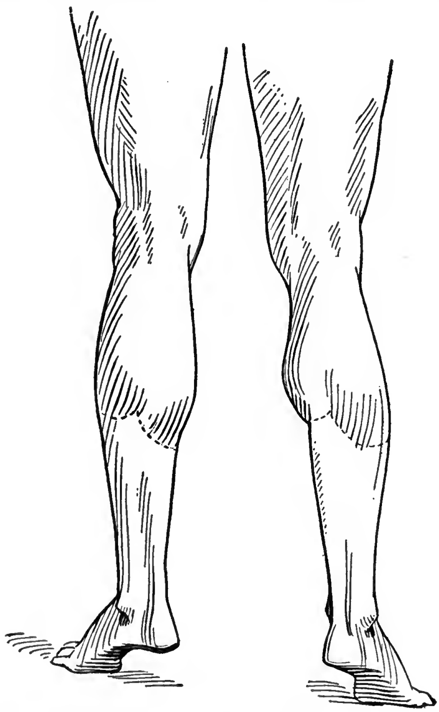

Fig. 3.—Rupture of Inner Belly of Right Gastrocnemius.

*In the leg,* the muscle most frequently torn is said to be the plantaris, resulting in what is called "tennis players' leg." As the pain from this alleged injury is often situated in the lower part of the leg, where this muscle is tendinous, there is grave doubt that the plantaris is always at fault. The gastrocnemius and soleus, also of the superficial group, may have their fibers torn and be responsible for the symptoms commonly laid at the door of the plantaris. There is no proof that the tibialis posticus and the long flexors of the toes and of the big toe may not at times be torn and give rise to the symptom-complex.

Proof is not always at hand, but the accompanying figure, made from a picture of an actual condition, shows that the gastrocnemius may be the torn muscle, producing the train of symptoms usually ascribed to the plantaris. Treatment has been indicated above.

**Subcutaneous Rupture of Muscles.**—Subcutaneous rupture of a muscle accompanying fractures and dislocations is but a minor part of the lesion and receives attention only when an open operation is undertaken for repair of the principal injury. Open wounds of muscles, resulting from trauma or involving laceration of the soft parts, or occurring in the course of an operation, are treated along the lines laid down for suture of muscle.

## DISEASES OF MUSCLES

**Degeneration and Atrophy of Muscles.**—Degeneration of muscles occurs from prolonged intoxication, in sepsis, tuberculosis and typhoid, and chronic poisoning from lead and alcohol. Regeneration can take place on recovery from disease, as is seen in typhoid cases, exhibiting that form of waxy degeneration known as Zenker's.

Fig. 4.—Paralysis of Trapezius. Double, following nerve section in removal of cervical lymph nodes; diagrammatic.

Atrophy of muscles may occur from disuse, overwork, malnutrition, and cutting off of their nerve supply, or may be of the physiological or senile type.

The treatment of the forms susceptible to improvement consists in the removal of the cause and the use of massage, electricity, hydrotherapy and exercise. In cases where the muscle atrophies from being deprived of its nerve supply—the nerve being torn as the result of some injury, involved in a callus during the repair of a broken bone, compressed in a mass of scar tissue, or accidentally divided in the course of an operation—return to normal, and relief from paralysis is possible, even after long periods of time, by suture of the nerve ends or by freeing the nerve from the structures that compress it.

**Volkmann's Ischemic Contracture.**—Volkmann and Leser describe a condition in the muscles following injury, occurring most often in the forearm, but sometimes in the leg, and resulting in the speedy degeneration of the muscles involved.

The injury most frequently causing this condition is a fracture of the humerus near the elbow, or a fracture of the bones of the forearm, in some way interfering with the arterial blood supply. In this manner, together with the application of too tight splints (though in some of the cases these have not been used), a condition of ischemia is brought about, inducing a speedy degeneration of the muscles deprived of their arterial blood.

Efforts to produce this condition experimentally have not been successful, yet when we consider that the muscles are the most highly specialized tissues in the extremities, it seems a reasonable inference that they should follow the rule of all tissues cut off from their blood supply; i. e. the more highly specialized the tissue, the more quickly, when deprived of blood, does it show degenerative changes. That the condition is not due to nerve injury, is proved by the failure to demonstrate disease of the nerves in the cases examined, and to the very prompt development of the hard, indurated muscle masses (often occurring within 24 hours) which is the characteristic lesion of this condition. That it is not an extension to the muscles from the pressure spots seen in the skin, is shown by the fact that the induration in the muscles occurs, at times, remote from the skin lesion.

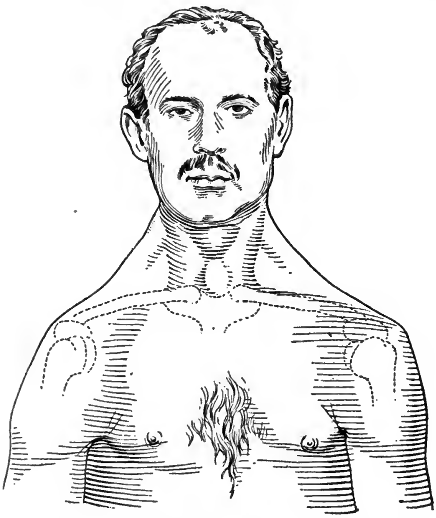

FIG. 5.—ANTERIOR VIEW OF FIGURE 4.

The secondary deformities and the paralysis of distant groups of muscles are the result of the contracture of the degenerate muscle mass. The shortened and functionless muscles cannot be extended, and the fingers are held flexed in the palm. If the wrist is flexed, the fingers can be extended. If the wrist is extended, the fingers are drawn back into their former position of flexion.

The paralysis of the muscles of the thenar and hypothenar groups comes later, due to the compression of the median and ulnar nerves as they traverse the indurated and contracting muscle mass in the forearm. These are not a part of the lesion, but the natural consequence of compression of nerve trunks traversing contracting scar tissue.

TREATMENT.—Treatment, to be intelligent, must be carried out with two conditions in mind: the one, the degenerated muscle mass; the other, the paralysis of distant groups of muscles due not to the original lesion, but to nerve compression by secondary contraction of scar tissue in the transformed or degenerated muscles. No rules can be laid down as to procedure, as each case must be judged by itself. It might be thought that prevention would be the best treatment. While not minimizing for a moment the importance of exercising the utmost care in the application of splints, especially those encircling an extremity, there seems to be plenty of evidence that this condition

FIG. 6.—VOLKMANN'S ISCHEMIC CONTRACTURE. (Drawing from a photograph loaned by Dr. F. S. Mathews.)

is the result of a combination of unfortunate sequences—unfortunate in that they occur close together—rather than the result of improper treatment on the part of the surgeon.

Not all cases are of like severity. In those where much muscle tissue has undergone degenerative changes, the prognosis is bound to be bad. In the lesser degrees of the lesion much can be accomplished by efforts at continuous traction, massage, hydrotherapy and the use of electricity. Volkmann advised the stretching of the muscles under an anesthetic. This was seldom followed by permanent improvement. Attempts to improve the position of the hand and diminish the deformity by lengthening the tendons, resecting the bones of the forearm, and dividing the tendons, have been undertaken. Division of the tendons gives no actual relief. Resection of the bones of the forearm, while accompanied by the risk of non-union, can only diminish the deformity and do little to help function, as it renders the muscles on the back of the forearm too long and in no way corrects the paralysis of the degenerated group. Lengthening the tendons was the only measure, among the earlier operations, attended by any degree of success. Drehmann in 1904 tried to dissect out the imprisoned nerves. He divided the sclerosed muscles, lengthened them and sutured them to the healthy flexor profundus. Bardenheuer, in 1906, and Hildebrand, in the same year, dissected through the scar tissue and freed the nerves. Bardenheuer "dissected off" the contracted muscles and freed the nerves. Hildebrand, Ferguson, Powers, Quinby, and Cushing dissected out the nerves, in some cases transplanting the nerves from their bed to beneath the skin and superficial fascia.

The procedures to be undertaken in an individual case must depend upon its peculiar features. Estimating the degree of involvement of the muscles in the primary lesion, recognizing what groups of muscles remain uninjured, which could be utilized to attach the tendons of paralyzed muscles to those having similar function, noticing what nerves must be freed to restore function in distant groups of muscles rendered useless by the compression of their nerve trunks traversing the cicatricial mass, will determine just what steps are necessary to improve the condition.

Liberation of the nerves should begin in healthy tissue on the proximal side of the lesion; the nerves are thus more easily followed through the dense cicatrix of the muscles. To correct the deformity, lengthening of the tendons of the involved muscles and their transplantation, in whole or in part, to tendons of muscles uninvolved, having similar function, should be undertaken. Time is an element to be considered, as most of those suffering from this condition are young subjects. It is inadvisable to attempt too much at a single operation. It would seem better to follow the nerves through the cicatrix, resecting and suturing when necessary, longitudinally dividing the sheath, freeing the axis-cylinders if there is scar tissue within the sheaths, and placing the nerves beneath the superficial fascia.

A second operation for the relief of the contractures and deformity, and tendon transplantation for the reëstablishment of function, should be undertaken if these cannot be accomplished within reasonable time at the first operation. The after-treatment of these cases is most important, and if not painstakingly carried out, all benefit from the operative procedures will be lost. It should consist in active and passive movements, massage, use of the faradic current, and hydrotherapy. These measures must be carried out for months to secure the full benefit from the operative work.

**Inflammation of Muscles.**—*Simple myositis* is usually the result of trauma, and being a stage in the process of repair, calls for no operative treatment.

*Suppurative myositis* occurs in 2 ways: (1) where the infecting pyogenic organisms reach the muscle through some wound or from some neighboring acute phlegmonous inflammation of the skin and subcutaneous tissue; (2) where the organism is carried by the blood stream in the acute infectious diseases, such as pyemia, typhoid, etc. As the muscle tissue itself is very resistant, the interstitial tissue is found to be the site of the cell proliferation and accumulation of pus cells. The pressure thus produced interferes with the nutrition of the muscle bundles, and they undergo granular, fatty, or hyalin degeneration. The process may be so intense that the muscle bundles disintegrate and gangrene occurs. The process may limit itself to the formation of 1 or more larger or smaller abscesses, or the process may involve the entire muscle.

Recovery in the majority of the cases of moderate severity, and in those not overwhelmed by the systemic disease, occurs by the evacuation of the pus, either spontaneously or surgically; and some restoration of function, by the formation of granulation tissue between the muscle fibers, takes place.

TREATMENT.—Treatment should be directed to the termination of the inflammatory process by early incision, thus limiting as far as possible the destructive tendencies of the disease, and promoting nature's efforts at repair by supporting measures. Operative interference should be confined to early and wide incision; scraping and cleaning such an abscess cavity is unnecessary, as once the pus is evacuated and pressure relieved nature will restore much that at the time looks beyond repair.

Acute parenchymatous myositis (or polymyositis hemorrhagica) and dermatomyositis are forms of disease but rarely seen, and their causes are but little understood. Their treatment is purely empirical.

**Tuberculosis of Muscles.**—The two varieties of muscle disease due to the presence and growth of the tubercle bacillus differ more in the method of invasion than in any essential difference in type. One type of the disease is an extension from some neighboring tissue or organ. In the other type the disease seems to be "primary" in the muscle. Tuberculosis of a muscle is an infiltration and replacement of the connective tissue stroma by tubercle tissue, often with the products of inflammation added. The muscle tissue itself is pushed aside and, compressed, undergoes atrophy or waxy or hyalin degeneration and may finally be entirely destroyed. The tubercle tissue goes through the various stages of its formation, development, degeneration, and final destruction; or if sufficient resistance on the part of the host is developed, it is transformed into connective tissue or is encapsulated. It is immaterial whether the exciting agent, the tubercle bacillus, reaches the muscle from some nearby focus, or is carried to the muscle by the blood from a distant part of the body—the disease is the same. In the second form the diagnosis may be delayed and treatment instituted too late to save the muscle from destruction.

TREATMENT.—In the discussion of the nature of this disease and its development, it was noted that the tuberculous tissue grows in the connective tissue stroma; that it destroys the muscle fibers themselves only through the effects of pressure, causing them to undergo waxy and hyaline degeneration, because of the diminished blood supply. The indication for treatment is, therefore, plain. When the disease in the muscle is secondary to tuberculosis of bone, articulation, or lymphatic system, the cure of the primary lesion is essential; otherwise the removal of the local disease in the muscle will be followed by a recurrence. When the disease in the muscle seems to be "primary," having originated from some undiscovered focus elsewhere in the body, through the medium of the blood stream, the careful removal of the entire muscle is probably the best procedure.

It is unnecessary to describe the precise steps to be taken, as the conditions calling for interference are too numerous to warrant an attempt at detailed discussion. Where an abscess or sinus has formed, its complete removal is indicated whenever possible. Where the anatomic conditions preclude this possibility, the abscess should be opened, its contents evacuated, and its cavity filled with an emulsion of iodoform in glycerin. The wound should be closed and sealed with an aseptic dressing, and the part immobilized.

It may be necessary to repeat this procedure. It should never be forgotten that one may prevent the infection of the wound by pyogenic organisms through the exercise of great precaution in the performance of these operations. Inability to pursue either of the above courses compels one to adopt other methods of treatment of tuberculous lesions, such as removal of as much of the diseased tissue as possible, sterilization of the tract or cavity with tincture of iodin, and treatment of it as an open wound.

Another method that has given very excellent results in the hands of its originator and many others, especially for the ramifying sinuses about a tuberculous articulation, is that described by Emil G. Beck.

Beck injects the sinuses with a mixture of bismuth subnitrate and vaselin in the proportion of 33 per cent. of the bismuth to 66 per cent. vaselin. This mixture is first rendered sterile, and is then liquefied before use by heating. The injection of the paste is made through a small incision, which allows the evacuation of larger particles of tuberculous débris than could be passed through a trocar or aspirating needle and assures the operator that he has entered the sinus. In cold abscesses Beck advises the use of 10 per cent. bismuth and vaselin paste. The danger of this procedure is in bismuth poisoning. Should symptoms of poisoning appear, the paste must be removed by washing out the cavity with warm olive oil. The sterile oil is retained from 12 to 24 hours, in order to make an emulsion and is then withdrawn by means of suction.

The care of tuberculous patients, whether suffering from surgical or general tuberculosis, should include fresh air, sunshine and proper hygiene. The use of heliotherapy, as practiced by Rollier in his children's clinic at Leysin, is one of the best examples of the benefit obtained by the action of sunshine in combination with proper surgical treatment.

**Actinomycosis of Muscles.**—This has been discussed at considerable length in the chapter on Inflammations of the Abdominal Wall, and a further elaboration of the subject in this chapter is unnecessary.

**Hydatid Disease of Muscles.**—This subject has also been discussed in the chapter on Inflammations of the Abdominal Wall.

**Syphilis of Muscles.**—In both the congenital and the acquired forms of this disease, involvement of the muscles takes place. The most common form is the development of gummata in the connective tissue planes of the muscles. These, according to the activity of the disease, grow slowly or rapidly; are painless or, when near nerves that are pressed upon, painful; they infiltrate the muscular planes, producing atrophy of the muscular bundles, and—in cases where the resistance of the individual or treatment does not bring about resolution—break down and form ulcers involving the muscle, fascia, subcutaneous tissue and skin. Except in the very exhausted and non-resistant, recovery is easily brought about by suitable specific treatment, and healing takes place by the replacement of scar tissue.

A rarer form is the so-called diffuse syphilitic myositis, evidenced by a stage of infiltration, rendering the muscle hard and rigid, followed by atrophy and sclerosis, and finally ending in contractures.

If treatment is instituted in the stage of infiltration, before the destructive changes due to the sclerosis have taken place, recovery and return to normal are possible.

**Trichiniasis.**—This disease is caused by the trichina spiralis. Infection occurs in man from the ingestion of insufficiently cooked pork. The muscle of the diseased pig contains the embryos of the parasite in an encysted condition. In the stomach the capsule of the worm is dissolved and the embryos are set free. They mature rapidly, increasing in size, and the females give birth, in the small intestines, to large numbers of young. These find their way through the mucous membrane and wall of the gut into various parts of the body. Their exact course in leaving the gut is not fully established; they probably traverse the tissues in different ways. At any rate, they find their way to the voluntary striated muscle tissue, which they penetrate, and enter the muscle fibers. In this situation they become encapsulated, the capsule after a time becoming partially calcified, and in this encysted state they may remain inactive but living for an indefinite time.

As a result of the presence of these parasites in the body, if the invasion be severe, acute catarrhal enteritis with diarrhea and vomiting, high fever and severe pain, is apt to occur. Edema of the face and other parts of the body, bronchopneumonia and fatty degeneration of the liver may be found in cases that have succumbed to the disease.

The flat muscles, especially near their tendinous insertions, is the favorite site for the lodgment of these parasites. A valuable diagnostic sign is the marked eosinophilia that regularly accompanies this disease.

TREATMENT.—Treatment consists in removing as many of the parasites as are still harbored in the intestine by active catharsis and intestinal antiseptics, while supporting the strength of the patient during the height of the disease. In the non-fatal cases the disease limits itself.

**Ossification of Muscles.**—Ossification takes place under conditions and for reasons little understood. One form manifests itself, usually in young persons, by an invasion of the interstitial tissue of the muscles, commencing in the groups of the neck and back. The disease is progressive, and nothing we now know can arrest its progress.

A second form, occurring in muscles subjected to sudden strain or repeated injury, would seem to have trauma as a causative factor. The bony growths seen in the shoulders of infantrymen and in the adductor group of horsemen appear to sustain this theory.

Bone formation is initiated by the dislodgment of small shreds of periosteum, which produce new bone near and continuous with the insertion of the muscle. In cases where the new bone is entirely free from the aponeurotic insertion of the muscle, we must believe that some shred of periosteum or fragment of bone has been pulled up into the belly of the muscle by muscular contraction. In opposition to this, we know that bone can be developed in any of the tissues of the body when there has been no possibility of transplantation. Whatever theory we may entertain as to causation, we do know that these last forms of ossification in the muscle, where they cause mechanical disability, can be benefited and cured by operation.

**Tumors of Muscles.**—Tumors of muscle usually develop in the connective stroma. Fibroma, chondroma, lipoma, myxoma, and sarcoma may occur as primary tumors. Carcinomata and sarcomata may develop secondarily in muscles, by extension from adjacent parts.

TREATMENT.—Treatment is the same as for these conditions elsewhere in the body.

## THE TENDONS

The tendons are composed of white fibrous tissue. To the naked eye the fibers appear as silvery-white, glistening bundles, running parallel with each other. They are covered by a quantity of loose, flocculent tissue binding them together and carrying the blood vessels. They are inelastic and exceedingly strong, but easily split. Regeneration, after division or rupture, takes place by the formation of new connective tissue between the divided ends. Whether this new tissue is developed from fibroblasts—derivatives from preëxisting connective tissue cells—or is in part formed from vascular and lymphatic endothelium given off as buds from the new capillary loops, is a problem for the pathologist rather than the general surgeon to determine. It suffices for the surgeon to know that the change from the young vegetative connective-tissue cells into long thin compressed cells surrounded by fine fibrils, and eventually into adult connective tissue, takes place in about 6 weeks.

### INJURIES TO TENDONS

**Subcutaneous Injuries.**—Subcutaneous injuries to tendons are the result of great force applied to the tendon where it is traversing a part of its course, supported by bone. Where it is lying among soft parts it is little liable to injury. When crushed, its fibers become frayed, and if this occurs in a narrow canal, as the sheaths of the palmar flexors, the subsequent healing leaves the tendon no longer smooth and of the same diameter, but gives rise to symptoms, the treatment of which will be described later.

**Rupture of Tendons.**—Rupture of a tendon is less frequent than tears in the muscle belly to which it belongs. When the tear is confined to the tendon alone, it occurs usually in the form of a "sprain fracture," i. e. a small scale of bone is torn from the tendon's attachment.

TREATMENT.—Treatment has been indicated in the section under muscles. Here it is only necessary to state that the earlier the operative relief is instituted, the better is the chance of success. Delay means shortening of the muscle and the filling in of the tendon's bed with connective tissue. An immobilizing dressing should be applied after operation, with the part in such position as will afford relaxation. This should be worn for a period of 6 weeks, or else the new formed tissue will stretch and there will be diminution of function, owing to redundancy in the length of the repaired tendon.

**Dislocation of Tendons.**—This condition is rare and occurs most frequently to the peronei muscles, 1 or both tendons being dislodged from their groove behind the external malleolus, after rupture of the fibrous bands and synovial sheaths which commonly hold them in place.

TREATMENT.—(A) CONSERVATIVE.—Reduce the dislocation and maintain the foot in such position, by means of an immobilizing dressing, as will hold the tendons in their place. Persist for about 6 weeks. This failing, one must operate.

(B) OPERATIVE.—Make an ample incision along the line of the fibula, but not directly over the groove. Search for the torn sheath, replace the tendons, and suture the sheath. If the canal has filled up and the margins of the sheath cannot be identified, reconstruct a canal behind the malleolus from neighboring fascia, or use a flap of periosteum, as suggested by König, turned downward or backward from the fibula.

**Wounds of Tendons.**—These occur more frequently in the hands, less often in the feet, from cuts with knives, sharp objects, bits of glass; and in association with extensive injuries and lacerations, as the maiming accidents from machinery. The tendons are cleanly divided, crushed, or fibrillated, according to the character of the wound.

Often in incised wounds about the wrist, the back of the hand and on the fingers, the division of the tendons is not discovered. In sharply bleeding wounds of this character the inexperienced operator is more concerned in checking the hemorrhage, and the disabling injury to the tendon goes unrecognized. It should always be the rule to test the function of all muscles, whose tendons traverse such a wound; for when the tendons are cleanly divided, the contraction of the muscle withdraws the proximal end from the field, and unless this precaution is observed a second operation becomes necessary.

TREATMENT.—In all wounds that can be rendered clean, or reasonably so, primary suture of the divided tendons gives the best results. In cases where the injury has not been recognized, and in wounds that are infected, secondary suture is of necessity the procedure to be adopted. Here it should be borne in mind that all wounds appearing black and soiled are not necessarily in-

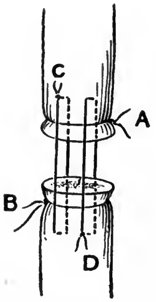


FIG. 7.

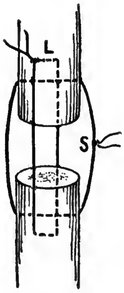


FIG. 8.

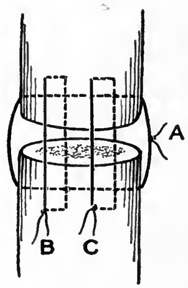


FIG. 9.

FIGS. 7–9.—METHODS OF TENDON SUTURE.

fected. As primary suture gives so much better results and entails such a saving of time, an attempt should be made at repair, even in the cases where the skin and surrounding tissues are soiled and black from the grime and grease of the machine. These wounds can often be rendered clean by placing a sterile pad over the wound, removing as much of the black and grease as will come away on 2 or 3 pads wet with turpentine, then cleaning the interior of the wound with salt solution, removing with forceps all foreign material, and finally painting the entire region with tincture of iodin. A wound so treated will often surprise one by healing as kindly as one surgically prepared. Too much scrubbing, in an effort to render the wound cosmetically clean, will defeat one's purpose.

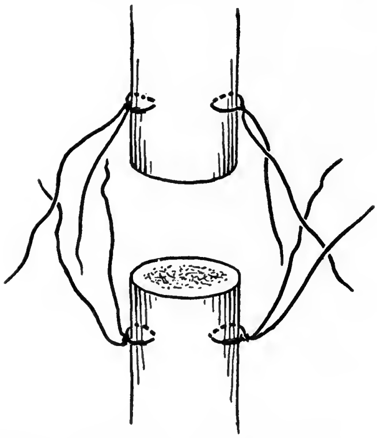

FIG. 10.—METHOD OF TENDON SUTURE.

PRIMARY SUTURE OF TENDONS.—The wound being clean, or prospectively so, after arresting all hemorrhage begin the search for the divided ends. The distal ends will retract but little and are easily found. The proximal ends may require an extensive search. Manipulate the part by flexion or extension as the case requires; "milk" the muscle belly toward the wound by pressure with the fingers or by means of a bandage applied from above downward; try to grasp the retracted ends by small hooks passed upward along the tendon's sheath, and draw them into the wound. Failing in these efforts, incise freely the overlying tissues and discover the tendon. Cleanly divided tendons

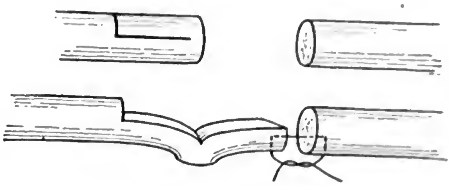

Fig. 11.—Method of Tendon Lengthening, Single Flap.

can, as a rule, be easily brought together. Unite them with sutures of silk passed in various directions. If the tendons are held in place with con-

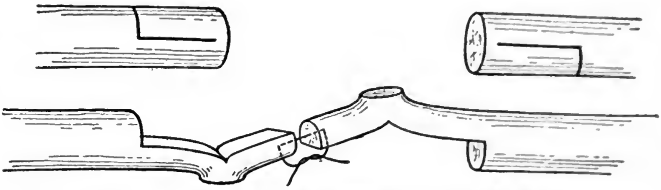

Fig. 12.—Tendon Lengthening, Double Flap.

siderable difficulty, the sutures are apt to pull out, by the splitting of the longitudinally running bundles. This can be obviated by encircling the

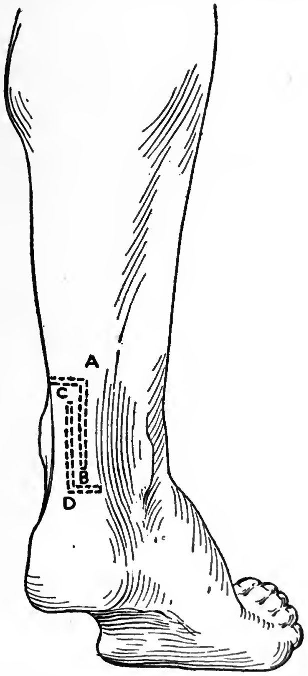


Fig. 13.—Tendon Lengthening: Hibbs-Sporon Method.

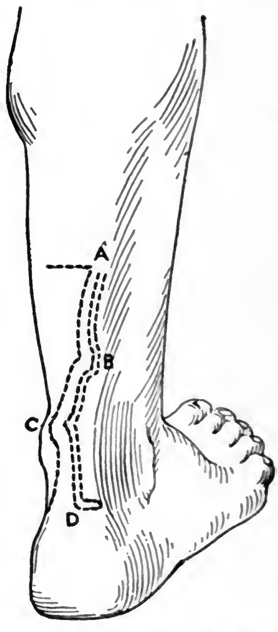


Fig. 14.—Tendon Lengthening: Hibbs-Sporon Method.

ends with a piece of silk and passing the retention sutures in such directions as to embrace the encircling ligatures. The method of placing the sutures is shown in the above diagrams. The simpler methods of suture are the best.

Secondary Suture of Tendons.—Secondary suture is necessary in the cases in which, at the time of the original injury, the division of the tendons was unrecognized; and in which, by reason of infection or too great injury to the soft parts, it was deemed unwise to attempt a primary suture.

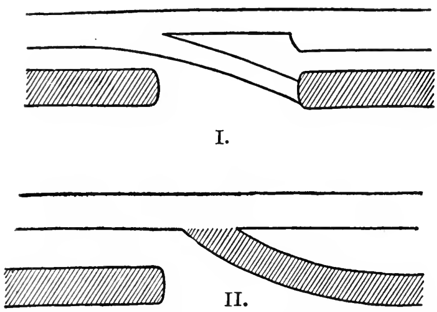


Fig. 15.—Tendon Transplantation. I, Flap from live tendon to tendon of paralyzed muscle; II, grafting "dead" tendon to "live" tendon.

The rules for secondary suture are the same as for primary suture, but in the latter many more difficulties must be overcome. The tendons will be retracted and bound down in their new positions, the tendon sheaths will be found blocked with new connective tissue, and in the cases originally the site of suppuration it will be found necessary to resort more frequently to tendon lengthening and tendon transplantation. Great ingenuity will be called for in the utilization of the material at hand, and considerable surgical dexterity will be required in dealing with tissues that do not readily lend themselves to plastic work.

In secondary suture valuable use can be made of free flaps of the subcutaneous fat to wrap around the suture, and to line the new beds made for the reconstructed tendons. Other material, such as serous sacks, may be used if at hand.

After-care Following Tendon Suture.—The surgeon, in these cases, is of two minds. To secure firm union and proper organization in his plastic work, he desires to keep the part at rest for 6 weeks. For the reëstablishment of function, he desires to begin the passive movements early. If he begins passive motion too early, the newly united tendons will stretch and, owing to redundancy, the functional result will be poor. If he delays too long, ankylosis will take place and all benefit of the operation will be lost. A middle course will be found the safest.

At the end of the third week, a few passive movements can safely be made. The wound in the soft parts will have healed, and massage of the part, with hot and cold bathing, can be done every day, care being taken to put the part back in its immobilizing dressing after each treatment. Voluntary efforts should not be attempted before the end of the sixth week.

### TRANSPLANTATION OF TENDONS

The principle that underlies these operations consists in utilizing part of the power of a healthy muscle or group, and transferring it to a paralyzed muscle or group; or in attaching a healthy muscle to the bone or periosteum to correct a deformity resulting from injury or disease.

It is impossible in the limits of this article to do more than indicate the uses to which this principle can be applied and leave the detailed description of individual cases to the writers of the chapters on orthopedic operations. It must be borne in mind that the successful outcome of these operations depends upon a nice balance of judgment, and that they should not be undertaken until the contractures and deformities have been corrected. There must be proof that actual paralysis of muscle exists. Often the loss of function is due to overstretching of the muscles while in a condition of temporary paralysis from a diseased, severed or bruised nerve.

**The Use of Foreign Substances in Tendon Transplantation.**—The most successful operations in tendon transplantation are those in which use is made of autogenous grafts. Heterogenous grafts are now successfully employed, but always will hold a second place to those taken from the same individual.

Use has been made of silk and linen threads of various sizes and strength, to piece out defects in tendons. Where these have been used about the foot, it has been found that the strain is too great and they have pulled out. In the hand they have met with more success. The reason for this seems to be that there is not sufficient organization of connective tissue about the implants, and the strain has eventually to be borne by the foreign material.

## TENOTOMY

Two methods are in use for performing tenotomy: the open operation and the subcutaneous operation. In the open operation the tendon is cut down upon and divided under the guidance of the eye. In the subcutaneous operation the tendon is put upon the stretch and divided with a tenotome passed through the skin to the side of the tendon. Division is usually made from within outward, or away from important structures. Each has its uses. The open operation is more used where fascial bands are to be divided in the neighborhood of important structures, as in the neck. The subcutaneous method is more in use for tendons. Tenotomy is useful in lengthening tendons, especially in young children. When a subcutaneous tenotomy is done to the tendo Achillis in these young subjects, the divided ends are drawn apart by the correction of the deformity, and a considerable gap is left in the bed of the tendon. By the time the little patients are ready to use the foot, the gap will have been bridged and perfectly good function of the divided tendon will be present. This would seem to indicate that the elaborate operations for tendon lengthening, at least in the young, are unnecessary.

The many conditions for which tenotomy is employed will be mentioned and the operations described in another part of this work.

### TENDON SHORTENING

It is sometimes found necessary to reef or shorten tendons. This should seldom be the case, as stretching takes place at the expense of the muscle and shortening the tendon will not help matters if its muscle belly remains functionless. In the cases where it seems indicated, resect and suture.

### THICKENING AND NODULATION OF THE TENDONS

As a result of trauma, small extravasations of blood will frequently take place in a tendon. This blood organizes and forms a nodule, or degenerates

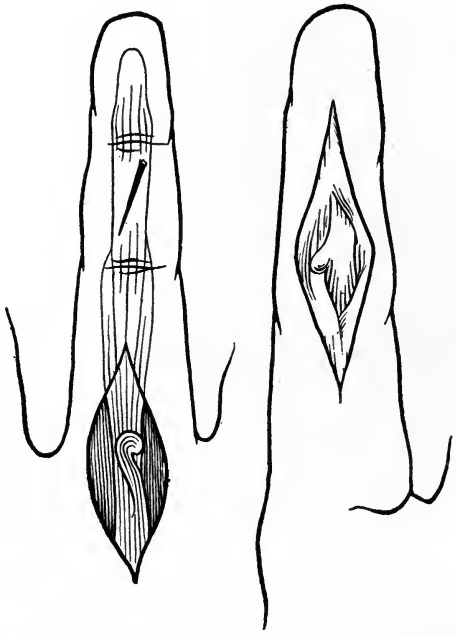

FIG. 16.—SNAPPING FINGERS. (Weir.) Needle in tendon: Payer's case. Split tendon: Haegler's case.

and forms a cyst. Again, as a result of long-continued pressure (wearing a ring, Weir), thickening takes place in the sheath. At times the tendon is bruised and some of its fibers are split, becoming curled up and forming a nodule. Any of these conditions can give rise to the condition known as trigger finger.

**Treatment.**—In the cases where the symptoms are due to a nodule, cyst or frayed portion of the tendon, incise the sheath, expose the tendon and remove the obstruction at the expense of the interior of the tendon. Diminish the diameter of the tendon after excision of the cyst, or removal of the nodule by very fine silk sutures buried in the interior of the tendon. Where the symptoms are due to a narrowing of the sheath Weir advises its simple division.

### GANGLION

A ganglion is a cystic formation developing in the tissues, usually in the neighborhood of the capsule of a joint, on a tendon sheath, or in the tendon itself. It is most frequently found on the extensor surface of the wrist, less often on the flexor aspect. Occasionally ganglia are seen on the dorsum of the foot, and still less frequently in the neighborhood of joints in other parts of the body. They are thin, connective tissue sacs, containing a clear transparent gelatinous fluid, attached to the joint capsule or tendon sheath by a broad or narrow base. Formerly they were thought to be extrusions, or

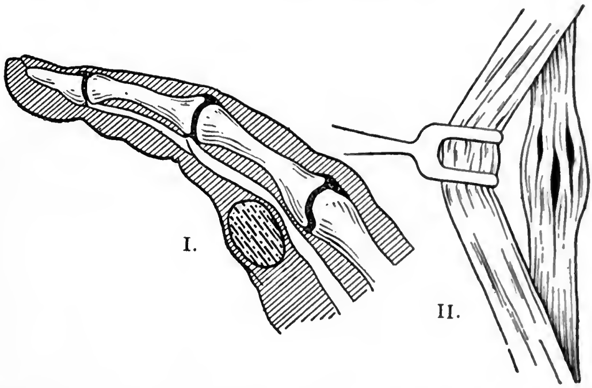


FIG. 17.—I, TUMOR CAUSING TRIGGER FINGER; II, ENLARGEMENT OF DEEP FLEXOR. (Weir.)

evaginations from the synovial membrane lining the joint, forced out by strains put upon the articulation, and later shut off from the joint by cicatricial contraction of the scar tissue (Gosselin). Later investigators have proved that these small cysts result from degenerative changes in the capsular tissue and in the tendinous and paratendinous tissue.

As the result of some slight trauma to the capsular tissue or tendon, an extravasation of blood takes place in the tissues and, associated possibly with an obliterating endarteritis, degenerative changes are initiated. Examination of the recently formed tumors shows trabeculæ running in various directions, evidence that the degenerative process is not complete and has not converted the tumor into a single sac. Very recent ganglia may even be semi-solid.

**Treatment.**—The indication for treatment of these small benign tumors arises from the sense of weakness, often experienced, and occasionally from neuralgia-like pains, seldom from interference with function.

NON-OPERATIVE TREATMENT.—In the thin-walled cysts a cure can often be effected by rupturing the cyst with a heavy blow, the part having first been rendered tense. Compression should be employed after this method of treatment. Recurrences may take place, and the treatment will have to be repeated. I have on several occasions ruptured the cysts by powerful pressure with the fingers, the part having first been made tense.

OPERATIVE TREATMENT.—Upon failure in the above measures, an operation conducted with the strictest aseptic precautions is advisable. As anything less than complete removal is apt to be followed by recurrence and consequent embarrassment to the operator, these operations should be conducted with great care, aided by artificial ischemia and the closest attention to surgical technic. The joint or the tendon sheath will often have to be opened, and infection occurring in a patient suffering from such a minor condition will be attended by great hurt to the surgeon's reputation and grave injury to the individual.

## BURSÆ AND TENDON SHEATHS

Synovial membranes of the body are divisible into 3 varieties or subdivisions: articular, bursal and vaginal. These membranes are derived from the connective-tissue layers and have in their interior a viscid fluid. This fluid is derived from the disintegration of other connective-tissue cells. The old theory of mucilaginous glands as the source of the synovial secretion has been abandoned. The bursal synovial membranes seem capable of development in any part of the body where the overlying skin is subject to pressure or friction on hard unyielding parts beneath. Thus we find bursæ interposed between the integument and bony surfaces. The bursal synovial membranes are again divided into the bursæ mucosæ and the bursæ synoviæ. The bursæ mucosæ are large, irregular cavities lying in the subcutaneous or areolar tissue, and contain a clear viscid fluid. This is the form found between the integument and the front of the patella, over the olecranon, the malleoli and other prominent parts of the body. The bursæ synoviæ (synovial sheaths) are found interposed between muscles or tendons as they project over bony surfaces or as they line the osseo-aponeurotic canals. These are found investing the tendons of the hand and foot. The membrane is here arranged in the form of sheaths, 1 layer of which adheres to the wall of the canal, and the other is reflected upon the surface of the contained tendon. The space between the 2 free surfaces of the membrane contains the synovia. The layer lining the sheath is known as the parietal layer, that covering the tendon is called the visceral layer.

The diseases of the articular synovial membranes are treated under their appropriate headings in other chapters of this book.

The diseases of the bursal and synovial membranes are the same as these attacking membranes in all parts of the body.

### INFLAMMATIONS OF THE BURSÆ

**Acute Bursitis.**—Acute bursitis is usually the result of a single injury and is more properly described as a hemorrhage into the bursal sac, as a result of the injury.

TREATMENT.—Treatment should be directed to the removal of the hemorrhage by measures which will promote absorption. This is best accomplished by rest and compression of the part, together with an ice pack for a few days, followed by the use of hot and cold bathing and massage. Aspiration of the contents of a hemorrhagic bursitis is seldom indicated.

**Chronic Bursitis or Hygroma.**—This results from the persistence of the acute hemorrhagic variety, or develops as the result of continued irritation of these membranes as seen in the so-called "occupation bursitis," as the prepatellar bursitis or "housemaid's knee" and the olecranon bursitis or "miner's elbow."

TREATMENT.—When the condition is of recent origin and in sacs not unduly thickened, resolution can often be brought about by rest and compression of the part with or without aspiration of its contents and the injection of the sac with a tincture of iodin. The more chronic cases with thickened walls will not yield to these measures, and excision of the bursa becomes necessary.

**Acute Suppurative Bursitis.**—This may arise in old chronic cases of bursitis or result from open, incised, or punctured wounds of the bursæ. Rarely does infectious bursitis occur through the medium of the blood stream. The simultaneous development of bursitis in various parts of the body would suggest rather a constitutional disease, such as tuberculosis or syphilis, as its etiology. The free communication which exists between the bursal sacs and the lymphatic system renders infection of the bursæ quite common from suppurative processes in their neighborhood. They may also become infected by direct extension along the subcutaneous layers from nearby suppurative foci.

The situation of the bursæ beneath fascial planes renders their infection peculiarly dangerous, by reason of the extensive cellulitis that may result from extension of the suppurative process beneath these confined spaces. Thus suppuration in the prepatellar bursa and in the olecranon bursa often gives rise to extensive cellulitis in the leg and arm. The pus, unable to make its way to the surface by reason of the resistance of the strong aponeurotic layers, invades wide areas of the extremities. As a result of the retention of inflammatory products beneath the fascial planes, grave constitutional symptoms due to the septic absorption are common.

TREATMENT.—As in the treatment of chronic bursitis, excision of the sac is indicated whenever possible. Unfortunately, owing to the peribursal inflammation, this cannot always be done. Here one must be content to incise the sac, giving vent to the pus, and taking care that by free division of the surrounding fascia exit is given to inflammatory products that may have made their way outside the bursal sac into the surrounding subcutaneous tissues. Care should be exercised that the materials used for drainage of the sac and fascial planes do not act as a plug. This can be obviated by transverse division of the fascia so that it is made to gape, and by placing the rubber tissue drains or rubber tubes in the extremities or angles of the wound. The dressings should be moist, light and preferably in the form of evaporating lotions. They should be changed frequently. The practice of using rubber tissue or rubber sheeting to keep the moisture in should not be tolerated, as this converts our wet dressings into poultices and favors the spread rather than the hindrance of the progress of the inflammation.

**Tuberculosis of the Bursæ.**—This is of slow and insidious development without the usual signs of inflammation. The diagnosis is often difficult, and only to be determined by operation or inferred from the presence of tuberculosis elsewhere in the body. Like all forms of surgical tuberculosis, the greatest measure of safety lies in its complete removal. A less efficacious method of treatment consists in attempts at sterilization of the contents of the bursæ by injection with iodoform and glycerin. Syphilis of the bursal sacs usually takes the form of gummata formation. These should be removed by operation whenever possible, and appropriate constitutional treatment instituted.

## DISEASES OF SPECIAL BURSÆ

**Subacromial Bursitis.**—Subacromial bursitis may be acute, chronic, or suppurative. This bursa, when it does not communicate with the subdeltoid bursa—which, however, is often the case—is easily approached and excised by incisions through the skin at the top of the shoulder.

**The Subdeltoid Bursa.**—ACUTE INFLAMMATION.—Acute inflammation of this bursa often develops as the result of a single injury, and very often leads to mistakes in diagnosis. It is often confounded with inflammation of the shoulder joint proper. Its situation deep beneath the deltoid, embracing the head of the humerus, gives rise to this confusion. Under the name of "peri-arthritis humeroscapularis," Duplay describes this as a chronic adhesive inflammation. It is distinguished from pure articular conditions by the ability to move the arm in a sagittal plane and to rotate it in its long axis. Abduction of the arm is not possible without movement of the scapula.

TREATMENT.—This consists in the avoidance of restraining dressings and the encouragement of the patient to use the arm as much as possible. Where the diagnosis has not been promptly made and great limitation of motion exists as a result of the extensive adhesions, these should be broken up under ether and active and passive motions continued daily, combined with hydrotherapy and massage.

TUBERCULOSIS.—Tuberculous disease of this bursa is recognized by the crepitus obtained by the rubbing of the rice bodies in its interior, by its slow formation, and by absence of inflammatory signs. Tuberculous lesions elsewhere aid one in forming a diagnosis.

TREATMENT.—The best treatment consists in total extirpation of the sac. This is accomplished through a longitudinal incision placed over the most prominent point of the swelling, entering between the fibers of the deltoid. Care should be exercised not to wound the circumflex nerve in its course on the deep surface of the muscle. Inability for any reason to pursue this method of treatment compels one to treat this condition by aspiration of the fluid contents and the injection of a sac with iodin or other antiseptics.

**The Olecranon Bursa.**—The olecranon bursa is subject to the same diseases as the other bursæ. It is rarely tuberculous, more often subject to chronic inflammation or hygromatous, at times the site of acute infectious bursitis. Owing to its situation beneath the strong aponeurosis back of the arm, infectious processes in this bursa require special attention to the freeing of pus which may have made its way into the subfascial planes. The chronic and tuberculous forms are likewise best treated by excision.

The bursæ in the neighborhood of the wrist and hand are small and unimportant. The diseases of the tendon sheaths are here more important and will be dealt with later.

**The Bursæ About the Hip.**—There are numerous bursæ about the hip. Those between the insertions of the glutei muscles to the trochanter are seldom the subject of surgical interference. The bursa overlying the tuberosity of the ischium is frequently the subject of surgical interference. This bursa is best approached with the thigh in the flexed position; the gluteus maximus is then withdrawn from over the tuberosity. The large multilocular bursa between the fascial expansion of the gluteus maximus and the trochanter major can be approached and excised by an incision parallel with the fibers of this aponeurosis. The iliac bursa beneath the psoas iliacus lies in the muscular compartment beneath Poupart's ligament, and can be incised and drained by an incision placed over the head of the femur to the outer side of the femoral artery. Care should be exercised not to wound the anterior crural nerve in dealing with this bursa.

**The Bursæ About the Knee.**—THE PREPATELLAR BURSA.—The prepatellar bursa is the most frequently involved of the bursæ about the knee. Operations for chronic and acute conditions of this sac are best performed through a transverse incision placed over the most prominent part of the swelling. This transverse incision should be extended laterally into the uninvolved tissues at the side of the bursa. The flaps are then more easily dissected in both directions. The approach to the bursa from the side and posteriorly will enable one to do a clean excision with less danger of entering the cavity of the sac.

THE POPLITEAL BURSÆ.—The popliteal bursæ most frequently the site of disease are connected with the tendon of the semimembranous and the tendon of the popliteus, the one at the inner side of the joint, the other at the outer side of the joint. As these two bursæ frequently communicate with the joint, total excision is impracticable. Injection of the interior of the sac with various irritants is attended with danger, owing to the liability of the injected material entering the interior of the joint. The best treatment is partial excision with careful suture of the remnants of the sac, compression, and application of a splint to insure rest.

**The Bursæ About the Ankle.**—The various small bursæ about the foot do not need a detailed description. The bursa situated between the tendo Achillis and the upper portion of the tuberosity of the os calcis, however, is important. This is approached for its various diseases by incisions placed on either side of the tendo Achillis. If necessary for complete enucleation, this tendon may be divided and later sutured.

## THE TENDON SHEATHS

Owing to their great importance and greater liability to infection, the tendon sheaths of the hand should be dealt with in fuller detail than those of the foot. One cannot approach the proper operative treatment of the tendon sheaths of the hand without a knowledge of their anatomy.

**Anatomical Points.**—A brief review of the special anatomy of the hand with reference to the tendon sheaths would seem indicated. The skeletal and vascular anatomy of this region is too well known to require repetition. The hand as a whole presents a convex surface dorsally, and a concave surface ventrally, and appears as a truncated cone—its base toward the fingers, its apex toward the wrist. The annular ligament bridges the concave aspect of the carpal bones, attached to the tuberosity of the scaphoid and ridge of the trapezium on its radial side, and to the pisiform bone and hook of the unsiform on the ulnar side. A canal is thus formed which lodges the tendons of the long flexors, their synovial sheaths and the median nerve. The floor of the hand widens out as we proceed distally, corresponding to the ray-like arrangement of the metacarpal bones. Between these last lie the interosseous muscles, covered by an aponeurosis, thin above, stronger below, continuous with and helping to form the (deep) transverse metacarpal ligament. The muscles of the thumb and little finger bound this region of the hand on either side. From the central portion of the anterior annular ligament the palmar fascia extends to the base of the fingers. This is the central strong part of the palmar fascia. Its thinner lateral parts invest the muscles of the thumb and little finger. The

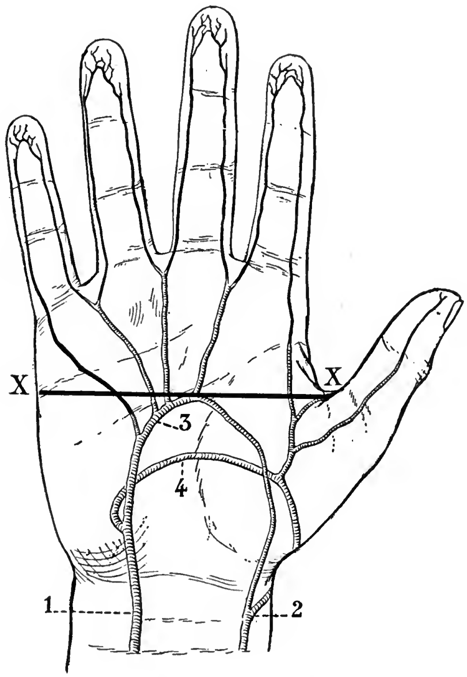

Fig. 18.—Position of the Palmar Arches. Diagrammatic.

middle region of the hand containing the tendons of the long flexors and their synovial sheaths is thus converted into an osseo-aponeurotic compartment. The central part of the palmar fascia divides into 4 slips, which go to the 4 inner fingers. It becomes perforated in this region by the wide interlacement of its longitudinal and transverse bands. The majority of the longitudinal fibers become continuous with the fibrous sheath or theca of the tendons. The remaining bundles of longitudinal fibers intertwine, dip down, and become attached to the deep transverse metacarpal ligament, serving to separate the flexor tendons from the digital nerve and artery and the lumbrical muscle of each interdigital cleft. We thus see that the hand is divided into 3 compartments, an outer and an inner, giving lodgment to the muscles of the thumb and little finger; and a central compartment lodging the tendons and their synovial investment as mentioned above. The subcutaneous tissue of

FIG. 19.—FETAL TYPE.

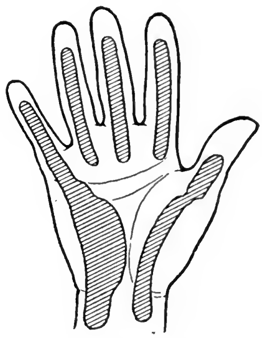

FIG. 20.—USUAL TYPE.

FIG. 21.—OCCASIONAL TYPE.

the front of the hand, and especially of the palm, is scanty and dense. The subcutaneous tissue on the dorsum is, on the contrary, lax, and has but a slight association with the skin. At the interdigital clefts or webs of the fingers, the subcutaneous tissue is continuous with that about the fingers, and merges into the loose areolar tissue on the dorsum of the hand. It is continued into the space beneath the central portion of the palmar fascia, blending with the areolar tissue found there. The transition in the character of the subcutaneous tissue found in the web of the fingers from that of the palm explains why exudates make their way to the deep surface rather than to the superficial surface of the palmar fascia.

The lymphatics of the palm are scanty and very small, whereas on the dorsum they are large and profusely distributed. This is the reason why infections on the dorsum of the hand and fingers are followed by lymphangitis, and abscess formation is more common on the palmar aspect of the hand.

According to Rosthorn, during fetal life there is a synovial sac for each finger, extending from the ungual phalanx to the head of the metacarpal bone. At birth, or soon thereafter, a fusion usually takes place between the synovial sacs of the thumb and little finger with the 2 large bursæ in the palm of the hand: the little finger sac uniting with the ulnar bursa, and the thumb sac uniting with the radial bursa. The 2 palmar bursæ extend into the forearm about a thumb's breadth above the anterior carpal ligament.

In the palm of the hand we have two large bursal sacs. The ulnar sac envelops both the superficial and deep flexors and extends upward above the wrist joint. This sac is prolonged downward along the inner tendons to the beginning of the digital sheath of the little finger with which it usually communicates. The tendons of the ring and little fingers are more extensively invested by this membrane than those of the index and middle fingers. The radial bursa is of less extent and invests the tendon of the flexor longus pollicis. This sac invests the tendon on its anterior, radial and posterior surfaces, but is

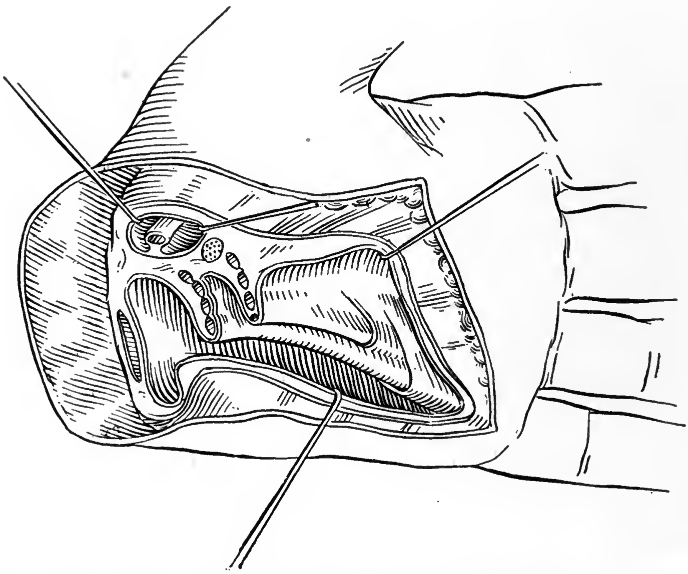

FIG. 22.—LARGE ULNAR BURSA OF THE PALM SHOWING INVAGINATIONS OF THE SAC. (Poirier and Charpy.)

attached by a mesentery along its ulnar border. In a certain number of cases a separate sac is found about the deep flexor tendons of the index finger. A sagittal septum or space is placed behind the median nerve, which serves to mark off the separation between the radial bursa and the ulnar bursa. If we open the ulnar bursa and note the position of the tendons in relation to the sac, we will see that there are 3 invaginations: 1 anterior to the superficial flexors; 1 between the superficial and deep group; and 1 behind the deep flexor. This arrangement was first described by Leguey, who called them the pretendinous, intertendinous, and retrotendinous spaces of the great carpal bursa. From the foregoing description it will be readily seen that infection of the synovial sheaths of the index, middle and ring fingers will be, for a time, confined to these spaces. Infection in the thumb and little finger sheaths can readily extend, the one into the radial bursa, the other into the ulnar bursa, and thence into the forearm.

The synovial sheaths of the extensor tendons at the back of the wrist lie beneath the posterior annular ligament, but superficially. The accompanying

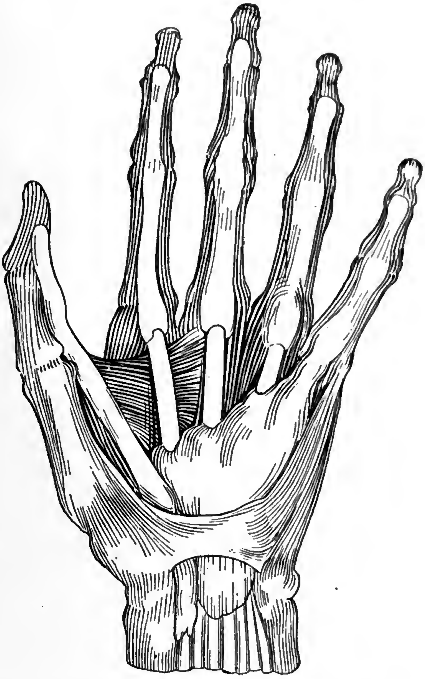

FIG. 23.—SYNOVIAL SHEATHS OF PALM, INJECTED.

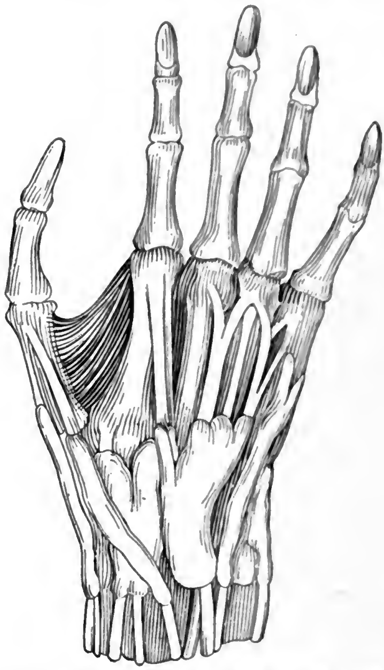

FIG. 24.—SYNOVIAL SHEATHS OF THE EXTENSOR TENDONS, INJECTED.

diagram shows well their arrangement and position. A further description is unnecessary.

**Suppurative Diseases of the Hand in General.**—A description of the infectious processes of the tendon sheaths cannot be undertaken without mention being made of the other sites where pus is found in the suppurative diseases of the hand. Thus, we must recognize the exact level at which the pus is situated, or else our operative efforts for the relief of these conditions will do much harm.

We recognize the following levels for the situation of the pus:

1. Subepidermic infections.
2. Subcutaneous infections.
3. (a) Subfascial infections, (b) infections in the tendon sheaths.
4. Subperiosteal or rather osseoperiosteal infections.

If one observes closely the symptoms referable to pus in these various levels, a distinct clinical picture will be obtained. Unless this is done, one may, by careless approach to the pus, transfer infectious material from a superficial to a deeper level, or, not finding the pus at a superficial level, desist and fail to give the relief necessary. Extension of the inflammatory products from one level to another very soon takes place, and unless these conditions are recognized in their very beginning permanent damage will be done to structures which otherwise might have been saved by prompt recognition of the condition. **Tendons bathed by pus for 48 hours will die. Two stages of the inflammation must be recognized: A stage of invasion and a stage of frank formation of pus. To save tendons involved in suppurative inflammations, relief must be instituted during the period of invasion or inflammation.** If it is undertaken later, the tendons will have died and the pus will have extended into the palm of the hand or into the

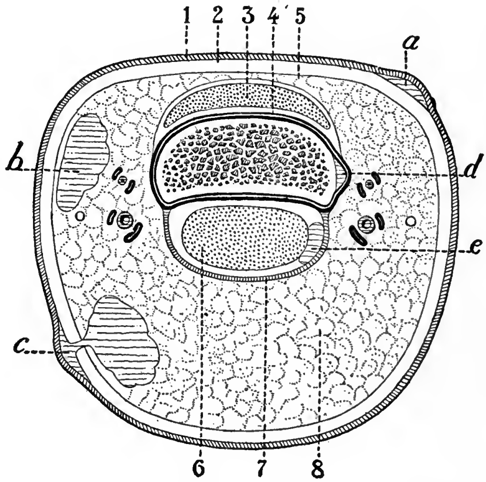


FIG. 25.—DIAGRAMMATIC REPRESENTATION OF THE SITUATION OF THE PUS, a, b, c, d, and e. (Simon Duplay.)

forearm. Operation, then, will be concerned in combating a general sepsis rather than the saving of anatomical structures. The inflammatory products make their way from one part of the fingers or hand to another by direct extension, by lymphatic channels and by the blood stream. By direct extension the pus in the subcutaneous level makes its way from the finger into the interdigital cleft, thence it can extend readily onto the dorsum of the hand or into the palm beneath the palmar fascia. The readiness with which inflammatory products travel along a given level renders the Kanavel explanation of the way pus makes its way onto the back of the hand or into the palm unnecessary. Kanavel believes that the lumbrical muscles or their fascial investments offer the channels along which pus extends from the fingers into the palm or vice versa. The well known resistance of muscle tissue to inflammatory processes seems to render this explanation erroneous.

## Diseases of the Tendon Sheaths

The diseases of the tendon sheaths are due to injury, over-use, rheumatism, gout, gonorrhea, syphilis, tuberculosis, and infection with pyogenic organisms.

Rheumatism, gout, gonorrhea, and syphilis of the tendon sheaths seldom call for surgical interference, their treatment being embraced in the treatment directed to the cure of the underlying condition.

Injury of a tendon sheath, where the tendon itself is not severely damaged, appears in the form of a hemorrhage occurring in its interior. The treatment is the same as for other small hemorrhages occurring in various tissues and cavities of the body.

**Acute Tenosynovitis.**—In the hand this form of inflammation occurs most often in the extensor tendons of the thumb. In the foot it occurs less often, usually in the sheaths of the peronei. It arises as a result of excessive use of the part, commonly in one unused to that particular form of exercise. The initial stage of the inflammation, evidenced by pain and the characteristic creaking (that has given the name of "tenosynovitis crepitans" to this particular stage of the disease), is, as a rule, soon followed by a pouring out of a serous effusion. With the occurrence of the serous exudate, there are disappearance of the pain and cessation of the crepitus.

TREATMENT.—It has been found that recovery is hastened by allowing a certain amount of use of the part, combined with support and compression in the form of a snug dressing, such as adhesive plaster. Discontinuance of the particular form of exercise that gave rise to the condition is, of course, essential.

**Chronic Tenosynovitis.**—Chronic tenosynovitis occurs when the exudate in the acute form persists, and in sprains of, and fractures about, joints treated by too prolonged rest. Here adhesions form between the layers of the sheath, and much disability results, until the adhesions are broken down and kept from reforming by exercise, massage, baking and hot and cold bathing.

PLASTIC TYPE OF CHRONIC TENOSYNOVITIS.—This type is sometimes met with, and is apt to give rise to much uncertainty in diagnosis. It occurs in those who persist in the exercise that gives rise to the acute variety. From the continued irritation, recovery is not allowed to take place in the inflamed sheaths, and the exudate, becoming thickened, forms a jelly-like mass that resembles very closely a type seen in the tuberculous form of disease.

This was the case in an organist in one of our cathedrals, who was operated upon by me. The patient, a thin, wiry man, had the extensor tendons of the wrist involved. Operation disclosed a jelly-like exudate filling the sheaths of the extensors of the wrist and the common extensors of the fingers. This was excised together with the sheaths, and in the belief that the case was one of tuberculosis, the wound was dusted with iodoform powder and closed without drainage. The patient made a perfect recovery and was soon at his old occupation. Examination of the tissue by Dr. Hodenpyl failed to reveal any evidence of tuberculosis. About a year later the patient returned and presented a similar condition on the back of the other hand. Operation disclosed an exudate of the same character. The same method of treatment was employed and again was followed by complete recovery. A few years later the patient returned, this time with a swelling in the palm of the right hand. This was found at operation to be of the same character. The sheath involved was about the tendon of the deep flexor of the index finger, and did not communicate with either the radial or large ulnar bursa. For a third time the patient made a perfect recovery, and has since remained well. At no time did he show any evidence of tuberculosis, and the case must be classed as one of chronic plastic tenosynovitis.

**Syphilitic Tenosynovitis.**—Syphilitic tenosynovitis occurs in the early stages of syphilis in the form of a serous exudate, in the later stages it takes the form of a gummata-like infiltration of the sheaths. Pain is not a prominent symptom, and recovery can usually be brought about by appropriate treatment directed toward the underlying condition.

**Gonorrheal Tenosynovitis.**—Gonorrheal tenosynovitis is most often of the serous variety, but is characterized by greater pain and more pronounced swelling in the tendon sheaths. The differential diagnosis is made on finding the gonococci in the urethral or cervical discharge.

TREATMENT.—Treatment in the vast majority of cases consists in the application of a splint, the use of an ice bag over the inflamed tendons, and the cure of the primary condition. Rarely will it be found necessary to puncture the sheaths and draw out the fluid if a proper fitting splint is employed to give absolute rest to the part. The autogenous vaccines have of late been extensively employed in this type of inflammation. Their method of administration will be found described in another part of this work.

**Tuberculous Tenosynovitis.**—Tuberculous tenosynovitis occurs as a result of the presence and growth of the tubercle bacilli in the tendon sheaths. The character of the inflammatory products presents a great variety. In the earliest form the exudate is generally serous. In the later stages the exudate becomes thicker and more fibrinous, often with the formation of rice bodies. The sheaths become thickened, and tuberculous granulation tissue forms in their interior, forming cheesy masses which are very liable to break down and form cold abscesses. The commonest site for this form of synovitis is in the great carpal bursæ of the hand.

TREATMENT.—From the point of view of surgical treatment tuberculosis of the tendon sheaths divides itself into 2 classes: one where the exudate remains fluid, or contains, at the most, rice bodies, the other where the sheath contains a plastic or cheesy exudate, or shows the various stages of tuberculous degeneration.

Cases of the first group may be treated by evacuation of the fluid exudate and the rice bodies, if they are present, and the filling of the sheath with a 5 per cent. emulsion of iodoform and glycerin. This may have to be repeated. The parts should be kept at rest by means of a splint for a period of 3 to 4 weeks.

The other forms of tuberculosis of the tendon sheaths should be treated by excision. This should be done through ample incisions, and with the help of artificial ischemia. Superficial portions of the tendons will have to be removed as well as the sheaths in some of the cases. The after-care, as in all forms of surgical tuberculosis, is most important, and should combine proper feeding together with an out-door life.

**Acute Suppurative Inflammation of the Tendon Sheaths.**—In the description of the anatomy of the tendon sheaths it was pointed out how important it was, for a clear understanding of these conditions, to have a classification based on the anatomical site of the original inoculation. The rapidity with which inflammatory products can make their way from one level to another, and extend to other parts of the same level, makes it necessary to seek for symptoms of inflammation of each particular level. When the disease has progressed, and one form has merged into another, unless one has followed the pathological picture closely, endless confusion in the conception of these diseases will be the result.

Infection may reach the tendon sheaths by extension from some neighboring focus in the skin or subcutaneous tissues, or may extend to the sheath from an underlying disease of bone or joint. It will thus be seen how impossible it is to discuss suppurative conditions in the tendon sheaths without taking count of other inflammatory conditions in the various parts of the hand.

The most usual way, however, for pyogenic bacteria to gain entrance, is through punctured wounds caused by some small, sharp object, such as a pin, needle or fish-hook.

Two stages of the inflammation must be considered, and the treatment employed differs according to the particular stage of inflammation. The first stage is characterized by a serous exudate with few pus cells. If treatment is initiated during this period, it is often possible to terminate the inflammatory process; if, however, relief is not started within 48 hours, the inflammation will have passed to the stage of frank suppuration. The treatment during the first stage is directed to the termination of the infection, and if successful, recovery and return to normal follow.

In treating the second stage, one must recognize the impossibility of saving sheaths and tendons bathed in pus. Here one is concerned in confining the inflammatory process to its original site, or in opening regions to which the disease has spread. If left untreated, the purulent exudate ruptures its synovial envelope and spreads to the subcutaneous regions of the hand and fingers, thence makes its way through the skin, and fistulous tracts are formed which give exit to the pus, with relief from pain and subsidence of the swelling. Eventually the necrotic tendons which have died during the course of the inflammation are cast off in shreds, or, remaining in the wound, keep up endless suppuration in the fistulous tracts.

The articulations may be invaded, and periostitis and ostitis of the phalanges take place, prolonging the period of the disease. The finger freed by the loss of the tendons yields to the action of the extensors and assumes a position of permanent extension. If healing takes place, the finger remains ankylosed, rigid and useless. When the articulations are involved and ostitis of the bones supervenes, great pain is experienced from lack of support to the joints, and amputation becomes necessary.

When the disease originates in, or has extended to, the palm, one must distinguish whether the suppuration lies in the bursal sacs in this region or is situated in the loose areolar tissue beneath the palmar fascia. When, in the great carpal bursa, the inflammation will have extended above the wrist joint. When, in the loose areolar tissue beneath the palmar fascia, the swelling will be more centrally placed. Determination of the original site of infection and a recognition of the progress of the inflammation will help one in determining the region involved.

COMPLICATIONS.—Gangrene, diffuse cellulitis, erysipelas and secondary foci in the forearm are among the chief complications.

In diabetics, *gangrene* of the tissues readily takes place.

*Erysipelas* adds its special symptoms and burdens to those already suffering from a severe disease.

*Cellulitis* of the forearm in the deep cellular planes, from extension of the disease in the hand, adds its dangers and often even jeopardizes the life of the patient from profound sepsis.

*Lymphangitis* occurs more commonly from subcutaneous foci on the dorsum of the fingers, their interdigital clefts, and the back of the hand. Extension through the deep lymphatics, following the line of the blood vessels into the forearm, may account for some of the abscesses found there.

INCISIONS.—Incisions for the relief of the above conditions should be placed as follows:

Small abscesses or furuncles on the dorsum of the hand or the dorsum or sides of the fingers should be incised over the most prominent part of the swelling. These arise usually from small wounds, abrasions, or infection of the hair follicles. The pus may be found just beneath the epidermis, or, following the tract of a hair follicle or sudoriferous gland, it may have reached the subcutaneous layer. When the epidermis is removed, a communication may be discovered between a superficial and deep abscess, constituting the variety known as the dumb-bell, or, as the French call it, "panaris en bouton de chemise."

Abscesses on the palmar aspect of the fingers and in the interdigital clefts are usually of the subcutaneous variety, arising from cracks, small wounds and punctures. If left untreated, they can rapidly extend into the areolar tissue beneath the central portion of the palmar fascia, gain entrance to the tendon sheaths, or extend to the back of the hand. These are best opened by incisions placed over the most prominent part of the swelling. Care should be taken not to transfer the pus in this variety to the tendon sheaths by carelessly placed or carelessly made incisions. The webs of the fingers should be preserved whenever possible, 2 incisions, 1 on the palmar aspect and 1 on the dorsal aspect of the web, being preferable to an incision that divides the web. The palmar incisions may be extended well into the hand, care being taken, in making them, to avoid the superficial palmar arch.

These palmar incisions give free access to the central space beneath the palmar fascia. Transverse division of this fascia may be necessary to insure free drainage.

Longitudinal division of the palmar fascia is usually not sufficient, unless drainage tubes, which are objectionable, are used.

Infection in the tendon sheaths of the fingers during the early stage of invasion is best relieved by incisions entering the sheath on either side, opposite the 2 proximal phalanges. These tentative incisions, combined with a thorough flushing of the sheath and the use of rubber tissue drains, will often terminate the infection in this stage. Complete restoration of function may be hoped for.

In dealing with infections of the sheaths in the second stage of inflammation, one cannot hope to save the tendons in their entirety, and the sheath must be opened from end to end. This, however, can be done through incisions which do not divide the folds of the skin opposite the articulations.

When the pus has invaded the great ulnar bursæ it can be evacuated and the interior of the sac thoroughly exposed through an incision that occupies the lower 2/3 of a line extending from the styloid process of the radius to a point over the head of the fifth metacarpal bone.

This line will be found to approximate closely the radial border of the hypothenar eminence. The bony landmark must be remembered, because, when the hand is swollen, the line of the second guide will be obliterated. In infections of the radial bursæ, an incision placed directly over the tendon opposite the lower 2/3 of the metacarpal bone of the thumb will give access to this sheath with but slight injury to the short muscles of the thumb.

Counter openings should be made on the proximal side of the annular ligament to drain portions of both these bursæ which extend into the forearm.

THE ANESTHETIC.—A general anesthetic should be given when performing these operations, as complete control of the operative field is very essential.

## THE FASCIÆ

The fascia is of great interest to the surgeon. His intimate knowledge of this structure will greatly facilitate his operative procedures (especially in dealing with the fluid products of inflammatory conditions) and greatly aid his understanding of the course that exudates and collections of blood take when occurring in various regions of the body. Thus the fascia of Colles offers the sole explanation of the course of the extravasation in rupture of the urethra. The position and the direction taken by the exudate in cold abscesses occurring in the cervical and lumbar portions of the spine are only to be appreciated by a knowledge of the fascia of those regions.

While the fascia determines the direction and progress of fluids along quite definite anatomical lines, instances are not uncommon where an abscess or growth seems to ignore these membranes, and to pursue a course of its own. This can, however, usually be explained by the abscess or growth having destroyed the limiting membrane, and gained access to different levels. The destructive character of cervical abscesses depends, without doubt, upon the unyielding nature of the fascia. The invasion of the thoracic cavity by inflammatory products in the neck and the extension of exudates and secretions following operations on the larynx, trachea, and esophagus are too well known to require mention.

The controlling and limiting effects of the fascia in various parts of the body will be discussed by the writers dealing with the diseases and operations of those regions. It remains for me to describe the general diseases of the fascia, which are not numerous. The involvement of the fascia associated with the various forms of wry neck is more properly dealt with by the writers on that region.

**Injuries to and Rupture of the Fascia.**—Injuries to and rupture of the fascia have been discussed in connection with the diseases of muscles.

**Dupuytren's Contracture.**—The disease of the fascia which the general surgeon is called upon to treat more often than his orthopedic brother is that known as "Dupuytren's contracture." This condition of the palmar fascia was first accurately and anatomically described by Dupuytren. A wide difference of opinion still exists as regards its etiology. The unfortunate frequency with which the disease returns after operation would make a complete understanding of its causation desirable. Lacking this complete elucidation of the subject, the surgeon must continue to base his treatment upon the pathology of the disease and the facts at present accepted as contributing to its causation. Langham believes the new formation of connective tissue to be of an inflammatory nature, as he describes nuclear proliferation in the cells in the coats of the arteries, as well as in the connective tissue between individual fibrous strands. This nuclear proliferation is best seen in the fibers which attach the fascia to the skin.

The growth of the connective tissue is not evenly distributed, as nodular formation takes place in the contracting bands.

Gout and rheumatism are commonly mentioned as contributing factors. Trauma, however, seems to play the greater part in the causation of the disease. Some authors believe that the loss of the subcutaneous fat, thus exposing the fascia to greater trauma, is a predisposing cause.

More recently Ledderhose, from clinical and microscopic study, has advanced the theory that the beginning of the disease is inflammatory in character from the proliferation of cells seen in the coats of the vessels and between the fibrous bands. He believes that trauma, acting upon the inflamed fascia, produces a reaction followed by nodular formation and subsequent contraction of the new tissue. Until proof of a very convincing character is produced, trauma, in the minds of most surgeons, will stand as the greatest causative factor.

The occurrence of the disease on the ulnar side of the palm, the side which bears the majority of blows and which is used in many occupations to deliver blows, as in the carpenter's use of the chisel, must convince one that trauma plays a most important part.

Fibromata occur in various parts of the body as the result of injury to the connective tissue. Ganglion is now believed to result from the transformation of small hemorrhages occurring in the fibrous tissue about joints and sheaths of tendons. Both the above arise as the result of injury to the fibrous tissue, and it is reasonable to suppose that the change in the fascia of the palm takes place in the same manner.

The measures for the relief of this condition are divided into palliative and radical operations. In the palliative operations the contracted tissue is divided subcutaneously, or a single or several incisions are made across the long axis of the bands without attempting to remove any of the tissue.

In the radical or open operations, as they are called, the removal of the restraining tissue, in part or in whole, is attempted.

Transplanting or shifting of skin flaps forms a part of some of these operations. The disease after a shorter or longer time involves the skin, thinning it out and making it very difficult to reflect it as a flap from the underlying fibrous tissue.

PALLIATIVE OPERATIONS.—DUPUYTREN'S OPERATION.—Extend the fingers and divide the bands by means of transverse incisions placed opposite the metacarpophalangeal joints. The incisions are carried through the skin and fascia, naturally not through the flexor tendons. The fingers are fixed in the extended position by means of a splint.

ADAM'S OPERATION.—At places where the skin is not adherent to the subjacent band, a fine tenotome is introduced and the band divided. This is done at several points. Fix the fingers by means of a splint in the extended position.

MULTIPLE TRANSVERSE DIVISION.—This is the same as Dupuytren's operation. After the division of the contracture, the fingers are extended. The skin will be found to gape at the site of the incisions. These gaps are covered by a Thiersch graft and treated accordingly.

After healing has taken place in the above operations, make use of massage, and retain the splint until there is no tendency in the fingers to resume their former position.

RADICAL OR OPEN OPERATIONS (KOCHER, HARDIE, ETC.).—LONGITUDINAL INCISION.—Through a longitudinal incision, after reflecting the skin to either side, excise as much of the contracted palmar fascia as can be reached.

(Hardie divides the fascia transversely, excising portions at times.) The after-treatment is the same as for the palliative operations.

The V-shaped incision, with base toward the finger involved, sometimes gives a wider exposure to the disease in the hand. After excision of the scar tissue and extension of the finger, the wound will gape widely and the subsequent suture of the wound will be Y-shaped.

Lotheissen's Operation.—This procedure exposes and removes the fascia through an L-shaped incision placed along the ulnar border of the hand and across to the base of the thumb. After excision of the contracture and straightening of the hand, the wound will be found to gape where the incision crosses the wrist. This incision gives access to a region in the hand ordinarily uninvolved by the disease, and a poor exposure of the region actually involved.

Lexer's Method.—Lexer recommends, even in the less advanced cases, excisions of the entire aponeurosis and sacrifice of a wide area of skin. The wound is closed by a whole-skin flap, the hand being placed beneath a flap raised from the abdomen.

The frequency with which our operative effort for the relief of this condition meets with failure, renders comment on these more ambitious operations unnecessary.

# CHAPTER XV

## GUNSHOT WOUNDS AND THEIR TREATMENT

Alexander Bryan Johnson

## GENERAL CONSIDERATIONS

Before discussing gunshot wounds and their treatment a few preliminary remarks may not be out of place. In order to treat these wounds intelligently special knowledge is necessary. They differ in many ways from other injuries. They are produced by projectiles fired by means of an explosive from rifles, pistols, shotguns, and from cannon. Another group of wounds which must be considered with gunshot wounds includes those made by the explosion of bombs, shells, hand grenades, and similar devices.

In character gunshot wounds resemble both punctured, contused and lacerated wounds. Sometimes these wounds are almost identical with punctures; in other cases the wounds resemble contusions, lacerations, and crushes. In severity they may be of any grade from a slight contusion to the loss of an entire limb, decapitation, etc. When made by bullets the wounds of entrance and of exit may resemble mere punctures, and often furnish no direct evidence of the extent and gravity of the destruction wrought in the deeper tissues. Often such destruction is extensive, and though it cannot be seen from without, it may be inferred from the known peculiarities of bullet wounds, such as loss of function, shock, and other local and general signs and symptoms. These peculiarities of bullet wounds are many and varied. No practical rules for treatment can be given without taking them into account; hence it will be necessary later to discuss at some length the effects of different kinds of projectiles upon the different tissues and organs of the human body.

Practically, an important distinction may be made between wounds received in warfare, whether afloat or ashore, and wounds received in civil life in times of peace. Not only are the weapons, the projectiles, and the wounds themselves, as a rule, quite different, but also the circumstances under which they are received and the facilities for their treatment.

## WOUNDS RECEIVED IN CIVIL LIFE

The gunshot wounds coming under our care at the New York and Hudson Street Hospitals are numerous. They are with few exceptions pistol shot wounds, fired at close range from pistols loaded with relatively small charges of black powder. The most common calibers are .22, .32, .38, and in a few cases of wounded Chinamen, caliber .45. The bullets are usually of soft lead. Such bullets, more especially of the smaller calibers, frequently lodge. They are easily turned by bone, by tendons, even by fascial edges, and thus an irregular track made by the bullet is common, as, for example, contour shots following the outer surfaces of the ribs sometimes half-way around the body. An explosive action is scarcely observed, except in the case of revolver shots of 45 caliber. These bullets are driven usually by the equivalent of about 40 grains or more of black powder, and the wounds resemble rather rifle bullet wounds of the old-fashioned type. With the small calibers the shafts of the long bones are rather rarely broken, and if fractures are produced comminution is not very extensive. Even on structures so soft as the brain the disintegrating effect of the bullet is often limited to a narrow tract in the cerebrum. Bullets of .22 caliber sometimes fail to penetrate, and are flattened against the thicker portions of the skull.

On the solid organs of the abdomen, the liver, spleen, and kidney, an explosive effect is absent or only slightly marked. These organs are usually drilled, sometimes with radiating fissures, but they are not burst and disintegrated in the manner observed after wounds made by modern military rifle bullets. The urinary bladder, if wounded, usually shows a ragged perforation, not much larger than the caliber of the bullet.

Wounds of the lung, unless the large vessels near the root are injured, are usually recovered from quickly. In a few cases empyema follows; in others a pneumothorax may persist for months.

In wounds of the alimentary canal the perforations, unless tangential, correspond pretty closely to the size of the missile. The perforations may be surrounded by a rather narrow rim of devitalized tissue. Escape of intestinal or stomach contents is the rule, followed by acute purulent peritonitis, or, if a part of the colon is wounded, uncovered by peritoneum, a fecal abscess is formed.

Wounds of the main blood vessels of the abdomen are, as a rule, rapidly fatal from hemorrhage. The main blood vessels of the extremities are only rarely injured, though an occasional traumatic aneurysm or arterial hematoma is observed.

Arteriovenous aneurysm is observed as a rarity in the extremities, and has followed in one or more cases bullet wounds of the base of the skull, with pulsating exophthalmos. In a number of instances small bullets have remained indefinitely quiescent in the brain until the patients were lost sight of.

Wounds of the nerve trunks of the extremities may be complete or partial divisions and may be followed by neuritis.

*Shock* is most marked after complicated abdominal wounds, and in these cases the symptoms of both shock and hemorrhage are often combined. In uncomplicated wounds and wounds of the extremities shock is usually absent or not marked.

During the past few years many of the homicides and suicides in this city were done with automatic pistols. The bullets are usually steel-jacketed, and the wounds produced are often more serious than those made by the old-fashioned revolver. The bullets are usually not large, but they have an unusual velocity, much greater than is the case with ordinary revolvers. The wounds, indeed, resemble those made by the small caliber rifle at greater ranges.

Some years ago I conducted a few experiments with automatic pistols, more to determine the effects of smokeless powder upon the skin than for any other reason, but incidentally I observed the effects of these bullets when fired at close range into the head and into the extremities. I quote from an article which I wrote at that time:

Wounds produced by Automatic Pistols: The Mauser pistol, caliber 7.63 millimeters; the Luger pistol, caliber 7.65 millimeters; the Colt automatic pistols, caliber .32 and .38. In 1897 Bruns conducted experiments with the Mauser pistol, and concluded that the effects of its bullet were identical with that of the military rifle at proportionately longer ranges. The following relations were found to exist: At 20 to 200 meters the effect of the Mauser pistol was the same as the effect of the military rifle at 1,000 to 2,000 meters respectively. In this connection, I insert the results of certain experiments made by me with automatic pistols in order to determine the effects of smokeless powder at short ranges upon the skin, and incidentally to observe the effects of the bullets upon the tissues, in comparison with the old-fashioned black-powder revolver firing a soft-lead bullet and a small charge of black powder.

A description of some of the shots in detail follows:

Shot I. Colt's automatic pistol, caliber .32; 4 grains of Walsrode powder; bullet weight, seventy-six grains, full cupronickel jacket; distance of muzzle of pistol from the skin, two inches. The shot was fired at the side of the head in front of the ear, skin covered with short hair. The hair was not singed. The skin was not burned. A few grains of a dark gray residue were found upon the hair, and upon the skin over an area one inch in diameter, surrounding the bullet wound. These grains were readily wiped off with a dry cloth, leaving no visible mark behind. The wound of entrance was a small circular orifice one-sixteenth of an inch in diameter. There was no fraying or discoloration of the edges. The wound at the point of entrance in the skull was found to be a round hole through the bone about the diameter of the bullet. The wound of exit from the scalp upon the opposite side of the head, back of the ear, was a mere slit in the skin one-fourth of an inch in length. The wound of exit from the skull was a round hole about the diameter of the bullet. No explosive effect was observed. The bullet struck, but failed to penetrate a barrel of sand used as a backing, and was picked up slightly flattened at the point.

Shot II. Colt's automatic pistol, caliber .38 of an inch; cupronickel jacket, incomplete in front (what is known as a soft-nosed bullet); charge, 7 grains of Walsrode powder; weight of bullet, 130 grains. The shot was fired into the temporal region at a distance of two inches. Wound of entrance was a round orifice in the skin one-eighth of an inch in diameter. Edges of orifice were slightly frayed. There were a few faint grayish stains upon the skin surrounding the wound. These specks appeared to be embedded in the skin and could not be removed with a wet cloth. The hole of entrance through the skull was round and about the diameter of the bullet. The wound of exit in the skin upon the opposite side of the head was an irregular tear about one inch in length, with radiating slits along its border. Brain substance escaped freely from this orifice, as well as from the external auditory canal on the same side of the head. Palpation of the skull showed a comminuted fracture surrounding the wound of exit. The comminution of the skull extended over an area three inches in diameter in the temporal and parietal regions. There was also evidently present a fracture of the base of the skull. After leaving the head the bullet buried itself in a barrel of sand. The explosive effect of this shot was well marked.

Shot III. For purposes of comparison, a shot was fired from a Hopkins and Allen revolver, caliber .32, ten grains black powder, Smith and Wesson ammunition, soft-lead bullet. The shot was fired into the temporal region with the muzzle of the pistol three inches from the scalp. The hair was singed. The scalp was burned and tattooed with powder grains, so that the skin was blackened over an area one and one-half inches in diameter. The wound of entrance in the skin was one-eighth of an inch in diameter, the edges were slightly contused and stained with lead. The hole in the skull was about the diameter of the bullet. The bullet lodged.

Shot IV. Luger automatic pistol; steel-jacketed bullet; jacket incomplete over a small circular area at the point of bullet where the lead interior is exposed; distance, three inches. Shot was fired into the cheek over malar bone backward, downward and inward. No powder marks were upon the skin. Orifice of entrance was three-sixteenths of an inch in diameter, and circular. Edges were slightly contused and white in color. No tearing of tissues nor explosive effect was observed. Bullet was extracted later undeformed.

Shot V. Mauser automatic pistol; caliber 7.63 mm.; steel-jacketed bullet; distance of muzzle of pistol from skin three and one-half inches. Shot was fired at outer aspect of upper third of right thigh. Powder stain was one inch in diameter, a grayish smudge without deposition of distinct grains. Wound of entrance was circular. Edges were slightly frayed and contused, white in color. Wound of exit on inner surface of limb was oval, three-sixteenths of an inch in diameter, slightly ragged. There was a wound of entrance on inner aspect of left thigh; wound of exit on opposite side the same. The bullet then passed through the distal phalanx of left thumb and entered a barrel of sand, penetrating a distance of one foot. Although the bullet passed through the center of both limbs, neither femur was fractured, nor was the bullet deformed.

Shot VI. Mauser pistol; fired into upper third of right thigh at a distance of one foot; full-jacketed bullet. A few dark-colored specks or grains were present on the skin around the wound over an area three inches in diameter. These were readily wiped off with a dry cloth. The bullet caused a fracture of the right femur, and passed across the body above the perineum, passed through the pelvic bone and was found just beneath the skin above the left great trochanter. The bullet was slightly deformed.

Shot VII. Hopkins and Allen revolver, black powder, .32 caliber, Smith and Wesson ammunition. Shot was fired at outer aspect of right thigh; distance, one foot. Skin was tattooed with powder marks too numerous to count over an area three and one-half inches in diameter. Wound of entrance was circular, three-sixteenths of an inch in diameter; edges stained with lead. Bullet lodged.

As a matter of experience, however, most of the pistol-shot wounds we see in the hospitals are produced by old-fashioned revolvers with soft-lead bullets. The patients are generally received soon after the receipt of the injury. They walk into the hospital, or the more severely injured are brought in by the ambulance. Cases requiring surgical interference are operated upon at once. They are surrounded by every care that a modern hospital affords, and the results are as a rule excellent, even though many of these patients are acutely alcoholic, and not in the best of physical condition, belonging, as the majority of them do, to the city's underworld.

Pistol-shot wounds of the extremities and trunk, when uncomplicated, heal as a rule promptly without suppuration, whether the bullet lodges or not. It is rare to find portions of clothing or other material as a cause of suppuration. A large number of such wounds are treated yearly in the Hudson Street Hospital, and when the injuries are not necessarily fatal the results are almost uniformly good.

Wounds from shot-guns are rarely seen. If fired at close range these injuries are often severely contused and lacerated, compound, comminuted fractures, or, if of the head or trunk, immediately fatal injuries. If the range be 50 feet or more the gravity of the injury will depend to a great extent upon the size of the individual shot pellets, and may be slight or serious. But in all these cases the patients may, and usually do, receive immediate and skilful treatment under favorable surroundings, aseptic treatment of their wounds, complete rest, good food, in short, they are well cared for from the start.

## WOUNDS RECEIVED IN WARFARE

In warfare conditions are quite different. The weapons, though usually fired at great ranges, are of a far more deadly character, both on land and sea. We shall consider the conditions of land warfare first. In *land warfare* gunshot wounds are caused by military rifle bullets, by shells and shell fragments, by shrapnel and canister, and in the most recent wars by fragments of bursting hand grenades, or from similar grenades fired by means of a small, blank cartridge from the muzzle of the military rifle. These grenades are now used both in day and night attacks in the final rush from the trenches. Their use has been attended by a terrible mortality, far greater than is possible by rifle fire at close quarters, where the rifle is at best rather an unhandy weapon. The fragments from these grenades produce wounds resembling those made by shrapnel and shell, namely, complicated extensively lacerated wounds **usually infected** and far more difficult to treat successfully than the clean perforations commonly made by the small caliber rifle bullet.

The modern military rifle sacrifices some of the destructive characteristics of the old-fashioned, heavy leaden bullet, for the sake of greater range and flatness of trajectory, but other qualities none the less or even more deadly are retained or acquired. The bullet is of small caliber, about .30 of an inch. At ordinary ranges it passes entirely through the body, no matter in what position. The character of the wound varies greatly under different conditions, and we shall now consider some of the peculiarities of modern bullet wounds.

Recently the United States, England, France, and Germany have adopted a new bullet (model 1906), which differs from the one which preceded it in several important particulars. Its use in actual warfare has now been sufficient for us to draw some general conclusions from actual experience, and experiments seem to show that the wounds produced are different in some respects from other bullet wounds. This bullet has a sharp point instead of the ogival shape of the old bullet. The particulars are as follows: The new bullet is of the same caliber as the model immediately preceding it, but is shorter, lighter, has a higher velocity, and a much sharper point. Its length is but 1.08 inches as against 1.25 inches for the model of 1903; its weight 150 grains, as against 220 grains of its predecessor. Its muzzle velocity is 2,700 feet per second, an increase of 400 feet. Its structure is as before, a core of lead and tin composition inclosed in a jacket of cupronickel. The charge is of pyrocellulose composition, very similar to the powder used for propelling charges in field and sea coast guns. The grains are cylindrical, perforated, and graphited. The normal charge weighs from 47 to 50 grains, varying with the lot of powder used. By the use of this cartridge (powder and bullet) the trajectory has been flattened, and the point blank danger space has been raised to 718.6 yards. At 1,000 yards the bullet will penetrate 12.8 inches of pine, and at 100 yards will penetrate a steel plate 0.3843 inch thick. Some experiments with similar bullets, quoted in Johnson's "Surgical Diagnosis," were made and recorded by Riedinger, and are here reproduced:

### Additional Remarks in Regard to Gunshot Wounds Produced by Military Rifle Bullets of the Most Recent Type

At the present time, Germany, England, and France have adopted a military rifle which fires a bullet of a caliber of 88 mm. The bullet differs from those used by other nations in certain particulars. Instead of a rounded or ogival point, the bullet is sharply pointed. It is probable that other nations will soon adopt this form of bullet. The pointed bullet offers less resistance to the air than other forms, and consequently a flatter trajectory is possible. The center of gravity of the bullet lies nearer its base than in the ogival-tipped bullets, and this produced, so it is said, a tendency for the bullet to tip over after it has reached a certain point in its flight. In order to overcome this tendency at ordinary ranges, the initial velocity given to the bullet is very high indeed. The German bullet is 27.8 mm. long and weighs 10.0 gms. A review of the experiments of others and the results of certain experiments made by himself has been published by Dr. Riedinger, and from his monograph the following data are derived:

The powder load is 3.2 gms. On account of the relatively small weight of the cartridges, soldiers are able to carry a larger number without notable effort. The rifle is most efficient up to ranges of from 800 to 1,000 meters. The initial velocity of the bullet is 855 meters per second. The extreme range is 4,500 meters. At a range of 800 meters the bullet will perforate in a sagittal direction any portion of the human body. At the same range, if the body is struck lengthwise, wounds are observed from 400 to 600 mm. in length. If at this range the bullet strikes flatwise, a wound of 130 mm. deep may be produced. At very great range the weapon is less efficient than the military rifles at present in use by other nations, and at similar ranges the bullet shows a decided tendency to tip over. It is therefore probable that wounds made by the bullet striking flatwise will be more common. Further, there is some tendency for the bullet to be deflected when it strikes hard bone.

In general, the destruction of bones and soft parts and the wounds produced closely resemble those made by the ordinary ogival-pointed bullet. In the shafts of the long bones the bullet produced comminuted fractures, the area of comminution and the lines of the fracture suggesting in shape the outlines of an ordinary envelope, or in other cases the outspread wings of a butterfly. At close ranges a large number of minute bone fragments of a generally quadrilateral shape are produced. At increased ranges the comminution is less marked, the number of fragments is smaller, and the size of the individual fragments greater. In these particulars the wounds do not differ markedly from those ordinarily observed. Comminution of the shafts of long bones, tibia and femur is observed up to a range of 2,000 meters. If the shaft of the long bone is struck near its border without opening the medullary canal, a groove may be cut in the bone without notable comminution and without any marked radiating lines of fracture. (Fessler.)

Upon the spongy ends of the long bones simple perforations are often produced, resembling those made by the ogival-shaped bullet. In other cases perforation occurs with more or less marked radiating lines of fracture. The more nearly the wound approaches the hollow diaphysis of the bone, the more marked are the splintering and comminution.

The wound of entrance in the skin from direct shots is very small, smaller usually than the diameter of the bullet. The edges of the wound usually show fine, radiating tears. The wound of entrance is slightly stained of a grayish color, due to powder residue which clings to the bullet. It is thus possible to differentiate the wound of entrance from the wound of exit. If the bullet strikes the skin obliquely or flatwise, the wound of entrance will, of course, be larger and of a different shape. The wound of exit is also, as a rule, quite small, irrespective of the amount of destruction of the bone or subcutaneous soft parts. When bones are fractured, minute particles of bone are scattered through the tissues and may sometimes be seen in the wound of exit. If the bullets strike flatwise, the wound of exit is usually much larger, and through it torn tendons and muscular bellies may protrude.

Riedinger says in regard to the most modern French military rifle that the ball is solid; it consists of copper, to which a small amount of zinc is added. It is pointed at the end, resembling in shape a torpedo or cigar. It is longer than the German bullet, 39.9 mm. as compared with 27.8 mm. The caliber is 8.0 mm. The bullet weighs 13.2 gms., and is therefore heavier than the German bullet. The initial velocity, however, is lower, 730 as compared with 830 meters. The trajectory is not as flat as the German rifle, but the weapon is effective at greater ranges.

Riedinger considers that the most important differences in the wounds produced by these pointed bullets will depend upon the tendency for the bullet to be upset in its flight and to strike flatwise. Sufficient observations have not as yet been made to determine how often such wounds will occur. (Experience in recent wars, notably in the Balkans, indicates that these bullets are more destructive than was supposed. They are so easily upset that mutilating wounds are frequent, and there are many body wounds which do not come under treatment. The wounded die on the field.—Editor.) If the bullet strikes point foremost, wounds of the soft parts alone will probably be simpler even than those produced by the ogival bullet, and the same will be true for wounds of the spongy bones. If, on the other hand, the bullet upsets, a considerable cavity will be produced in the track of the wound. The wounds of the shafts of the long bones do not differ materially from those made by other small-caliber bullets. When the bullets strike flatwise, the destruction of both bone and soft parts will be greater. The wounds of entrance and exit will be larger and aseptic healing will be more difficult to obtain. Riedinger says that, if the bullet strikes some very massive obstruction when moving at high velocity, any massive hard portion of bone, for example, the mantle may be torn and the leaden core of the bullet may split up into fragments, producing very severe wounds.

The pointed bullet is even more apt to make a clean perforation in blood vessels than the ogival form. Wounds of nerve trunks will probably resemble those already observed. Fessler fired twelve experimental shots through the abdomen. In all but one the intestine was wounded. The effects upon the skull were said to be even more destructive than usual. Wounds of the thorax, when the bullet preserves its proper line of flight, will not differ from those produced by the ogival bullet. If, however, the bullet is upset and strikes flatwise, more serious injuries are to be expected. Thus a certain proportion of the wounds will be more serious than ordinary, and there will exist another group in which the injuries will be relatively slight.

With the exception of the greater tendency of these bullets to upset in their flight, or to upset when they strike home, it does not seem to me that the wounds produced are likely to differ materially from those ordinarily observed.

In regard to the cavalry arm of the U. S. Navy and Military Service, recent experience and experiments seem to show that revolvers of .38 caliber are not sufficiently powerful and do not produce sufficient shock to stop a charging horse, unless the shot be a particularly fortunate one. Experiments were conducted upon steers for the purpose of testing the stopping power of various pistols. It was found that a heavy revolver of .45 caliber, when fired through the body of an ox, would nearly always cause it to drop instantly, so that it was unable to regain its feet. Revolvers with lighter bullets and of smaller calibers fail to do this. The automatic pistols, therefore, of the United States Cavalry have been increased in size and caliber to .45, and at present this is the standard pistol both for the Army and Navy. The bullet is jacketed.

It is necessary for us to revise our conclusions in regard to the humane character of the wounds caused by the pointed bullet. They are much more destructive than was supposed, chiefly owing to the ease with which they are upset. Thus, La Garde, "Gunshot Injuries," 1914, page 60, says:

The effects of the pointed bullet in the Turko-Balkan War of 1912-1913 have sustained the estimates of the experimenters as to its degree of deadliness. The body wounds in the two belligerent armies seldom lived to receive hospital care. The high ratio of wounds by shrapnel, which in themselves cause an excessive mortality among body wounds, have come in to mask the deadliness of the pointed bullets, but the reports of all the observers are unanimous on the field mortality.

Major P. C. Fauntleroy, M. C. U. S. A., our attaché with the armies in the field from January 1 to March 15, reports approximate total casualties in the Bulgarian Army as follows:

| | Killed | Wounded | Died from Wounds |
|---|---|---|---|
| Officers | 400 | 1,000 | 300 |
| Soldiers | 23,000 | 55,000 | 10,000 |

About 20 per cent. of all wounds were from shrapnel. If we add the number of officers and men killed and wounded, we find the ratio of killed to wounded to be 1 to 2.5. The very few abdominal wounds that lived to reach the hospital care were prone to develop septic peritonitis with abscess. Penetrating chest wounds by the Spitz-ball, as the pointed bullet is called over there, were prone to the development of complications like pneumohemothorax, pyothorax, etc.

Of the wounded by the Spitz bullet that reached hospital care, the majority were not serious, and recovery occurred in from four to six weeks.

Much to the surprise of the observers, the pointed bullet often lodged; this was attributed erroneously to defective ammunition.

It requires no prophet to predict that the war wounds of the future will be much more grave. Body wounds will be more uniformly fatal; injury to the bones will be more extensive and prone to suppuration.

The humane character of the reduced caliber bullet wounds so happily noted in recent wars will be less frequent. This will be especially true of wounds of the lungs and epiphyseal ends of the bones.

## GENERAL TREATMENT OF GUNSHOT WOUNDS

Experience shows that in a large proportion of uncomplicated gunshot wounds conservative treatment gives excellent results. This treatment is absolutely simple, and may be outlined in a few words. The external wounds and the surrounding skin are painted with tincture of iodin, without previous washing in water. If the skin be grimy and oily, the surface may be cleaned with turpentine, with equal parts of alcohol and ether, with alcohol, or with benzin or gasoline. After wiping dry with a pad of sterile gauze, the iodin may be painted on with another similar pad, or a plug or pad of gauze saturated with iodin solution may be left in or upon the wound. An occlusive sterile dressing follows, preferably covered by an immobilizing splint. In addition, rest, food, and attention to the bowels are usually all the treatment that is needed. The Medical Department of the Army now furnishes iodin to troops in the field. It is issued in sealed glass tubes, each tube containing one gram of iodin and one and one-half grams of potassium iodid. The contents of a tube dissolved in 50 cubic centimeters of alcohol, or, in default of it, in water, makes a solution of suitable strength for ordinary use.

So long as a bullet wound is not infected, does not penetrate an important body cavity, and is not attended by the signs and symptoms of injury to a large blood vessel or a nerve trunk, its lodgment is rarely of much importance. **Probing of bullet wounds is unnecessary and unwise.** The bullet can be located quite accurately by two X-ray pictures, preferably stereoscopic or with Sweet's localizer or some similar device. Such a bullet can usually be removed by a suitably placed aseptic cut if desired, with but little or no risk. Many patients are anxious to be rid of such lodged bullets, and in general their wishes may be granted. Such removal can often be done under local anesthesia (novocain and adrenalin). It will usually be wise to cut down upon the bullet directly, irrespective of its track through the tissues. There are conditions under which a large missile should be removed even at considerable risk, for example, when a missile is lodged in a position such that it presses upon a nerve trunk, causing pain or even serious neuritis, or when it lies at the bottom of an infected track or free in a joint. These conditions will be mentioned more fully under the wounds of various structures and characters.

It has been observed in recent wars that rifle-bullet wounds involving the spongy ends of long bones and large joints may heal perfectly under an occlusive dressing with little or no impairment of function. It was learned first by German surgeons in the war between France and Germany, and has been emphasized by experience in every war since then, that under the conditions of an active campaign the wounds would do far better under an occlusive antiseptic dressing with immobilization of the wounded part until they can be transported to a well-equipped hospital, than by attempts at active interference in the field, except in cases of absolute necessity, as, for example, the arrest of active bleeding. In recent wars this has been notably true of gunshot wounds of the abdomen. When operations have been done in these cases in field hospitals the mortality has been very high, higher than would be normal after the same injuries and operations done in a well-equipped hospital in time of peace. Among the cases treated conservatively without operation the mortality has been high, yet there has been a fair proportion of recoveries, though in some of these it seemed certain that the alimentary canal was perforated. The recoveries were due apparently to the fact that the soldiers went into action hungry and with but little food, either in the stomach or in the intestine. In consequence no leakage occurred and no infection.

The very high mortality following laparotomy for gunshot wounds involving injury to the abdominal viscera in battle depends upon three factors, namely:

(1) Time.
(2) Unavoidable absence of aseptic surroundings.
(3) Improper after-care owing to the necessity of transporting the wounded often to great distances, entailing want of rest and quiet and the passing of the wounded through many different hands. Moreover, at the field hospitals, the number of the wounded may be very great. The number of attendants and surgeons is of necessity small. But little time can be given to the individual case.

In civil practice in time of peace it is a matter of common experience that the prognosis of operations for perforation of the stomach and intestine, whether due to injury or disease, depends largely upon the *number of hours elapsed* since the perforation took place. Thus, after twelve hours, the chances of recovery grew smaller rapidly hour by hour. Toxemia and paralysis of the bowel, having reached a certain grade, render the patient's condition hopeless. Under the conditions met on the battlefield many hours may elapse before the wounded receive even first-aid attention. Transportation to a field hospital consumes some time, and still further delay may occur before the wounded can be operated upon, and then under conditions anything but favorable.

Following such operations in time of peace the patient has absolute rest and unremitting skillful care and attention, without which he will almost certainly die. Unavoidable absence of aseptic surroundings and want of proper after-care, however, contribute to render abdominal operations upon or near the battlefield desperate measures only justifiable under exceptional conditions, or in cases where the indications are absolutely plain, as when intestinal contents, gas, or feces escape from the wound, when active bleeding calls for control, or when, after shell wounds, the bowel or some other abdominal viscus, spleen, kidney, or omentum, is prolapsed.

In time of peace in well-equipped hospitals attended by surgeons of experience gunshot wounds of the abdomen should be, and commonly are, treated by an exploratory abdominal incision at once, whenever perforation of the abdominal wall is probable, whether the symptoms of shock or hemorrhage point to the injury of important structures or not. The exploration adds little or nothing to the peril of the wounded individual, and if any serious injury has occurred to the viscera immediate operation gives the best possible chance of recovery.

The position of the incision will depend to some extent upon the position of the external wound and the probable course of the bullet. Where no signs or symptoms are present to serve as guides to the probable situation of the intra-abdominal injury a median cut is commonly regarded as best. The abdomen having been opened, search is made for the lesions present according to the rules and principles governing modern aseptic surgical technic as applied to the interior of the belly, fully described elsewhere in this book. It is well, in my experience, if much free blood is found, to search for the bleeding points and stop the hemorrhage first, before searching for wounds in the bowel, stomach, or other viscera. It often happens that the necessary manipulations will start wounded vessels bleeding afresh and violently, and if such bleeding be disregarded while holes in the intestine or stomach are sought for and sutured the surgeon may suddenly find himself finishing his operation hurriedly and perhaps inefficiently upon an exsanguinated patient. It is better to stop the bleeding first, whatever its source, by ligature or suture, if possible—by packing, if necessary—and to attend to the removal of blood and intestinal contents and the suture of perforations later. If, however, the operating-room be equipped with an efficient aspirating device, such as described in Chapter VII, Volume I, a good assistant may, with advantage, and without much interference with the operator, remove much of the blood or other material, while search is made for the source of hemorrhage. To do these operations well requires an experienced operator, trained assistants, good retraction, etc.—in fact, a well-equipped and well-conducted operating-room. Though haste never produces efficient work, speed may be essential to success, and this is only to be attained in work of this kind by a thoroughly trained staff accustomed to working daily together.

It has been suggested that wounds of the belly should be treated on the battlefield or in the field hospitals by complete rest, starvation, and large doses of morphin or opium. It seems probable that some patients might thus be saved who would otherwise die. A very marked difference certainly exists between the results of wounds made by old-fashioned, large, heavy, soft-lead bullets and the modern hard projectile fired at high velocity and used at present. A larger proportion of the wounds made by the latter are immediately fatal, but in those who recover wound infection is less frequent, and complete and rapid restoration to health is the rule, so that wounds apparently of a serious character may be recovered from in ten days or a fortnight, and the soldier again be ready for duty in a surprisingly short time. With the old lead bullets prolonged suppuration, resections, amputations, and greatly delayed convalescence were the rule rather than the exception. The recent wars in the Balkans have seemed to show that the sharp-pointed, small-caliber bullets produce in general wounds of a character even more deadly than those with the rounded point.

## WOUNDS RECEIVED IN LAND WARFARE

We shall now consider the conditions of fighting on land in more detail. Soldiers fighting on land may find themselves in one of three positions. (1) They may be attacked while occupying a fortified post. Here the conditions for the care of the wounded are relatively favorable. The fortifications themselves usually offer some protection for the wounded and for the surgeons, who are able to care for them on the spot, and immediately. Moreover, a good hospital is usually within easy reach, and transportation of the wounded to it is not difficult; neither is it exposed to the perils of transportation to a field hospital during an engagement. Even if a fortified post be captured, the peril of the wounded need not thereby be increased.

(2) Troops may be employed as an attacking force against a fortification. Such operations give time to the medical department in consultation with the commander of the forces to arrange its field hospitals and dressing stations in suitable places where, except in case of disastrous repulse and counter attack, the wounded can readily be transported and cared for. If, however, the attack is not successful, the wounded who fall between the advance lines of the attack and the fortifications must lie sometimes for hours or days without help, unless a truce is declared for this purpose. This belt of ground between the lines will be so swept by rifle and artillery fire that no aid can be given until the engagement is over. Such conditions happened before Port Arthur after assaults made by the Japanese, and occurred repeatedly in the battles of

our Civil War. Under these conditions the wounded suffered greatly, and many died whose lives might have been saved by prompt assistance.

(3) One mobile body of troops may attack another force also movable. Here the conditions for the care of the wounded are most difficult. The fire of modern artillery and of rifles is so deadly, even at great ranges, that the Medical Department may find it very difficult to establish stations at once sheltered from fire and accessible to the wounded.

**Method of Giving Aid to the Wounded on the Battlefield.**—The following very brief summary of an article written by General Robert M. O'Reilly, in Keen's "Surgery," gives the method of aiding the wounded that is used in the United States Army.

The wounded are cared for in four ways, or, one might say, stages.

1. Regimental Aid.
2. Dressing Stations.
3. Ambulance Stations.
4. Field Hospitals.

1. REGIMENTAL AID.—Regimental aid is such as may be rendered by the regimental surgeon and his assistants. The regimental surgeon or the medical officer next in rank has under his command the men of the hospital corps detailed for first-aid work. They are distributed in the rear of the fighting line and as near to it as possible, within 1,000 yards, if practicable, and on rough ground perhaps much nearer. Their duties are to render first aid to such of the wounded as can be reached, to apply first-aid dressings, to check bleeding, to provide improvised splints, to secure immobilization, to help the wounded to places sheltered from fire if possible, and to help them to the rear. The regimental surgeons also supervise the work at the dressing stations, preserve order, and see that malingerers return to the front, and that those who require transportation by ambulance are properly cared for. If necessity requires, the members of the regimental band and a detail of men from each company act as litter bearers. During an engagement, however, most of the badly wounded must lie upon the field where they fall, because litter bearers can rarely reach them in safety, or, if they do, can only attempt to carry them to the rear at great peril to both bearer and wounded. Accordingly this work can only be accomplished in a satisfactory manner after firing has ceased, or after a considerable advance has been made by the firing line. The only aid that the wounded can receive at the immediate front will be such as can be given to them by their companions on the firing line. The better the soldier is instructed in first-aid duties, the better the care he will receive.

In the United States Army each soldier is supplied with a first-aid packet, in a light metal case. The contents are a sterile gauze pad and bandage, so arranged that the pad can be applied to the wound and bandaged to the limb or other part without handling the pad itself. A small tube of iodin in solution, if such can be made stable, is valuable to pour over the wound and the surrounding skin, or, if the wound is large, the pad of gauze may be soaked in iodin solution and applied to the raw surface. It is important that these first-aid dressings should extend well beyond the wound edges, and that they should be so applied as to remain firmly in position, protecting the wound area completely from soiling by dust or by the friction of dirty clothing. If well applied, such dressings will protect a wound from outside infection for many days, or until danger of infection from without has passed, unless the wound surface be extensive and much contused.

In city hospitals many dressings are held in place by strips of oxid of zinc plaster. This does not slip, nor does it irritate the skin, and affords some support to the wounded part. A small roll of such plaster would be a valuable addition to a first-aid packet. It is useful for support and immobilization, for holding splints and dressings in place, and for many other purposes.

In recent wars many wounds have been healed under this first-aid dressing. **On no account should a finger or an instrument be inserted into these fresh wounds.** The less the interference the better, except for the control of active bleeding. For extensive lacerated wounds the so-called "shell wound packet," now in use in the navy and artillery arm ashore, is efficient.

Before applying the first-aid dressing the clothing should be cut away and the wound completely exposed to the air. No oiled silk, rubber tissue, or other impervious material should be used, either on the wound or outside the dressing; such a covering prevents evaporation, keeps the wound from drying, and thus favors bacterial growth.

On no account should the wounded be brought to the rear by unwounded comrades engaged on the firing line. The defense is thus weakened to no purpose, and often seriously. This was observed many times on the Russian lines when fighting the Japanese. To prevent this those detailed to render first aid should make every possible effort to reach and bring back the wounded. If they fail in this, human nature will assert itself against the strongest discipline, and from sympathy—not from cowardice—the soldier will desert the firing line in order to help his wounded comrade to the rear.

2. DRESSING STATIONS.—The dressing stations are in charge of the brigade surgeon. These are located as near the firing line as possible, but sheltered from fire. They should be as near as practicable to some road or track over which horse or automobile ambulances can travel to the field hospitals. From the dressing stations squads of litter bearers are sent to seek and bring back the wounded from the firing line, or as near to it as they can approach without too much exposure. When the wounded reach the dressing stations they are examined and classified as to the apparent gravity of their injuries. Each man is tagged with a provisional diagnosis, and an "urgent" tag is attached to those who require immediate attention. Only emergency aid is given at these stations. Active bleeding is controlled, first-aid dressings are applied, injured limbs are immobilized, and remedies are given to combat shock.

3. AMBULANCE STATIONS.—The function of the ambulance station is to transport the seriously wounded with the least possible delay to the field hospital. When practicable, the dressing stations and ambulance stations may be consolidated.

4. FIELD HOSPITALS.—At the field hospitals the wounded are more carefully classified. Dressings and splints suitable for transport to the base hospital are applied. Only such operations as are absolutely necessary are performed, since aseptic technic is almost impossible under the conditions. However, with boiled water, tincture of iodin, boiled instruments and boiled rubber gloves, and with a trained staff, the necessary procedures may be carried out with some approach to cleanliness. The large number of cases to be cared for is always a serious handicap to efficiency, and experience shows that the patients suffer less if they aré sent at the earliest possible moment to a base hospital or to a civil hospital in the nearest large city.

The several kinds of missiles and their effects may be taken up *seriatim*. They are:

1. Rifle bullets.
2. Projectiles fired from cannon, shell, shrapnel, and canister.
3. Hand grenades.
4. Explosion of mines, etc., in naval warfare.

## WOUNDS DUE TO RIFLE BULLETS

Modern rifle fire is said to be annoying at 2,000 yards, effective at 1,200 yards, decisive at 600 yards. The pointed bullet is more easily upset than the heavier bullet with an ogival point, hence, it might be expected that the former would more often strike sidewise, and produce graver injuries. Observations during the most recent wars show that this is very often the case.

The following description is based upon experience with the earlier type of bullet, which is still being used by troops in the Philippines and elsewhere. The effects upon different tissues when struck by the small caliber hard bullet vary with the range and also with the physical quality of the tissues or organs struck. The kinetic energy of the bullet at ordinary ranges is enormous, and the destructive effect upon the body varies in severity directly with the resistance offered by the tissues. Thus, upon skin, subcutaneous tissue, muscle, tendon and blood vessels, since these structures offer but a trifling resistance, the missile, assuming that it travels head on, produces a mere puncture or narrow tract with little or no lateral destruction. If the bullet is upset in its flight and strikes sidewise or butt end foremost, or if it be deformed by ricochet, the laceration of the soft parts will be much more widespread and the skin wounds larger, particularly the wound of exit, and consequently more apt to become infected. When the bullet strikes the skin point foremost, and traverses only soft parts, the wounds of entrance and of exit are much alike, circular, with slightly ragged edges, about 1/3 in. in diameter. The orifice is soon filled with a black crust of clotted blood. Slight necrosis of the edges may occur after a few days, but if the wound is covered with an aseptic dressing and not disturbed, primary union occurs as a rule in a week or ten days. If the bullet strikes the skin obliquely, the wound of entrance will be oval. As stated, these results are modified when the bullet is deformed or strikes sidewise.

Upon solid organs or hollow organs filled with fluid, liver, spleen, kidney, stomach and urinary bladder, the resistance offered is much greater, and at ordinary ranges, extensive laceration and bursting are to be expected. Upon the spongy ends of the largest bones, femur and tibia, clean perforations with radiating fissures are common. Upon the smaller bones, metacarpals, metatarsals, etc., the part struck is usually pulverized. Upon the hard shafts of long bones, which offer great resistance, extensive splintering and widespread destruction of bone and soft parts are the rule. In the immediate vicinity of the point of impact the bone is pulverized. The bone dust and bone splinters become secondary missiles, and often cause widespread destruction of the soft parts, and a wound of exit of large size, sometimes slit-like with radiating tears. If the bullet strikes the bone obliquely, a large part of the shaft may be reduced to bone dust and splinters. These explosive effects are observed up to a range of 600 yards, beyond which they gradually diminish, while at great ranges, 1,500 to 2,000 yards, they nearly or quite disappear, so that the track of the bullet becomes a simple channel with little or no lateral destruction, modified, however, by deformed and upset bullets, when, on account of the greater striking area, the destruction of tissues is increased.

With these general remarks we may consider the effects of rifle bullets more in detail. As already noted, the modern rifle kills a larger proportion of those hit outright than the earlier rifle; for example: 1 in 2.5 in the Turko-Bulgarian War and 1 in 4.12 of those wounded in the Anglo-Boer War as compared with 1 in 5.57 in the American Civil War. However, with the modern bullet, of those wounded who do not die on the field, a large proportion recover completely and promptly. Permanent disability is also less common. No doubt these results are modified by early aseptic and antiseptic treatment, and by avoidance of fingering and probing the wound. Also, while in earlier wars immediate amputations and resections were done in field hospitals and were nearly always infected, at present, great conservatism is the rule, and a large proportion of the wounded recover without infection.

We have already noted the characters of wounds of the skin.

**Wounds of Tendons.**—Tendons are not pushed aside, but are cut and may be cleanly severed, as from the cut of a knife. Such severed tendons should be sutured at the earliest possible moment.

**Wounds of Nerves.**—Nerves may be wholly or partially divided. While early suture is the best treatment, such nerve injuries are peculiarly liable to be followed by peripheral neuritis and rather extensive central degeneration with paralysis and severe pain. The prognosis following even early nerve suture is not as favorable as after suture following incised wounds or nerves. If a nerve trunk is included in a mass of scar tissue, and is very painful, it may be freed by careful dissection with hope of relief.

**Wounds of Blood Vessels.**—Arteries and veins are cleanly cut or perforated by rifle bullets. If the main artery of a limb or a large artery anywhere is cut, speedy death from bleeding may occur. In some cases if the hole in the vessel is small, and the track of the bullet uncomplicated and narrow, passing through firm tissues, the bleeding may stop spontaneously. The caliber of the vessel may be subsequently normal, reduced in size, or even obliterated by scar tissue. In other cases an arterial hematoma or traumatic aneurysm will form. It is said that, in a few cases, mere contusion of the vessel wall has resulted in an aneurysm resembling the pathological variety. *Arteriovenous aneurysm and aneurysmal varix* have both been observed.

The treatment of wounds of vessels will depend upon whether the bleeding stops spontaneously after rest and immobilization or continues or recurs. In the last two groups aseptic incision and distal and proximal ligation of the vessel is the method of choice. If, however, this is not possible, proximal ligation through a separate incision nearer the heart may be done, always with the risk of gangrene, especially of the lower extremity. Such risk will increase proportionately to the destruction of tissue and infiltration at the site of the original wound. If the wound is or becomes infected, gangrene is all the more likely to occur.

A caution of value is this. Bleeding from many of these bullet wounds tends to stop spontaneously. This result may be favored by moderate pressure over the wound or by aseptic packing, by rest, immobilization and elevation of the limb. A little knowledge is a dangerous thing. The immediate and prolonged application of a tourniquet has cost in civil as well as military practice the loss of many a limb and many a life. The natural impulse of the inexperienced is to apply a ligature to a limb for bleeding, even though it be quite moderate in amount. Such a ligature should remain in place for the briefest possible time. If it must remain for an hour or more, it is better to loosen it now and then for a few moments, thus permitting some blood to reach the parts beyond the wound. This caution does not apply to the cases of furious bleeding where the main artery of the limb is cut, but in such cases the wound will usually be fatal before any help is given.

RECURRENT BLEEDING.—From the necessity of transporting the wounded to some distance and the consequent jarring and shaking, bleeding from fresh wounds may recur. The wounded should be inspected from time to time with this fact in mind.

SECONDARY HEMORRHAGE.—Secondary hemorrhage is a complication of badly infected and sloughing wounds, and is due to necrosis of the vessel wall. It should be treated by proximal and distal ligation of the bleeding vessel in healthy tissues. For this purpose the infected wound must be enlarged and cleaned as carefully and gently as possible with a weak iodin solution. The vessel must be sought for and tied above and below the seat of the bleeding. If the main artery of the limb be the source, amputation will often be the safest mode of treatment.

Wounds of vessels in body cavities, thorax and abdomen, where the surrounding soft parts afford no hindrance to the continuance of bleeding are particularly dangerous. If the surroundings are such that search for the bleeding point under aseptic conditions is impossible, then absolute rest and quiet, the application of cold to the surface, and a full dose of morphin, hypodermically, together with adrenalin, are the measures offering the best chance of spontaneous arrest of bleeding.

**Gunshot Fractures.**—The recognition of gunshot fractures of the long bones is usually very easy. Only incomplete fractures may escape recognition. The details of the fractures are best learned by taking a series of X-ray pictures.

The treatment, so long as the wound remains clean, is by the application of an aseptic, occlusive dressing, and immobilization, according to the principles and rules which guide the surgeon in the treatment of fractures in general. Moulded plaster-of-Paris splints are applicable to many fractures, as are also moulded wire splints, and during the early days of treatment are to be preferred to circular splints of plaster-of-Paris. The former are easily removed and renewed. They permit easy inspection of the wound, and will not cause gangrene by constriction of the limb. If the wound remains clean, after the position and nutrition of the limb are assured, the moulded splint may be replaced by a circular one in suitable cases, with a window cut over the wound for inspection and dressing. In such a splint, early ambulatory treatment is possible in nearly all fractures except those of the spine, pelvis and femur.

If a gunshot fracture becomes infected it must be treated on general surgical principles. Incisions must be made for the relief of tension and for drainage. Loose fragments must be removed. Pus pockets should be carefully sought for and opened. The wound should be cleansed frequently but gently by irrigation with iodin solution, saline solution or both. Open air treatment day and night, if possible, is of great benefit. The various vaccines are sometimes useful. Food should be abundant but easily assimilated, such as milk, cream, eggs, soup. Under good surroundings many of these cases finally do well, good union is obtained and the limbs regain their usefulness. If they do badly and become so septic that the general and local conditions grow progressively worse, amputation should not be too long delayed. If amputation is done, it will usually be wise to leave the amputation wound open. The skin flaps may be held loosely approximated by one or two silkworm-gut sutures. The face of the stump may be lightly packed with sterile gauze. If the amputation must be made, as sometimes happens, through infected tissue, the wound may be painted with strong tincture of iodin or with a solution of camphor and carbolic acid in alcohol (Chlumsky's Solution). In these cases the use of autogenous vaccines is sometimes beneficial. In default of these, mixed commercial vaccines may be tried.

**Wounds of Joints.**—Recent wars have shown that rifle bullet wounds of the larger joints may do very well under conservative treatment; so long as the wound remains aseptic, rapid healing and more or less perfect restoration of function are the rule. The result will be modified by the greater or less regularity of the joint surfaces, due to displaced fragments and the formation of new bone, causing mechanical interference with the free mobility of the joint, and also by the greater or less extent of fibrous ankylosis remaining. In deciding for or against a secondary operation upon such joints, the X-ray will usually furnish important information. My own experience leads me to believe that conservatism in these cases is often the wisest course. A stiff joint in good position is often more comfortable and useful than a weak and movable one.

Wounds of the smaller joints, owing to the small size of the bones and the smashing effect of the bullet upon them, are commonly followed by more or less complete destruction of the joint surfaces, and consequent loss of function in the joint.

INFECTED WOUNDS OF JOINTS.—No more deadly and insidious type of sepsis exists than a badly infected wound of a large joint. Some of these cases baffle the most skillful and earnest efforts of modern surgery. Only rarely does the patient recover with a movable joint. Ankylosis is the result in some, amputation in many, and death from septic poisoning, often with pyemic abscesses, is all too frequent. The treatment consists in free drainage, irrigation, and frequent and careful dressings. The use of vaccines is sometimes valuable; also open air treatment and plenty of easily assimilable food. The progress of these cases should be watched with exceeding care. They usually run a semi-chronic course, and since human nature is imperfect and acute cases are more interesting, the dressing of these unfortunates is apt to be relegated to inexperienced members of the staff, who fail to recognize the insidious spread of the infection until it is too late.

Various elaborate methods have been devised for the treatment of infected joints; more especially the ankle and the knee. Infection of the ankle joint may be treated with good results in certain cases by removal of the astragalus. In several instances I have treated infections in one or other of the smaller tarsal joints by removal of one or more of the tarsal bones with good results. In the knee, the method of opening the joint widely and treating it in a flexed position has not furnished good results in my hands, though highly spoken of by several competent surgeons. Usually the joint will be treated conservatively by tube drainage, irrigation, etc., until decided improvement occurs, or, if the case does badly, until resection or amputation will be the only resource left. Amputation in the bad cases of knee and ankle infection is, as a rule, safer than resection. In the hip, free drainage, resection if necessary, and disarticulation at the hip joint in the worst cases are the several steps in the downward path.

In the upper extremity, drainage, followed if necessary by resection, are the methods used. Amputation will be less often called for than in the lower extremity. It is to be borne in mind that any live appendage to the shoulder and elbow joints, armed at its end by a thumb and one finger, is a member of the greatest usefulness. An artificial arm and hand, though never so skillfully devised, is an expression not of our mechanical deficiency as makers of machines, but an accentuation of the fact that no device born of human intelligence can compare with the most perfect mechanism with which we are acquainted, namely, the human hand. Therefore, in the upper extremity, the utmost conservatism is to be practiced, and no effort omitted to avoid amputation. A stiff shoulder accommodates itself through the movable scapula to nearly all the exigencies of a strong and useful arm. A stiff elbow in half-way good position is almost no handicap at all to most occupations. A stiff wrist is unpleasant, but scarcely crippling, and some sort of a hand, however crippled, is an invaluable possession.

**Bullets Lodged in or near Joints.**—A bullet lying free in a joint cavity will usually require removal. Unless it can be felt and identified, it should be carefully located by the X-rays. The removal should not be attempted until the patient can be surrounded by every aseptic precaution. If the bullet is lodged in the spongy end of a long bone near a joint, there is no more reason for removing it than though it lay elsewhere, so long as it is not associated with wound infection, and does not interfere mechanically with joint mobility. Here again no random search should be undertaken. The missile must be accurately located. If possible, it should be removed through the overlying bone without invading the joint.

**Wounds of the Head.**—Wounds of the soft parts covering the skull not involving the bone are serious only on account of possible bleeding, as from the occipital or temporal arteries, or infection. Wounds of the scalp are treated on general surgical principles.

Wounds involving the skull are serious. At short range the explosive effect of the small bullet when it traverses the cranial cavity is well marked. The brain may be extensively disintegrated, the wound of exit large, and the skull extensively comminuted. In such cases death is instantaneous, or nearly so. As the range increases, the lateral destructive effect diminishes. At extreme ranges it may be absent and the bullet will often lodge. An upset bullet will, however, cause greater and more widespread destruction.

As a matter of practical experience it has been observed that even at moderate ranges the small caliber bullet produced less lateral destruction in its passage through the brain than experiments on the dead body would seem to render probable. Its path may be a simple track with little or no lateral destruction.

Tangential shots may cut a groove in the outer table and this may be associated with fracture of the inner table and laceration of the dura and brain. All bullet wounds involving the skull, whether they appear to penetrate or not, deserve careful exploration under aseptic precautions. It will often be found that a tangential shot has produced comminution of the inner table and laceration of the dura and brain of unexpected gravity. Loose fragments of bone, hair, and other foreign bodies should be searched for and removed. In some cases the rongeur and periosteal elevators will be the only bone instruments required. In others, one or other form of trephine, or the circular saw, or some other of the common instruments in use may be required. The main object in these, as in all surgical work on the skull and brain, is to limit the bleeding and to prevent infection. If infection occurs several results are possible. Abscess of the brain may follow, and may or may not be opened with success. In other cases a localized meningitis will ensue which may be drained. In bad cases diffuse meningitis will develop and end fatally.

PENETRATING AND PERFORATING GUNSHOT WOUNDS OF THE SKULL. —The signs and symptoms of these injuries will, of course, depend upon the seat and extent of cerebral laceration and intracranial hemorrhage. The outlook is worse when the wounds involve the lower temporal and parietal regions and the cerebellum than when the frontal and upper portion of the parietal regions are the seat of injury.

In civil practice my own observations of pistol shot wounds of the brain have caused me to be astonished at the recoveries, apparently complete, following penetrating wounds of the cerebrum, with lodgment of the bullet. Some of these are mentioned in Johnson's "Surgical Diagnosis." Others I have seen since that book was published. Some of these patients have passed out of our observation apparently quite well. In others, some focal symptoms have remained, slight paralysis representing destruction of small motor areas or interference with special senses.

The question of the removal of such lodged bullets must be decided by the circumstances of the particular case. If the wound is healed, and no symptoms of irritation are present, it is probably wiser to do nothing, unless the foreign body is easily accessible and its removal involves no risk of destruction of important areas, whether centers or nerve paths. If, however, the wound is slightly infected, and remains open, or if the bullet is manifestly causing irritation, as shown by headaches or other significant local or general symptoms, search for the missile through the track left in the brain involves, in my experience, no great risk. The foreign body must be accurately localized, so that the operator knows exactly the depth and direction from a fixed point on the surface of the skull (usually the wound of entrance) to the situation of the bullet. The hole in the skull may then be enlarged to convenient size with the rongeur, and a toothed forceps of suitable size and shape (a Kocher clamp is often good) or some form of bullet forceps is gently inserted in the proper direction and to the measured depth. The forceps may then be opened to an extent sufficient to clasp the bullet in the diameter which it is known to present in that plane, then advanced a little, and gently closed. If the bullet is seized, the forceps and bullet are carefully withdrawn. If not, another effort may be made to touch and grasp it with the forceps, or the forceps may be gently withdrawn and a thick, blunt-pointed probe introduced in order to recognize by touch the metallic surface. If these manipulations are made with due care and gentleness, no great harm will be done, and they will usually be successful. When the bullet has ploughed through and lies more or less completely imbedded in the base of the skull, it is better to let it alone, for under these conditions the surgeon may have great difficulty in touching and recognizing the missile, and even greater trouble in extracting it without doing more damage than the conditions warrant. In some cases the telephonic probe might be useful. I have never used it.

When bullet wounds of the brain are infected and are complicated by abscess or localized meningitis, the indications are for drainage. The outlook is not very good. When as the result of a bullet wound there are considerable loss of substance of the skull and laceration of the dura which cannot be repaired, a so-called "hernia cerebri" may develop. If not complicated by severe infection, it is not so serious a condition as would appear to those not familiar with the course of this phenomenon. For a time it grows larger and may form a large protrusion. After some weeks the mass always shrinks, and upon healing the scar is depressed below the level of the skull.

**Wounds of the Face.**—Gunshot wounds of the face may be of any degree of severity. No rules for their care can be given other than that they should be kept as clean as may be by mouth washes, sterile food, and nasal douches. In general their treatment must be modified according to the special characteristics of the individual case.

When the undeformed bullet strikes point foremost, the face may be traversed in almost any direction without producing grave injury. The track of the bullet is simple, and if clean soon heals. Two types of injury are, however, more serious: (1) Fractures of the lower jaw and fractures of the upper or lower jaw when the bullet strikes the teeth, (2) wounds of the eye and orbit. In wounds of *the jaw,* more especially the lower jaw, it is to be borne in mind that the bone is hard and dense, and that the increased resistance offered permits the flying bullet to expend a larger part of its energy. Hence, comminuted fractures are produced. The teeth also may become secondary missiles, and greatly increase the extent of the injury. In these cases modern dental surgery may do much by the use of interdental splints and cleanliness, and later by plastic operations upon the face and by the use of cleverly devised artificial teeth, plates, and their addenda.

*The eye* may be injured in any degree of severity, from a mere contusion to a complete destruction of one or both eyes, or the optic nerve may be cut. In some of these wounds the anterior fossa of the skull may be entered. The treatment of destruction of one eye is immediate enucleation. Less severe injuries may be treated conservatively sometimes by iridectomy, by the use of atropin and cocain, iced cloths, etc.

**Wounds of the Neck.**—Gunshot wounds of the neck may be slight, severe, or immediately fatal injuries, according to the structures through which the bullet passes. The large vessels, the nerves, the larynx and trachea, the esophagus, the spine and spinal cord may any of them be injured. Those which come under the surgeon's care will not be as a rule very severe injuries. The small caliber bullet may pass through the neck in almost any direction, and yet the important vessels, nerves, etc., may not be touched.

Aneurysm and aneurysmal varix as well as varicose aneurysm have all been observed. Their treatment is operative. Wounds of important nerves can rarely be treated by operation with success.

TRACHEA AND LARYNX.—Wounds of the trachea and larynx demand immediate tracheotomy to avoid the danger of laryngeal obstruction.

ESOPHAGUS.—Wounds of the esophagus demand immediate exposure of the esophagus, repair of the wound in the gullet, and open drainage to avoid abscess and cellulitis. The patients should be fed through a long rubber tube, size about 24 French, passed through the nose or mouth into the stomach.

**Wounds of the Thorax.**—Wounds of the thorax may be penetrating or non-penetrating. The former group as a rule present no serious problem to the surgeon, provided they remain clean. An intercostal artery, if cut, should be tied. The internal mammary may bleed fatally, and should be exposed and tied if possible.

Penetrating wounds of the thorax, when they wound the heart or the great vessels, are usually immediately fatal and do not come under treatment.

THE LUNG.—The lung offers but slight resistance to the small bullet, and the track through its substance is usually narrow. The treatment is at first conservative by an occlusive dressing and immobilization of the chest by strapping and bandages. Empyema is to be treated by resection of a rib and drainage. In most instances, hemothorax is best let alone, for a time, for the bleeding to cease permanently. If the blood accumulates in large amounts it may be removed by a powerful aspirator. If the surgeon chooses to do an open operation this must be performed under intratracheal anesthesia, in a regularly equipped hospital. Under less perfect conditions interference would not be justifiable. I recently treated a gunshot wound of the lung where a large amount of blood had accumulated in the pleural sac, first by aspiration. In a few days, however, empyema developed and required the resection of a rib and drainage.

*Pneumothorax* is to be treated by rest and later by lung exercises, namely, by blowing water from one bottle to another.

The signs and symptoms of injury of the lung when marked are pain, hemoptysis, cough, subcutaneous emphysema, friction sounds, and other changes determined by physical examination, sometimes shock and the general symptoms of bleeding. External bleeding is rare.

Wounds of the lung usually remain clean, but if the bullet has passed through the stomach or bowel first, then empyema or abscess of the lung will be very likely to follow. When a bullet enters and lodges in the lung, it may remain quiescent indefinitely, and do no harm.

**Wounds of the Spine.**—Bullet wounds of the spine may or may not involve the spinal cord. Those which injure the bodies of the vertebræ may be mere perforations. Those which involve the processes and arches are more apt to be comminuted and the latter are usually attended by cord symptoms. The nerve roots may also be cut. In the wounds involving destruction of the cord the prognosis is bad and operation, as a rule, useless. Wounds without cord symptoms heal, if clean, under conservative treatment. The only method of determining the situation of a bullet in the spine is by means of the X-rays. If such a bullet appears to be pressing on the cord, and its presence is attended by the symptoms of a partial lesion, it may be removed with possible benefit.

**Wounds of the Abdominal Viscera.**—Theoretically, wounds of the abdominal viscera should be operated upon and the injury repaired. Practically, the conditions of warfare forbid interference in most cases. There is a fair percentage of recoveries reported as the result of conservative treatment. To surround a patient in a field hospital with the necessary asepsis and after-care, is well-nigh impossible. Still, the surgeon must be guided by circumstances, and if he be well trained in abdominal work, as many of our young men who leave our large city hospitals and enter the army are, he may find opportunity to operate and save lives in gunshot wounds of the abdominal viscera. He will bear in mind that time is everything. A man with a wounded bowel or stomach or one who is bleeding to death from a hole in his mesentery may be operated on successfully now, an hour after he is wounded. After 6 hours it may be too late. I have observed this more especially in perforated ulcers of the stomach. If these cases are operated upon within 1 or 2 hours after the perforation has occurred, the mortality is very small, and should not exceed 5 per cent. After peritonitis is well developed, the mortality rises very high indeed, and even after 12 hours many of these cases are hopeless.

WOUNDS OF THE LIVER.—It will rarely happen that a bullet wound of the liver can be treated successfully on the battlefield. The wounds are either slight, mere gutters on the surface of the liver, in which case bleeding may stop spontaneously, or they are more or less wide tracks through the liver substance, sometimes with widespread destruction of tissue. Some of these can be treated successfully in civil practice by packing, but many die in spite of the best care. In warfare, operative interference upon the battlefield is scarcely likely to be beneficial.

WOUNDS OF THE SPLEEN.—In civil life, gunshot wounds of the spleen may often be treated successfully by splenectomy. On the battlefield operative interference would not be justified.

WOUNDS OF THE URINARY BLADDER.—Wounds of the urinary bladder are to be treated by suture if possible, usually with drainage. They require careful after-treatment by frequent aseptic catheterization. Sometimes it may be found best to tie a catheter in the bladder for several days. The signs and symptoms of urinary infiltration are to be treated by incision and perineal drainage.

WOUNDS OF THE URETHRA.—Wounds of the urethra may sometimes be treated conservatively. Usually they will require perineal drainage.

WOUNDS OF THE TESTES.—Wounds of the testes are rarely serious, and may be treated conservatively in most cases.

**Wounds of the Extremities.**—In an earlier part of this chapter an outline has been given of the treatment of gunshot wounds of the extremities. It should be conservative whenever possible. It is well to remember that, while a wooden leg is very useful, an artificial hand is a poor substitute for one of flesh and bone.

## WOUNDS PRODUCED BY PROJECTILES FROM ARTILLERY AND HAND GRENADES

"Artillery projectiles are classified as shot, shell and case shot.

"**Shot.**—Solid shot is no longer used in modern cannons, the projectile called a shot being hollow with thick walls. It is principally used to perforate armor and carries a small bursting charge.

"**Shell.**—The shell is a hollow projectile with thinner walls than the preceding. It is also provided with a large bursting charge. It is used to destroy persons or material. Pom-pom shell is another kind of shell. It derives its name from the report of its discharge. It is fired from the one-pounder Vickers-Maxim Automatic Gun. It is 1.457 inches in length, and weighs 16 ounces. It explodes by percussion. This shell is used to kill and wound the enemy; hence, like the common shell, it breaks into many fragments.

"**Case Shot.**—This consists of a number of shot held together in a metal case, which may be ruptured by the shock of discharge or by a bursting charge. The term canister or grape shot is applied to the latter.

"The modern projectiles of the artillery are all cylindrical with an ogival head, except the canister, which has a flat head.

"**Canister.**—In this projectile the metallic envelope is filled with small balls which are liberated by the shock of discharge. Canister is used at short range when the guns of a battery are in danger of capture. Each 3-inch canister contains 244 iron balls, ⅝ of an inch in diameter, weighing 30 to the pound, placed in a receptacle the shape of an elongated can. The canister has been entirely superseded by the modern shrapnel.

"**Shrapnel.**—The shrapnel is of special interest to surgeons because of its increasing importance in augmenting the casualty list of battles in modern wars. The shrapnel is a projectile which carries a number of bullets at a distance from the gun where they are discharged with added energy over a wide area from the point of bursting. It has become the principal projectile of all modern field artillery. It forms 80 per cent. of the ammunition supply of field guns. It is used against troops in masses and material as well" (1).

"It is used, also, in mountain and siege artillery, and in the smaller guns of sea coast fortifications to repel land attacks. In this shrapnel the case is a steel tube with a solid steel base. The weight of the 3-inch field gun shrapnel complete is 15 pounds, length 10 inches, muzzle velocity, 1,700 f. s. The bursting charge is composed of 2¾ ounces of black powder placed in a chamber at the base. There is a stopper of gun cotton in the central tube to hold the powder in place and to assist in the explosion. There are 252 round balls, flattened on six faces, of .50 inch caliber, composed of lead. The balls are surrounded by a smoke-producing matrix, which is used to locate the point of bursting. This shrapnel is said to be a man killer at 6,500 yards. At the latter distance the shrapnel has a remaining velocity of 565 f. s. On bursting, an additional velocity of 300 f. s. is conferred on the lead bullets, making altogether a remaining velocity of 865 f. s. at 6,500 yards. The fuse can be set to cause the projectile to explode at any one-fifth second of its flight.

"The older shrapnels were made up of a cast-iron case and diaphragm that separated the balls. The case was constructed to invite rupture into a number of fragments. The bursting charge was placed generally in the head of the projectile.

"The old-time shrapnel broke into a greater number of fragments, but they were not always possessed with sufficient energy to inflict severe injury. The present shrapnel has the bursting charge located in its base. It is made of a stout case, which remains intact at the time of bursting, except for the blowing out of the head" (2).

**Modern Artillery.**—Modern field artillery is terribly effective, even at great ranges. Several varieties of projectiles are in common use. Common shell is used against defences to break them down and render an assault more hopeful. Shrapnel is the most common form of projectile used against troops. The only smoke on the modern battlefield is made when these shells, filled with powder and leaden bullets, burst, thus enabling the artillerists to estimate the accuracy of their fire, or the want of it. In modern field operations, artillery plays an important part, and is used massed, and very freely, to render positions untenable for infantry or to silence the artillery fire of the enemy while the infantry advance by short rushes. The rapidity of fire is such that a storm of shells can be brought to bear on a position. It is said that the modern French Canet field gun can be fired ten times a minute. At short ranges canister was formerly used, but it has been superseded by shrapnel.

**Hand Grenades.**—Hand grenades, though not fired from cannon, are shell filled with a bursting charge of powder. The effect of shrapnel and hand grenades is much the same. Wounds are produced by fragments of the steel case and by the bullets. The wounds made by the bullets themselves do not differ essentially from those made by rifle bullets of the old soft lead type fired at low velocity. Often the bullets will lodge. The wounds are, as a rule, severe and frequently become infected. Their treatment needs no especial notice here.

**Nature of Wounds.**—Shell fragments, the case of shrapnel and hand grenades produce wounds of a very varied but commonly very serious character. They are contused and lacerated wounds often of large size, and to keep them from infection is very difficult—under the conditions of warfare practically impossible. It can be readily understood that a flying, jagged mass of iron, besides producing a ragged wound surrounded by devitalized tissues, is apt to carry with it into the wound portions of clothing or whatever it may chance to pass through before entering the body. It is one thing to seal aseptically a mere puncture, such as the small pointed bullet makes, and quite another to protect effectually an extensive contused raw surface. The wounds produced by shell fragments are often multiple—in naval warfare, commonly so. Hence the conditions to be met in their treatment are far more complicated than is the case with wounds produced by rifle bullets. In the worst cases, where the victim is struck by an unexploded shell, or large fragment, decapitation, disembowelment, the loss of an entire limb, etc., are common injuries, or the front of the chest or the abdominal wall may be torn away. The modern shell breaks into hundreds or thousands of fragments, and a hundred wounds have been observed in one individual. Some of the fragments are minute, and the wounds produced may, therefore, be of any grade of severity, from a mere scratch to instant death. In wounds characterized by extensive loss of substance and contusion of the adjacent tissues **shock** is frequent and usually severe. In fact, many shell wounds closely resemble the extensive, contused, and lacerated compound fractures seen in civil life as the result of machinery accidents, dynamite explosions, and the like.

**Treatment.**—The so-called "shell-wound first aid packet," and the "Stokes' shell wound dressing," furnished to the navy, which contain a large aseptic absorbent dressing with a wire netting basis for support and immobilization, are better first aid dressings for this class of injury than the simple pad and bandage furnished to the infantry of the line.

Of all the local applications to wound surfaces, in the probably infected, contused, and lacerated wounds of civil life, **nothing compares with tincture of iodin liberally swabbed into every crack, crevice, and corner of the raw surface.** Its irritating effects are insignificant and it is a really efficient disinfectant. It does not even interfere with primary union when used on well-nourished tissue, such as the scalp and face. Any excess should be wiped away.

Since shell wounds are more or less contused, the bleeding from small vessels is usually not so severe as in incised wounds. If a large vessel is cut, bleeding will be profuse and often fatal. Large shell wounds of the extremities resemble railway crushes and machinery accidents. They will often require amputation. If an attempt is made to save the limb, shredded and evidently dead tissues are cut away, all visible vessels ligated, and the wound cleaned as thoroughly as possible. Doubtful skin may usually be left for a line of demarcation to form. The after-care of these cases is that of infected wounds in general.

See Chapter on the treatment of infected wounds, Volume I.

In smaller shell wounds where suppuration persists, aseptic exploration is indicated for the removal of a shell fragment, a piece of cloth, or other foreign body, as well as for disinfection and drainage. The X-rays will detect the presence and location of a piece of metal, if such is present. As in similar injuries observed in civil life, the more grave shell wounds require, first, treatment for **shock and bleeding**. Abundance of water should be introduced into the system by enema, subcutaneously, by the Murphy irrigation, or into a vein. Warmth, rest, immobilization, and the other common measures are used. These patients should not be transported while in shock, if it is possible to avoid it. No serious surgical procedure, except the control of bleeding, should be undertaken until the patient has emerged from shock. If he must be moved, the removal should be delayed, if possible, until he has reacted to some degree, the wound has been cleansed and dressed, and the limb or body immobilized. **Too much stress cannot be laid upon the importance of such immobilization.** One of the long bones may have been injured, but not completely fractured. If the entire extremity is immobilized, a complete fracture may be avoided. Without such immobilization, transportation of the patient over rough roads will probably render the fracture complete.

## WOUNDS RECEIVED IN NAVAL WARFARE

**Conditions During Engagement.**—Whoever has gone over a modern battleship and kept his eyes even half open must have realized that in action the wounded, while the battle lasts, must of necessity receive but scant attention. To pass from one compartment of the ship to another may be a physical impossibility. The crew are, of necessity, confined in coffers of massive steel, to open which might imperil the entire ship. To get from a turret magazine to the open air, even in time of peace, one must climb a vertical iron ladder perhaps 76 feet high, and thence pass through a small hole in the bottom of the turret and descend by an iron ladder to the deck. Communication through the bowels of the ship can only be carried on by the telephone, electric signals, or a speaking tube. At the time of going into action, the crew, in groups of varying size, are confined, each group in its own compartment, the steel doors are closed, and there the men must remain so long as the battle lasts. To open such a compartment during the action might place the entire ship in serious peril. Those working in the engine and fire rooms are fairly protected from gun fire, but not from torpedo attack, mines or internal explosions. A whole shell may, of course, drop to the bottom of the ship and burst; but this will be rare. The men in the several compartments are as effectually shut in from escape as though buried in a steel coffin underground. The superstructure and secondary battery cannot be protected from the mighty shock of the heaviest of modern guns. One shell from a 14-inch gun, or even a much smaller one, exploding in one of these more lightly armored parts of a ship may kill every man in the compartment. Those not killed by flying fragments may be poisoned by the fumes and gases of the powder ($CO$ and $NO_2$), scalded to death by steam from broken pipes, or burned. The ship may be set on fire and the whole compartment turned into a scrap heap in a moment. Thus, in one of the battles of the Russian-Japanese War a shell entered the sick bay of one of the Russian ships and exploded. The surgeons and others who were there attending to the wounded were killed to a man, and the entire compartment wrecked. For such reasons, at the present time no attempt will be made in battle to use the regular hospital compartments of the ship, which for hygienic reasons are always above the water line. Everything will be transported below the water line and behind the heaviest armor. In action between battleships in the daytime the secondary batteries will not be manned, since at the great ranges of the big guns the former would be ineffective, being only useful for repelling torpedo attack, and the like. Indeed, when a battleship goes into action, not more than six or eight men will be exposed outside the armor. These will be the men in the tops, one or two officers, and a few men whose business it is to determine the ranges and the effect of the fire. The extreme range of a 14-inch gun is about 14 miles; at 8 or 9 miles it can be fired rapidly and accurately at a moving target.

Just what the next naval battle between the dreadnaughts and the superdreadnaughts of to-day may be like no man knows, but that it will be terrible there can be no doubt. The action will probably not last more than twenty minutes or half an hour. It is now possible to fire even the largest guns with great rapidity, so that a perfect hail of monstrous projectiles will fall upon that ship which fails to get the range of its antagonist.

**Treatment During Engagements.**—During an engagement then, the wounded, no matter how elaborate the preparations may be for their care at other times, must, for the most part, lie where they fall. Certain precautions, however, may be taken. First-aid dressings in abundance may be distributed at various stations, and the men may be made to bathe and put on clean clothing before going into action. Suits of sterile underclothing should be distributed to the entire personnel of the ship, and outer clothing should be clean or as nearly so as possible, and the smallest amount of clothing should be worn. In hot climates, and in enclosed parts of the ship, the men fight, as a rule, as nearly naked as may be. Plentiful supplies of cold drinking water should be placed in every compartment, and a bucket of boric acid with absorbent cotton for bathing the eyes irritated by powder gases. Such a bucket should be placed near each gun; also plenty of dressings, splints, iodin solution, adhesive strips, etc., should be close at hand, with a nurse or orderly to apply them. In the newest ships the effort has been made to provide stations, more or less protected from fire, and accessible in a definite area to a certain proportion of the ship's company during action. These stations may be of three kinds, or, rather, may be arranged in three groups. At least two stations, fore and aft, should be placed within the citadel, or beneath the water line, behind filled coal bunkers. Here, necessary operations for the control of bleeding may be performed, and dressings may be applied. These spaces may be quite large, and would offer protection to a large number of wounded. In each, both hot and cold water can be had. Several secondary stations should be established in less protected positions, where first-aid dressings, tourniquets, etc., may be applied, and when it is necessary to man the secondary battery, dressings, water, boric acid solution should, as already stated, be kept in the vicinity of each gun. Provision must also be made for the temporary disposal of the dead, since the sight of their mangled bodies must be terribly depressing to the other members of the crew. Empty coal bunkers may be used for this purpose. Blood should be cleared away at the earliest possible moment, since it soon putrefies and emits a horrible, cadaveric odor. When men can be moved within the ship to dressing stations, or to places of greater safety during action, it has been found that one or two men, without any apparatus, can carry a wounded companion through the narrow spaces on shipboard better than in any other way. If a wounded member of the crew is to be carried by one companion, he may take him on his back; if by two, they may make a chair with their arms and hands. The battle over, the severely wounded must be transported to hospital ships at once.

**Nature of Wounds Received.**—In naval warfare, expeditions are often sent ashore in boats for special duty. Under such circumstances they fight with rifles, and may be wounded by rifle fire or field artillery. These wounds will be the same as are observed in land warfare.

In fights at sea, the wounds will nearly all be caused by shell fire, and by the secondary missiles which exploding shells create from the structure of the ship itself.

From the size and terrific force of the projectiles and the havoc created when they penetrate and explode within the ship's structure, it will follow that many of the injured will be killed outright, burned to death, smothered, torn to pieces, decapitated, cut in two, have their limbs amputated. In fact, whole groups of men are often annihilated in an instant by a single shell of even moderate size. The victory will be gained by the ship that in the shortest time pours the heaviest fire into the enemy, and the conquered vessel may be literally torn to pieces in a few minutes, soon after her victorious adversary gets the range.

The wounds of the injured who survive will usually be multiple. They will all be contused and lacerated wounds. Moreover, the heat from impact and from the burning charge of powder makes the fragments nearly red-hot, so that the tissues are seared and devitalized. The burning powder may also inflict serious or fatal burns of the skin, and if, as sometimes happens, a quantity of ammunition is lying near by and is exploded, all the men in a compartment may be burned to death; in fact, these burns are among the most frequent and painful injuries received in modern naval engagements. An unexploded shell of large size may destroy the human body, or cut off the head or a limb.

**Amputations.**—If a limb is cut off, the stump may be fairly smooth. The far side of the stump may be filled with bone dust, and the skin and muscles shredded, contused and torn, but if the missile was moving at high velocity, the bone will be cut quite cleanly, without much splintering. If the shell was moving slowly, the splintering of bone will be more marked, and the contusion and laceration of the soft parts more widespread. If extensive, reamputation will be required, but not necessarily a formal amputation at once. These cases resemble closely the accident cases seen almost daily in large metropolitan hospitals: machinery accidents, crushes of limbs from locomotives and trolley cars, elevator accidents, and the other numerous forms of violence which take their toll of human life among the dwellers in a great city. A long experience with such cases teaches that it is well in the first instance to proceed as follows:

First, wrap the body in heated blankets.

Second, stop bleeding by ligation of bleeding points at once.

Third, treat shock by intravenous saline infusion, .9 of 1 per cent. in strength, at a temperature in the hand irrigator of 118 degrees F., using any convenient, subcutaneous vein, the median basilic vein in the bend of the elbow, for choice. In amount, the infusion may be from 1,000 to 2,000 c. c., or it may be continued until the volume of the pulse is plainly increased and its frequency diminished. If 3,000 c. c. is given, because *less* produces no improvement, the patient will die.

Hypodermoclysis is simpler and efficient.

At the same time, a hot, stimulating enema is given, which consists of

| | | |
|---|---|---|
| ℞ | Extract of coffee | ʒii |
| | Tincture of digitalis | ♏x |
| | Whiskey | ℥ii |
| | Hot water | ℥iv |

We also administer beneath the skin sulphate of strychnin, 1/30 grain. This may be repeated once. Morphin sulphate is also useful in the dose of about one-third of a grain and atropin sulphate up to about 1/50 grain. Camphor dissolved in sterile olive oil is a useful subcutaneous stimulant. The wound may be washed and disinfected as elsewhere described, and dead tissues cut away. A large dressing of loosely shaken gauze is applied firmly to the raw surface of the stump, and a large sterile dressing over that. A splint of wood, wire netting, or moulded plaster-of-Paris, according to the site of the injury, secures immobilization. These various measures should be carried out as rapidly as may be, and the patient placed in a bed previously warmed. The foot of the bed should be elevated, and in an hour or two a Murphy irrigation started. The question of further operative treatment must be decided according to the conditions of the particular case. Certainly nothing should be done until the patient has entirely reacted from shock. To perform a serious amputation upon a man in a state of profound depression from a recent injury is to kill him without fail. Every means should be used to refill the depleted circulation. If a donor offers, blood transfusion may save a life. Failing this method, water must take its place, and the Murphy drop method is usually the most efficient means to this end. Strychnin and other heart stimulants may be given at intervals as long as the patient remains depressed, and hot liquid food should be given in small and often repeated doses as soon as the stomach will retain it. The nature of the operation to be done must be decided by the surgeon after the patient has entirely emerged from shock. Since these wounds are always infected, the character of the infection and the severity of the septic and sapremic symptoms must be taken into account, as well as the position and character of the wound. Sometimes the surgeon may wait with advantage until the wound has cleaned up and commenced to granulate. In other cases, a spreading infection, with severe symptoms of intoxication or the presence of a cadaveric odor from the wound, will demand early interference. This may be in the nature of wide multiple incisions, or amputation above the infected area, if this be possible, leaving the stump sufficiently open for the freest drainage. No fixed rules can be formulated for the character of the amputation. It will often be atypical and devised to save the greatest amount of tissue and secure the most useful stump. As elsewhere stated, conservatism is most important in the upper extremity, less so in the lower.

**Shock.**—Some additional remarks in regard to shock as observed in naval engagements are here added. In the care of the injured, shock will often be the all-important condition to combat. The effect upon the nervous system of the men, of the awful din, the jar and vibration, the intense nervous strain, the smoke and the stifling fumes from the guns and bursting shells, the cries of the burned and wounded men, and, in fact, every horror of a positive inferno, with much in addition never dreamed of by any mediæval imaginer of Hell, is terribly demoralizing, and yet the effects upon the wounded vary much with the temperament of the individual. If the ship is punishing the enemy while she herself is suffering less, the intense elation of spirit may enable a man to receive the gravest hurt and yet show few symptoms of shock for hours; in other cases, the wounded become delirious; in others, even the bravest are overcome by uncontrollable fear, and are rendered weak and horror-stricken to a pitiable degree.

**Care on Board Battleship.**—It is the aim of the hospital ship to remove and care for all who are seriously hurt as soon as the battle is over. In the meantime the ship's surgeon may do much to relieve suffering and aid the wounded. If the operating room and sick bay are not destroyed, they are, of course, invaluable after the action is over; but placed, as they are, in less heavily armored parts of the ship, they must often be destroyed. It has been suggested that on shipboard local anesthesia and spinal anesthesia should, as far as possible, take the place of chloroform, and this on several grounds: namely, a smaller number of assistants is required in operating; patients do not need so much after-care and attention, and they may be able to walk and care for themselves at once. I am not an advocate of local anesthesia for serious surgical procedures, and in my experience it often requires not one, but several persons, to hold down the wretched patient. Under such circumstances, good surgery is difficult, or impossible. Spinal anesthesia is only applicable in a restricted way to operative work, and is at best a dangerous substitute for chloroform. It has not been used in the New York Hospital for a number of years.

**Transportation of Wounded.**—For transferring the wounded to launches, hospital ships, etc., special stretchers of many kinds have been devised intended to protect the wounded from falling while being transported and from the movement of injured limbs. The best is probably that of Stokes. They consist of a light steel frame, with a covering of wire netting. In this, the patient, however badly wounded, can easily be immobilized, and can be slung by a rope and hoisted or lowered from the vessel without danger of falling out, no matter in what position the stretcher may be. Stokes has devised an apparatus whereby the wounded in the stretchers may be transferred from ship to ship by trolley. These stretchers are kept in numbers in the U. S. battleships. They are readily nested, and occupy but little space.

**Treatment.**—When heavy shells burst, the fragments are numerous and of various sizes, some large, some small. Of the larger fragments, some will be large enough to inflict frightful mutilation, a detailed description of which is scarcely possible. If not immediately fatal, the wounds produced, whether the fragments are large or small, have certain characters in common. Many are wounds with loss of substance. The velocity of the fragments is not very great, and hence they often lodge. The wound of entrance is often smaller than the size of the fragment. The walls of the cavity in which the fragment lies are devitalized. The depth to which such necrotic tissue extends is variable and often extensive. Its limits cannot be determined from early inspection. Fractures may or may not exist. Hair, clothing, dirt and other foreign bodies are often carried into the depths of the wound. When wounds, with loss of substance, are made by large fragments, they are often terrible injuries. A large part of the abdominal wall may be carried away, and the viscera torn and contused. The loss of a large part of the chest wall is another fatal injury. The outer wall of the orbit may be torn away, leaving the eyeball exposed. The lower half of the face, including the lower jaw, may be shot away, leaving a hideous mutilation, or a portion of the skull may be carried away, leaving the brain exposed. There is, indeed, no end to the possible variety of these mutilating injuries.

In all blind wounds, the indications are to remove shell fragments and all other foreign bodies, through a suitable incision, to clean and disinfect the walls of the wound cavity, to stop bleeding and to establish the freest possible drainage. Such wounds should not, as a rule, be sutured; yet in certain regions, the face and scalp, for example, the wound edges may be drawn partly together, and, even in less vascular regions, a suture or two, here and there, may be used to support the tissues. Such wounds should be packed with sterile gauze, or, if evidently infected or widely necrotic, they may be packed with gauze, soaked in Chlumsky's solution. Voluminous absorbent dressings are required, and such dressings require frequent renewal. If the wound be of an extremity, some form of supporting and immobilizing splint is necessary, and the entire limb should be immobilized. The subsequent treatment will depend upon the character and severity of the infection, and upon the extent of sloughing of the skin and deeper structures. Drainage must be of the freest description. Pocketing, burrowing, and tension must be relieved by free cuts, and the case must be most carefully watched for such insidious complications.

When such wounds have cleaned up, skin grafting by Thiersch's method greatly hastens healing, and diminishes scar tissue formation, deformity, and loss of function. Concerning the treatment of shell wounds of special regions, the principles of their treatment are those already briefly described. They are all lacerated and almost invariably infected wounds.

**Injury to the Ear.**—Rupture of the tympanic membrane is a frequent accident. It is caused by the sudden blast of air from exploding shells and the gun fire of the ship itself. In addition, a permanent gun deafness occurs in certain cases from repeated shocks to the auditory nerve. Prevention is, therefore, all-important. The shocks can be made less dangerous by various devices. Ordinarily the ears may be plugged with cotton wool. A more efficient device now in use in the United States Navy is that of Elliott. It consists of a small tube with rubber washers of a size suitable to fit the external auditory canal. The tube is perforated by a minute canal, sufficiently large for hearing purposes, but small enough to protect against the sudden increase of atmospheric pressure. The men may wear rubber-soled shoes, and are advised to stand on tiptoe at the moment of gun fire. Rupture of the tympanum is, nevertheless, a very frequent accident. The men, not realizing the danger, think it unmanly to use precautions and suffer in consequence. The accident is, however, only serious when it becomes infected. Theoretically, before going into action, the men should have their ears washed clean with warm boric-acid solution, and the ears plugged with sterile cotton wool. Their prejudice against plugging of the ears is quite natural, since it is all-important that they should hear and answer instantly to the word of command, and this is hard enough to do under the conditions, even with perfect hearing.

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# CHAPTER XVI

## THE TREATMENT OF WOUNDS AND THEIR DISEASES

JAMES M. HITZROT

The effect of mechanical violence is to produce some form of injury to the tissues it acts upon. Depending upon the nature and force of this violence and of the presence of various chemicals, of a specific virus, or of bacteria, the changes which occur require variable forms of treatment.

To facilitate the description of the treatment to be used, a classification is appended merely to serve as a working basis for discussion.

The constitutional effects of injury, shock, collapse, and syncope are treated elsewhere in this work, and will only be spoken of here when mention of the treatment would otherwise be incomplete.

The classification of wounds is as follows:

1. Subcutaneous wounds (contusions).
2. Open wounds.
   (a) Abrasions.
   (b) Incised wounds: Linear and punctured.
   (c) Contused and lacerated wounds.
3. Gunshot wounds (for description of treatment, see Vol. I, Chap. XV).

The open wounds may be:

1. Penetrating.
2. Perforating.
3. Poisoned or infected.
   A. Non-bacterial, i. e., those in which the resulting symptoms are due to:
      1. A definite chemical poison.
         a. Insect bites and stings.
         b. Bites of reptiles.
         c. Poisoned weapons.
      2. A specific virus.
         a. Hydrophobia.
         b. Vaccination.
   B. Due to bacterial invasion, i. e., the infectious wound diseases.
      1. Group of the ordinary wound infections in which the infection in the wound may cause:

a. Abscess formation (infected wound).
b. Lymphangitis or lymphadenitis.
c. Cellulitis (including erysipelas).
d. Varying types of blood infection (bacteriemia) and the metastatic infections (pyemia).

2. Putrefactive infections.
3. Group of wound infections due to specific micro-organisms.
   (a) Tetanus.
   (b) Wound diphtheria.
   (c) Anthrax.
   (d) Glanders.
   (e) Tuberculosis.
   (f) Syphilis.
   (g) Actinomycosis.
   (h) Blastomycosis.

## SUBCUTANEOUS WOUNDS (CONTUSIONS)

The effect of blunt violence which does not break the skin is to injure the skin and underlying structures. The extent, force, and location of the violence will determine the result.

For injuries to the head, see Vol. II, Chaps. IX and X; to the chest, see Vol. III, Chap. XI; to the abdomen, see Vol. III; to the eye, see Vol. III, Chap. I; to the nerves and blood-vessels, see Vol. I, Chaps. VIII and XIII; to the bones, see Vol. II, Chap. V. These will not be considered here.

In general, the result of such blunt violence on the tissues is to produce capillary hemorrhage and an exudative reaction in the tissues far beyond the injury. This hemorrhage and the exudative reaction are best treated by cold applications, preferably by an ice-bag placed upon a few thicknesses of moist gauze. The sooner this cold is applied, the less marked will be the tissue reaction. The cold applications should be applied from 12 to 24 hours, depending upon the degree of reaction to be anticipated, and applied over an area at least 3 times the size of the contusion. Care should be taken not to have the cold too intense, as otherwise the skin may undergo a dry gangrene. To prevent this latter complication, it is wise to move the bag every few minutes, so that its action is widespread without being too definitely localized.

In places where it is applicable (joints, extremities), a tight bandage possessing some elasticity will aid in preventing the exudate. Elevation of the part will also help.

As soon as the exudative reaction has ceased, hot moist applications should be used, followed by massage to help carry off the extravasated blood and the exudate.

Should a hematoma form, which cannot be dissipated by the above method, it should be opened under strict aseptic precautions and the blood washed out with saline solution, the cavity dried, and the wound closed by suture. A tight bandage is then applied, to bring the walls of the cavity in close contact. Aspiration and small punctures of such hematoma, with or without drainage, are more likely to become infected than is the case in the above-mentioned method, and for that reason are not recommended.

## OPEN WOUNDS

**Abrasions.**—Abrasions may consist in small areas in which the superficial layers of the skin are scraped off, or in more or less extensive skin abrasions into which are ground cinders, stone, sand, and other forms of grit and dirt. The former should be painted with iodin and covered with a sterile dressing until a scab forms, after which simple protection is all that is essential. In the latter, the area should be painted with tincture of iodin and the grit, etc., removed by scrubbing it with a scrubbing brush and alcohol, after which it may be dressed with alcohol to hasten scab formation. After the scab has fully formed, the area may then be covered by some bland grease (Liq. Petrolatum U. S. P.).

Should suppuration occur under the scabs, moist dressings of warm saline solution will hasten the healing process.

**Incised Wounds.**—LINEAR WOUNDS.—Linear wounds comprise a number of wounds of varying depth, from those which merely pass through the skin to deep wounds to the bone, which sever all the intermediate soft parts and frequently cut off a fragment of bone or actually pass through it, and, in the small extremities, sometimes actually sever it from the patient.

First Aid.—For the simple wounds a clean dressing, with or without tincture of iodin painted over the injured area, will suffice until the more complete treatment can be carried out.

In the larger incised wounds the first essential is to control the bleeding, which is free and rapid. The hemorrhage may be controlled by elevation in the extremities, by a tourniquet, by digital compression, or, where these do not avail, by hemostats. After the hemorrhage is temporarily arrested, the skin area may be painted with iodin and covered by sterile dressing, or a sterile dressing may be firmly bound over the wound to protect it.

Later Treatment.—In any case, the interference under improper surroundings should only be sufficient to protect the wound until the patient can be brought into surroundings suitable for proper treatment. When the patient has been brought into suitable surroundings, all hair should be removed by shaving. Grease should be removed by wiping with gasoline, then with a mixture of alcohol and ether. When the skin is dry, it should again be painted with the tincture of iodin.

In small cuts the skin may be drawn together by strips of chiffon painted over with collodion or sutured by a fine needle and horsehair suture, and suitably dressed to protect the suture line by a sterile pad.

In the more extensive lesions the patient should be anesthetized (local or general, as the case may indicate), the wound washed with sterile salt solution, all bleeding points caught and tied, and all severed structures appropriately sutured so that the normal anatomical conditions are reproduced. The skin, etc., is then closed in layers with fine horsehair for the skin, and the wound is dressed with sterile dressings, etc. If ideal conditions can be carried out, drainage is unnecessary unless the wounds involve the trachea, esophagus, or rectum, and repair will proceed as in an operative wound.

Irrigation of the wound by any form of chemical antiseptic is to be condemned. Should the operator doubt the wisdom of immediate closure, the wound had better be left wide open and closed after reaction has set in, rather than to resort to doubtful attempts at chemical sterilization, which are more apt to injure the tissues than to kill any germs which may be present.

Should infection occur, the wound should be widely opened, dressed with saline solution, and kept wet. (For further details, see Infectious Wound Diseases.)

PUNCTURED WOUNDS.—Punctured wounds comprise a group of wounds in which the skin opening gives no idea of the depth of the wound. Punctures are produced by a large variety of implements and vary extensively in their character, for example, pin pricks, nail wounds, stab wounds, wounds by spicules of glass, iron, etc., punctured wounds by insects, reptiles, various forms of animal bites, etc., all of which may be found in this group. Undoubtedly a large number of the minor puncture wounds never require surgical treatment, but a sufficient number result in infections of varying extent to make it wise to take precautions in all. Infections from these small pricks will decrease in number if the area involved is painted with tincture of iodin and temporarily protected by an alcohol dressing. All other puncture wounds should be converted into incised wounds and explored throughout. Under the proper surgical precautions, they may then be cleansed with salt solution, any foreign material removed, the nerves sutured, blood-vessels sutured or ligated, and the wounds closed with capillary drainage by a few strands of silkworm-gut introduced to the bottom of the wound. Wounds of the feet and where infection seems inevitable may be left open and drained by a small piece of rubber or rubber tissue. After 24 hours the drainage may be removed and the wound will heal like an incised wound. Infection is a rare exception in the cases thus treated.

Punctured wounds which involve the joints and tendon sheaths should be opened and treated as above, except that the wounds in these cases should be closed with drainage down to but not into the tendon sheath or joint.

Punctured wounds of the head, chest, abdomen, and any other regions are treated elsewhere in this book and are not considered here.

Probing and cauterization by strong chemicals can only do harm, and a drain shoved into a wound of the character described, through the small aperture in the skin, can do little but act as an irritant plug. The exceptions to the statement regarding cauterization will be found under the punctures produced by snakes, poisoned weapons, dog bites, etc.

**Contused and Lacerated Wounds.**—Contused and lacerated wounds are the result of blunt mechanical violence which bruises, tears, crushes, lacerates, or actually pulpifies the tissue. Extremities may be crushed or torn off, fingers or arms avulsed. The lesions vary extensively in type from small jagged tears, such as saw cuts, to those horrible injuries in which the body is actually cut asunder.

Among the injuries of this variety are found railroad accidents, injuries by vehicles and machinery, the injuries by building materials and explosives—in fact, the vast majority of the injuries of industrial life. The injuries may likewise be multiple and comprise injuries to the head, chest, abdomen, and extremities in a great variety of combinations.

The essential features in the treatment of such a complex group are: (1) The treatment of hemorrhage; (2) the combating of the shock; and (3) the prevention of infection. The remaining steps in the treatment comprise practically all of the surgical methods of traumatic and plastic surgery.

The treatment of the hemorrhage is placed first because in traumatic amputations and avulsions its rapidity and volume are especially dangerous. A tourniquet should be placed above the injury to compress the vessels. A hypodermic injection of morphin should then be given; the patient should be covered by blankets or other warm covering, and surrounded by hot-water bags or bottles, hot stones or bricks, in fact, anything hot which is available; and the wound should be covered by a sterile or clean dressing. If any hot tap water, coffee, or tea is available, a quart of it may slowly be introduced into the rectum through a funnel, catheter, rectal tube, or anything at hand which can be inserted into the rectum to permit of the introduction of the above fluids.

The patient is then transported, with the head lower than the hips, to a location suitable for the further treatment and the shock combated by intravenous saline infusion, hypodermoclysis, and hot rectal irrigation, as the condition demands. As soon as the patient reacts, further treatment, amputation, etc., may be proceeded with. In cases which show a slow reaction from the shock of the injury, the better procedure is to coat the injured area with the tincture of iodin, rapidly ligate the bleeding vessels, and postpone any further operative treatment until the following day.

In the less severe lacerations, the wound is cleaned with iodin, the skin shaved, all foreign material removed by picking it out or cutting away the tissues which it involves with a flat curved scissors. The wound is then thoroughly washed with saline solution, ragged, devitalized tissues are cut away, and the wound dressed wide open in copious, moist saline dressings and kept wet. Continuous saline irrigation or saline bath may also be used to advantage in certain cases.

In those lacerated wounds into which so much sand, lime, or grit is ground that its removal would cause too much tissue destruction, 4 or 5 drams of a mixture of iodin, 1; kali iodid, 2; guaiacol, 5; glycerin to 100, may be poured into the wound to increase the tissue reaction and prevent putrefaction.

When the wound becomes a granulating one, it may be closed by secondary suture, drawn together by adhesive plaster, covered by skin grafts, or allowed to granulate as the case may demand.

Small lacerated and contused wounds, especially those about the head and face, may be cleaned and loosely sutured. Especial care must be taken in the tying of these sutures not to tie them too tightly, since strangulation of the tissue will result.

Should any of the above wounds become infected, they should be treated as infected wounds (see below).

## POISONED AND INFECTED WOUNDS

### Non-Bacterial Wounds

**Wounds in Which the Resulting Symptoms Are Due to a Definite Chemical Poison.**—In one group of these wounds the resulting symptoms are referable to the action of a definite chemical substance, and the treatment to be instituted is to combat the action of these poisons by neutralizing or destroying them locally, and by such constitutional measures as are suitable to bolster up the patient until the crisis is passed.

INSECT BITES AND STINGS.—The bite of the mosquito, fly, tick, bedbug, etc., may convey certain special diseases as malaria, yellow fever, trypanosomiasis, etc., the treatment of which belongs to works on general medicine.

The resulting local reaction (itching, swelling, etc.) may be treated by the use of alkaline solutions, such as sodium bicarbonate and carbonate, dilute ammonia, aromatic ammonia, saturated permanganate of potash solutions, etc. On the face and about the lips and eyes the application of cold compresses of these solutions, especially the bicarbonate of soda, may aid in restricting the excessive swelling which is so apt to occur.

In old neglected wounds and ulcers, eggs may be deposited by flies and hatch into the larvæ (maggots) which permeate the wound in all directions. These may be removed by irrigation with dilute iodin, formalin, carbolic acid, or mercury oxycyanid solutions, and dressed with wet dressings of 1:100 permanganate solutions.

Should the bites of these insects become infected, they are treated as described under infected wounds (see below).

The Stings of Bees, Wasps, and Hornets (the Hymenoptera).—The local reaction of the stings of these insects is due to an acid which may be neutralized by dilute alkaline solutions. In emergencies, a moist poultice of mud or clay may be very effectual.

In bee stings, the barbed sting is usually left behind in the wound and should be removed. In severe cases with multiple stings, morphin and strychnin should be injected, and hot saline irrigations of the rectum given to combat the constitutional symptoms which may occur.

If the punctures become infected, they are treated as infected wounds (see below).

Spiders, tarantulas, centipedes, and scorpions produce local and general symptoms of varying intensity. The treatment should be constriction of the limb above the sting, free incision in the wound, and the application of permanganate crystals or strong ammonia to the wound.

Should constitutional symptoms occur, these should be treated by appropriate stimulation. Should infection or gangrene occur, these are treated by the measures detailed elsewhere.

SNAKE BITES.—The first essential is to determine whether the bite is that of a poisonous or a harmless snake.

If this is not possible from the patient, the character of the wound produced (i. e., the double uniform row of tooth marks in harmless snakes and the fang marks, double on each side in vipers, single on each side in the cobra, with or without tooth marks) will aid in determining the character of the treatment to be instituted.

The psychical symptoms in bites of harmless snakes are best treated by morphin injection and a local dressing of alcohol. When the patient awakes to find himself in the land of the living he will usually believe that recovery is possible and a cure may be expected.

Local Measures.—For the bites of poisonous snakes, energetic local and constitutional treatment must be instituted promptly. Local treatment after the first half hour is probably useless. A tourniquet should be placed above the site of the bite, i. e., on the proximal side, to prevent the absorption of the venom. The fang wounds should be opened widely and the venom cupped or sucked out.

Pure crystals of permanganate should be rubbed into the wound and a solution 1:100 of permanganate should be injected into the tissues about the wound (Mitchell); or 1 : 60 solution of calcium chlorid (Calmette); or 1 : 100 solution of chromic acid (Kauffman) injected into and about the wound. If these cannot be obtained, the wound may be cauterized by hot coals, red hot iron, a knife blade, pipe, bar, fuming nitric acid, etc. Mason suggests bandaging the limb from both extremities toward the wound, to squeeze out the venom.

Constitutional Treatment.—Whiskey, brandy, etc., may be given by mouth in repeated small doses. Hot coffee and tea should be given by mouth and rectum; 10 to 20 drops of dilute ammonia or aromatic ammonia may be injected intravenously.

Free lavage of the stomach should be practiced with dilute permanganate solutions to wash out the venom excreted into it and free catharsis may be resorted to in the more chronic cases.

Artificial respiration should be resorted to, and a pulmotor used, if available, for a long period.

Noguchi (15) states that antivenene should be used if obtainable, but that the success of treatment by this method requires an antivenene of greater potency than now exists.

WOUNDS DUE TO POISONED WEAPONS.—(See Johnson's Surgical Diagnosis (8) for varieties.) While the wound produced may be relatively insignificant, it is usually sufficient for the introduction of the alkaloidal poison with which the arrow or spear has been coated.

Treatment, to avail, must be prompt. The limb should be constricted above the wound, the wound freely incised, and the poison removed by sucking or cupping the wound. The wound should be irrigated with permanganate of potash solutions or pure crystals of that salt may be rubbed into the wound. The remainder of the treatment is symptomatic and is directed toward counteracting the symptoms as they arise.

**Wounds in Which the Resulting Symptoms Are the Result of the Action of a Specific Virus.**—VACCINATION.—The wound resulting from vaccination produced as a prophylactic against smallpox needs no treatment unless the local reaction is unusually marked, in which case moist dressings of saline solution, aluminum acetate, etc., may relieve the coincident pain.

HYDROPHOBIA.—The main wound disease of this group is hydrophobia. The essential feature in the treatment of this condition is the determination whether the animal which produced the wound has rabies or not. Rabies is not a common disease, and many of the so-called mad dogs are sick from other diseases. In the dog, at least, the symptoms are characteristic, if observed without undue hysteria.

Since rabies most commonly results from the bite of a rabid dog, the treatment of the bite of a suspected dog may be used as descriptive of the type.

In general, the wound or wounds should be opened widely and cauterized by fuming nitric acid, carbolic acid, iodin, or the actual cautery in the suspected cases and left wide open. Rambaud suggests mercuric chlorid (1:1000) as the best antiseptic.

The animal should either be killed and sent to a reliable pathologist for examination, or kept under observation in an enclosed kennel, if the former is not available, and observed by a competent veterinary to determine whether it has rabies or not.

Meanwhile the patient should, in cases in which any doubt exists or in which rabies was undoubtedly present in the animal, undergo the Pasteur treatment.

The Pasteur treatment consists in the injection of an attenuated virus of fixed strength, made from the spinal cord of rabbits dying of rabies, in gradually increasing doses, and extends over a period of 2 to 3 weeks. The theory is that this immunizes the individual against the disease. For the treatment the patient may be sent to the nearest Pasteur Institute or the set of vials required for the treatment may be obtained from a reliable firm producing the fixed virus for the treatment.

To be of value the Pasteur treatment should be begun before the symptoms of rabies appear. When these are undoubtedly present, treatment avails little, and is, as a rule, symptomatic. The patient should be placed in a darkened room and kept absolutely quiet; morphin and chloroform should be used freely from the start, and the patient should be forcibly restrained.

Care should be taken to destroy all clothing, sheets, gauze, etc., which have come in contact with the patient, by burning them.

## The Infectious Wound Diseases

The infectious wound diseases are those in which the resulting symptoms are due to the entrance of bacteria into the wound and their growth there, with (1) the dissemination of the micro-organisms from the portal of entrance by way of the lymphatics; or (2) the dissemination of a toxin with manifestations at a distance (tetanus, diphtheria); or (3) the production by the micro-organisms of changes in the tissue known as putrefaction, in which case the resulting symptoms are due to the absorption of the products of this putrefaction.

The general principles of any treatment for such infections are based upon the fact that the tissue reaction is insufficient to overcome the infection. In general the treatment should, then, be such that a free exit for the toxic products of the bacterial growth is provided (free incision); the local tissue reaction should be increased by hot moist dressings or cupping (active and passive hyperemia); the dissemination of the micro-organisms or their toxins should be prevented by increasing the constitutional resistance, by the regulation of intercurrent conditions, etc.; and, when it exists, the specific antitoxin should be given to combat the action of the toxic products of the bacteria.

The type of the infection in a wound determines its treatment. On page 681 is given a classification to form a working basis for treatment.

**Ordinary Wound Infections.**—WOUNDS INFECTED BY THE ORDINARY PYOGENIC BACTERIA.—Should a wound become infected, it should be freely opened, rubber dam or split rubber tubes inserted for drainage, and the wound dressed with saline solution and kept wet. A hot water bag may be placed against the dressing to keep it hot or a constant drip of hot saline solution may be allowed to fall on the dressing. If the wound is in an extremity, the extremity may be placed in a warm saline bath. When the acute necrotic process has subsided and the discharge begins to decrease, the wound may be dressed on alternate days with balsam of Peru and a solution of iodin, 1; kali iodid, 2; guaiacol, 5; glycerin, to 100, to stimulate the granulations. When the wound becomes healthy, it may be strapped or dressed dry.

LYMPHANGITIS.—Lymphangitis should be treated by a moist dressing, preferably of salt solution or aluminum acetate, and the part elevated. An ice-bag should be placed over the lymph glands which drain the infected area. Should suppuration occur along the course of the lymphatics (suppurative thrombolymphangitis), the foci of suppuration should be freely opened and drained and dressed as in the suppurating wounds.

LYMPHADENITIS.—Should the lymph glands become swollen and tender, they should be treated for the first 24 to 48 hours by an ice-bag, and after that by a hot water bag on top of moist dressing. Should the inflammation extend beyond the gland or the gland suppurate, it should be incised and drained and dressed, as in simple infected wounds.

The complete and radical excision of the lymph glands draining the infected area, especially in rapidly spreading infection, has been practiced, but it is based upon the erroneous supposition that the infection can be stopped by this means and has nothing to recommend it.

CELLULITIS.—When the infection enters and spreads along the deeper cellular lymphatic planes, these should be opened by appropriate incisions and drained and dressed as an infected wound.

ERYSIPELAS.—The treatment of erysipelas, when it occurs as a wound infection, has simplified itself materially in recent years. The disease is primarily self-limited, and attempts at limiting the disease locally by scarification, the injection of carbolic acid, etc., ahead of the disease, have little justification. Painting the infected area and a wide zone about it with the tincture of iodin is of doubtful utility. Probably the most comfortable local application consists in a cold moist compress of boric acid or 2 per cent. sodium bicarbonate solution to the involved area. This should be changed every few minutes and the part kept cool and moist.

Constitutional treatment should be instituted to meet the requirements of the case, and such intercurrent conditions as starvation, alcoholism, nephritis, diabetes, etc., treated by appropriate measures.

In general, water, lemonade, and fluids should be given generously. The patient should be sponged for temperatures above 103° F. and the bowels kept open. The diet should be fluid and high in caloric value.

Antistreptococcic sera, vaccines, etc., have proven of no value.

Patients with erysipelas should be isolated and care taken not to carry the infection. All attendants should wear rubber gloves while dressing these cases, and all dressings, etc., used in the case of erysipelas patients should be sterilized by immersion in formalin solutions or burned.

GASEOUS OR EMPHYSEMATOUS CELLULITIS.—When crepitation is found about a lacerated wound into which street dirt has been ground, the crepitant area and the tissue around and beyond it should be opened by long incisions and the wound and the line of incision irrigated with hydrogen dioxid solution, and the part dressed with dressings dripping wet with the peroxid solution.

Should the smears and cultures from the wound show the presence of the gas bacillus (Bacillus capsulatus aërogenes, Welch), especially if the organism occurs in conjunction with the streptococcus, great care must be used to prevent pocketing of the discharge. Unless free incision is made, this pocketing is bound to occur, and the infection will spread from this source along the contiguous lymphatics.

The subsequent treatment will depend upon the presence or absence of the gas bacillus in the circulating blood. Once the organism gains a foothold in the blood stream, such local treatment as amputation avails little. When the extremity is so badly lacerated by the original injury that its circulation is seriously interfered with, the early recognition of a gas bacillus infection and a prompt amputation are indicated.

When the laceration is extensive, without any definite injury to the main circulation, the treatment is that used for lacerations in general. Should the lacerated tissues show signs of extensive necrosis and the wound give a sweetish, fetid odor, with a grayish green surface, the patient should be anesthetized (gas and oxygen) and the whole wound filled with pure strength formalin solution. After 5 minutes the necrotic mass should be cut away, every recess of the wound opened, and the action of the formalin then neutralized by a 10-volume solution of peroxid. The wound may now be dressed in this solution. The essential feature in the treatment of this type of infection, in my experience, has been the prevention of pockets in which the anaërobic conditions suitable for the growth of the gas bacillus exist.

VARYING TYPES OF BLOOD INFECTION (BACTERIEMIA, SEPTICEMIA, SEPTICOPYEMIA, PYEMIA, ETC.) WHICH RESULT FROM WOUND INFECTIONS. —PREVENTIVE MEASURES.—Rigid surgical asepsis and the proper treatment and drainage of all injuries will reduce the above infection to a minimum.

LOCAL TREATMENT.—Any infected wound should be freely opened and proper drainage provided (see Wounds Infected by the Ordinary Pyogenic Organisms).

GENERAL TREATMENT.—The patient should be put to bed and, if the temperature is high or if there is marked delirium, sponged. The diet should be liquid, easily digestible, and of a high caloric value, and nourishment should be given at short intervals (every 2 to 3 hours). Those patients who can take a relatively large amount of nourishment show greater resistance to this type of infection and the vast majority of the recoveries from general blood infections of the surgical type will be found among such patients. Water, lemonade, etc., should be given freely, and the case treated symptomatically by strychnin, digitalis, whisky, etc.

SPECIAL FORMS OF TREATMENT.—Many other forms of treatment have been recommended, as follows:

1. *Intravenous injections of various antiseptics* (bichlorid of mercury, silver nitrate, colloidal silver, electrargol, formaldehyd solutions).—The purpose of these injections is to render the blood antiseptic and thus to inhibit the

growth of or to destroy the micro-organisms. All of the above antiseptics can be introduced in sufficient quantity to theoretically inhibit the growth of the micro-organism. Practically the only result of their introduction is an increased leukocytosis. In the human, blood-cultures in streptococcus infections show no change after repeated injections of any or all of the above chemicals.

2. A second type of treatment is suggested, which has as a basis for its existence the *increase of the bacteriolytic action of the blood* (a) by causing an increased leukocytosis, or (b) by increasing the opsonins in the blood-stream. The increase in leukocytosis may be produced by saline infusion, the injection of nucleinic acid, etc. The opsonins, etc., are increased by the so-called vaccine therapy, i. e., the injection of the dead bodies of the infecting micro-organisms, either autogenous (made from the culture obtained from the patient) or from stock cultures. (See Vol. I, Chap. VI, for complete exposition of the subject.)

3. *The production of chemical abscesses in suitable localities* (for example, the buttocks) by the injection of such substances as turpentine, zinc chlorid, formaldehyd solutions, etc. The purport of such treatment is stated to be the formation of abscesses in which a sufficient number of micro-organisms are destroyed to produce an autovaccination and an active immunization against the specific infection.

4. *The introduction of drugs by mouth, rectum, or inunction* to destroy the micro-organisms in the circulation (quinin, unguentum crede, etc.).

5. *Serum Therapy.*—Many forms of antistreptococcic sera have been prepared, but none have proven of any value.

It is probable that a lengthy search would reveal many more equally inefficacious forms of treatment. Of the above, only the vaccine therapy is of probable value, and that only in the hands of an expert. The indiscriminate injection of the stock cultures is not likely to do any good and may do harm.

**The Putrefactive Infections.**—The features essential for the development of putrefactive infections are (1) the presence of necrotic or sloughing tissue; (2) pocketing of the wound secretions; (3) the infection by putrefactive micro-organisms. (The chief micro-organisms of this group are the proteus vulgaris, the colon bacillus, and the anaërobic bacilli, of which the bacillus capsulatus aërogenes is the chief member; see gaseous cellulitis). (Here likewise may be grouped diabetic and moist gangrene, noma, and wound phagedena or hospital gangrene.)

It is difficult to group the treatment of conditions of such a wide etiologic organ. Since the resulting processes are all susceptible to the same general laws and differ only in the location of the process, such an attempt will be made.

Inasmuch as the presence of necrotic or sloughing tissue, that is tissue in which the circulation has been destroyed, is one of the main factors in the putrefactive infections, all sloughing and necrotic tissue should be removed by free incision to the normal tissue or by amputation as the case requires. Wide incision should be made into the adjacent normal tissue (when amputation is not done) and all pockets and recesses freely opened and drained. Since the majority of the infections of this type exhibit their most virulent form under anaërobic conditions the wounds should be filled with peroxid of hydrogen solution, dressed, and kept wet with this solution.

In those cases of gangrene in diabetes, in senile gangrene, and in traumatic gangrene which do not permit of immediate amputation, the part should be subjected to constant dry heat (that is, submitted to desiccation).

This may be done by passing a current of dry hot air, generated by a gas or alcohol flame over the involved area, which may either be left exposed to the air or covered with dry gauze and protected from the bed clothes by a suitable wire or wooden cradle with openings at both ends to allow the current of hot air to pass freely over the tissue. Later when demarcation is evident and desiccation is so far completed as to permit of the rapid removal of the dead tissue, amputation is indicated. Wet dressings are to be avoided inasmuch as the putrefactive processes develop rapidly under the influence of moisture and heat.

Noma and allied condition should be treated by excision by the actual cautery through the normal surrounding tissue (see face, etc.). For putrefactive infections in the uterus, penis, scrotum, perineum, and peritoneum, see the chapters devoted to these regions.

**Group of Wound Infections Due to Specific Micro-organisms.**—TETANUS.—Tetanus results from the entrance and growth of the tetanus bacillus in a wound. Due to its prevalence in street dirt and in the excreta of herbiverous animals, it is prone to complicate wounds received in locations likely to be contaminated by street dirt, manure, etc. The treatment of wounds likely to be contaminated by infection from the tetanus bacillus may be divided into two parts: First, the local treatment of the wound; second, the prophylactic injection of 1,500 units of tetanus antitoxin into the region proximal to the injury, that is, if a wound of the right hand, into the right arm; of the foot, into the leg, etc. This latter procedure is the most important of the two, and in view of the danger of tetanus, especially in blank cartridge wounds and lacerated wounds into which street dirt, etc., has been ground, its more extensive use would seem warranted.

When the manifestations of the tetanus infection become definitely marked, the treatment likewise becomes local and constitutional, and here again the latter is of the greater importance.

INTRASPINAL AND INTRAVENOUS INJECTION OF TETANUS ANTITOXIN.—Park and Nicoll (16) recommend the use of intraspinal and intravenous injections of antitoxin.

In every case of suspected tetanus, from 3,000 to 5,000 units of tetanus antitoxin should be given intraspinally through a lumbar puncture. The patient should be anesthetized, lumbar puncture done, and an amount of cerebrospinal fluid slightly in excess of the amount of antitoxin to be given should be withdrawn. To insure its dissemination, the antitoxin should be diluted to a volume of from 3 to 10 c. c., according to the age and size of the patient. The diluted antitoxin is then allowed to flow into the spinal canal slowly by gravity. In acute cases this procedure should be repeated in from 24 to 36 hours.

In addition to the above, from 10,000 to 15,000 units of tetanus antitoxin should be given intravenously, coincidently with the intraspinal injection. After a period of from 3 to 5 days 10,000 to 15,000 units should be given subcutaneously to insure a continuance of the highly antitoxic condition.

It does not lie within the scope of this article to discuss the merits and demerits of the various methods recommended for the use of antitoxin in cases of tetanus, but the above treatment of Park and Nicoll meets the conditions to be treated more satisfactorily and deserves a much more extended trial than the other less efficacious forms of treatment.

Intracerebral Injection of Tetanus Antitoxin.—Roux and Borrell (18) injected the antitoxin through a trephine opening into the brain tissue directly, believing that the toxin was more quickly neutralized by this method. As stated by Frazier (5), it is difficult to understand the rationale of injecting the antitoxin into the brain when the toxin acts chiefly upon the cord and medulla.

Intraneural Injection of Tetanus Antitoxin.—Marie and Morax (11) in their experiments on animals found that toxin was absorbed by the end plates of the nerves. Meyer and Ransom (13) found that the toxin was absorbed by the motor nerves and explained the period of incubation by the length of the nerve from the site of the original infection. They also found that the intraneural injection of the antitoxin into the nerve trunks which supply the area of the wound infection prevented the passage of the toxin to the cord; hence tetanus did not result. From this arose the intraneural injection of antitoxin into the nerve trunks. Rogers (16) was the first to apply this method clinically, but in his cases he likewise injected the antitoxin subcutaneously, intravenously and into the spinal cord, so that it is difficult to determine the relative value of this method from his clinical observations.

Other Therapeutic Measures.—Of the other therapeutic measures suggested in the treatment of tetanus, mention must be made of the carbolic acid treatment of Bacelli (1), the subdural injection of magnesium sulphate by Melzer (12), and the use of chloretone by Hutchings, 1909 (7).

*The carbolic acid treatment for tetanus* (*Bacelli*) consists in the subcutaneous injection of a 1 per cent. solution of carbolic acid until 80 gr. (5 gm.) have been given in the 24 hours. The results outside of Italy are not convincing.

*Subdural Injections of Magnesium Sulphate* (*Melzer*).—Melzer advises 1 c. c. to every 20 pounds of body weight in the adult male, 1 c. c. for every 25 pounds of body weight in the female, and in the child never more than 1 c. c. for every 25 pounds of body weight. Blake (3) considers it a reasonably safe means of relieving the pain and modifying the convulsions in the disease.

*Chloretone.*—Hutchings considers chloretone a very useful medicament in controlling a convulsion. It is given in from 30 to 60 gr. doses dissolved in whisky or hot olive oil—by mouth or rectum—and repeated sufficiently often to control the convulsions.

Local Treatment of Suspicious Wounds.—The local treatment of a suspicious wound, or one in a case in which the symptoms of tetanus are present, should be radical. Under an anesthetic the wound should be widely opened and disinfected with iodin or carbolic acid solutions, and freely drained.

In cases in which tetanus has developed, or in suspicious wounds, McFarland advises the use of a dry powdered form of tetanus antitoxin as a dusting powder for the wound.

The further treatment consists in the use of rest in a quiet room, the use of sedatives to control convulsions, together with chloroform inhalations in the severe forms. Care, however, should be used in not overdoing the use of sedatives. The nourishment should be fluid, and care should be taken to keep the bowels open.

WOUND DIPHTHERIA.—This is found, as a rule, secondary to nasal, throat, or laryngeal diphtheria. It occurs in many forms (see Knowles and Frescoln, 9, for types and literature).

Since the treatment is dependent upon the presence of the Klebs-Loeffler bacillus in the wound, it should wait for a culture made from the wound. When the Klebs-Loeffler bacillus is reported as present, from 5,000 to 20,000 units of diphtheria antitoxin should be given, depending upon the severity of the case. Locally the wound should be cleansed with peroxid and dressed with a moist alcohol or saline dressing.

Patients with wound diphtheria should be isolated, and all dressings, etc., which have been used should be burned.

ANTHRAX.—The essential lesion of the infection, as a wound disease, is the malignant pustule.

The treatment depends upon the recognition of the type of the infection before it has spread beyond the localized lesion. When seen early and recognized, complete radical excision of the involved area by the knife or cautery or both may be successful. If seen after the lesion has lasted for some days, excision is likely to avail little, as the blood stream is invaded early in the course of the disease.

Sclavo (18) advises the use of a serum prepared by actively and passively immunizing an animal, especially the ass. The dose suggested by him is 30 to 40 c. c. of the antitoxin injected into the abdominal wall at 3 or 4 different points. In severe cases the injection should be made intravenously and the dose repeated every few hours.

When the serum cannot be obtained and when excision is impossible or has been too long delayed, injections of carbolic acid, 1:20 (Strubel, 19), with hot moist compresses, may be used.

The general treatment should be dietetic and symptomatic, but in the absence of the serum, avails little.

GLANDERS.—This disease is transmitted to man from an infected animal, usually the horse, and the cutaneous lesions, i. e., the small superficial skin wounds, closely resemble chronic pyogenic infections. There is, however, usually an acute febrile disease (acute glanders), or the case may continue as chronic glanders as a result of the local infection.

Wounds, therefore, received by stablemen, etc., had best be regarded with suspicion, and, if a history of attention given to a sick horse is obtained, the wound area should be freely excised, cauterized with pure carbolic acid, and dressed with alcohol or with the iodin-guaiacol solution.

Chronic abscesses may form periodically, and these should be opened, cauterized by pure carbolic acid, and dressed with the iodin-guaiacol solution previously described.

In a case reported by me (6) an abscess on the arm appeared 8 months after the infection. This abscess, located on the radial side of the forearm, resembled a gumma, but the man's history made the diagnosis of chronic glanders possible, and the injection of some of the pus into a male guinea pig proved the presence of the bacillus mallei. The treatment above outlined produced a cure of the local abscess, and no others occurred during the succeeding year.

Mallein (Bonome, 4) may be used in the chronic cases.

TUBERCULOSIS.—Tuberculosis may occur as the result of wound infection from infected meat, or in post-mortem wounds.

THE ANATOMICAL TUBERCLE.—This result of local infection by the tubercle bacillus should be excised.

SYPHILIS.—Syphilis may result from wounds infected by instruments which have come in contact with a syphilitic. The recognition of the chancre and its treatment by calomel ointment, salvarsan, mercury, etc., need no further comment.

ACTINOMYCOSIS.—Actinomycosis occurs chiefly as an infection about the head and neck (mouth and teeth), the digestive tract, pulmonary tract or the skin. In the latter it may be present as an infection of a wound due to the presence of a foreign body, splinter, piece of straw, etc., in the wound.

The treatment of actinomycosis consists in excising the infected area when possible, cauterizing the area of the excision with pure carbolic acid, and dressing it with the phenol camphor solution of Chlumsky (phenol 30, camphor 60, alcohol 10). When the area cannot be excised, all the sinuses should be widely opened, cauterized with pure carbolic, and packed with gauze saturated with the iodin-guaiacol solution or with the phenol-camphor solution.

Potassium iodid should be given internally in large doses at broken intervals, i. e., the drug should be given for 1 week, then stopped for 1 week.

Bevan (2) recommends the use of cupric sulphate internally in from ¼ to ½ gr. doses thrice daily. He also advises irrigating the wound and sinuses with a 1 per cent. copper sulphate solution.

The further treatment is hygienic, and should consist in rest, fresh air, sunshine, and an easily assimilated diet of high caloric value.

MADURA FOOT.—Madura foot is closely allied to actinomycosis, and its treatment is similar to that described for the latter. Permanent cure follows the amputation of the involved foot.

BLASTOMYCOSIS.—(For literature, etc., see Lexer-Bevan, 10.) In the cutaneous cases, this disease has occasionally followed a local wound and may, therefore, be considered a wound disease.

When the disease remains a localized cutaneous infection, the entire lesion may be excised. Abscesses occurring in the generalized forms require incision and drainage. Radiotherapy may be tried in localized infections. Constitutional treatment consists chiefly in the administration of large doses of potassium iodid (600 gr. a day in some of Bevan's cases).

Bevan also recommends cupric sulphate in 1/4 gr. doses 3 times a day, and a dressing of 1 per cent. cupric sulphate solution as a wet dressing.

## BURNS DUE TO HEAT AND COLD, ACIDS, ELECTRICITY, AND LIGHT RAYS; POISONING BY CARBON MONOXID, ETC. ACCIDENT CASES PRODUCING MULTIPLE INJURIES

### BURNS AND SCALDS

The injuries produced by the various agents (thermal, chemical, friction, electrical, light rays) which cause the tissue injuries known as burns, are divided into three degrees—first degree, second degree, and third degree—according to the extent to which they involve the tissues.

In general the reaction in the tissues to the injury produced is greater than is required for the repair process, i. e., excessive reaction. This excessive reaction exhibits itself primarily as an excessive exudation of serum into the tissues which, in given localities, the throat for example, produces obstructive symptoms of alarming nature. The later excess in the tissue reaction produces an amount of scar tissue far in excess of that necessary for the repair of the injured area, hence the disfiguring scars and contractures so commonly found following burns.

The constitutional effects of these injuries comprise shock, edema of the brain, anuria, ulcer of the duodenum, and areas of toxic necrosis in the various solid viscera.

Hence the essential features in the treatment of burns must be directed toward the alleviation of the pain, the treatment of the shock, and the use of such local treatment of the burned surface as will tend to prevent the excessive tissue reaction above mentioned.

The treatment will of necessity be directed toward relieving those symptoms which are most pressing. That is, shock and pain in the extensive burns and tracheotomy in burns of the mouth with obstructive laryngeal symptoms, will need the most attention, while the use of merely local measures at the site of the injury will suffice when the constitutional phenomena need no attention.

**First Aid.**—The most useful application and one which can be obtained everywhere is a solution of baking-soda made by adding a heaping teaspoonful of baking-soda to a pint of cold water. This solution should be applied cold on clean cloths or cotton to the burned area and kept moist. The applications should be quite cool so that the excessive tissue reaction may be limited in so far as it is possible to limit it.

It has been my experience that those cases which have been treated by oil in any form, usually the abomination known as Carron oil, have taken longer to heal and have caused more discomfort than occurred when the soda solution was employed. Estes ("Keen's Surgery," Vol. VII) states that he has found that flour paste, oils, etc., are not desirable forms of treatment.

In extensive burns of the trunk and especially over the abdomen, the application of this solution *cold* is contra-indicated and in that case it should be applied after heating it (tepid application).

The patient should be given a cup of hot coffee, tea, milk, or even water and kept quiet.

**Local Treatment.**—FIRST-DEGREE BURNS.—The most comfortable application is something cooling. Many lotions fill that requirement.

The two which have given me the most satisfaction are cold compresses of sodium bicarbonate in one to two per cent. solutions, or one of the many forms of lubricating jellies put up in collapsible tubes under various trade names.

These should be applied until all the burning sensation has disappeared, when a bland oil, such as petrolatum or "cold cream" may be rubbed over the part to relieve the itching.

SECOND-DEGREE BURNS.—The most advantageous application to second-degree burns is a one-half to one per cent. aqueous solution of picric acid. The solution should be applied on sufficient gauze to make a firm moist compress and the compress moistened with cold sterile water for the first 12 hours, when it may be allowed to dry. When the burned area is large, the weaker solution should be used and a certain amount of judgment must be employed to determine just what amount of the body may be safely covered without symptoms of picric acid poisoning. In healthy adults little danger is to be feared unless more than one-third of the body is covered, while in debilitated individuals, and in the two extremes of age, the area should be restricted to one-quarter or less of the body area.

Should the above not be available, compresses wet with sodium of bicarbonate solution, or weak solutions of alcohol (25 per cent.) may be used. Blisters should not be opened at the first treatment. After the use of one of the above solutions for from 24 to 48 hours, the blisters which remain may be opened and the burned surface dressed in a variety of ways; that is, covered with silver foil, zinc stearate powder, or rubber tissue, or dressed in a moist saline compress.

When the irritant symptoms have disappeared and desquamation has begun, paraffin oil, cocoa butter, or one of the toilet cold creams will render the disquamation less annoying and relieve the itching.

THIRD-DEGREE BURNS.—The local treatment for this class of burns may be substantially that given for the second-degree burns or the burned surface may be dressed with moist saline solution. The main effort in burns of this type is to prevent, or at least to limit the amount of infection which occurs.

Two other rather different forms of treatment may be used to advantage in selected cases, namely the dry treatment and the continuous bath.

In the dry treatment the patient is placed naked on a sterile or a clean, freshly laundered sheet.

The bed clothes are placed on a cradle over the patient so that those portions of the body not resting upon the bed are entirely free from covering. The patient is kept warm by the heat of an electric stove, or more advantageously by the dry heat generated by a gas or alcohol flame passed under the bed covers by a suitably protected piece of stove pipe. The essential idea is to dry the serum discharging from the tissues into a protecting scab by this process of desiccation. It is necessary that the heated air should have an outlet at the upper opposite end from the site at which it enters the cradle.

[The electric hot air apparatus used by women to dry the hair is a safe and reliable substitute for the lamp.—EDITOR.]

In hot weather the heating apparatus may be dispensed with.

Various dusting powders have been used such as talcum, starch, zinc oxid and stearate, etc., to aid in the drying process. If used at all they should be dusted upon the sheet upon which the patient rests to aid in the absorption of the secretions. Elsewhere they are a hindrance rather than an aid.

Should too much secretion form or should the scabs become malodorous they may be softened by moist saline dressings and removed or the patient may be placed in a tub of clean water containing a little borax and the scabs washed off, when the drying process may be repeated.

The continuous tub (Hebra) is especially valuable in burns which involve the trunk, the axillæ, the buttocks, or the groin.

The water should contain sufficient salt to make a normal saline solution (teaspoonful to the pint) and the water should be kept between 95° and 100° F. and frequently changed. (The temperature should be regulated to suit the patient's comfort but the mean average temperature will be found between the figures given.) The patient should be kept in the bath until the exudation has ceased and reparative reaction in the tissues has been established. Those cases in which the tub bath is well borne usually do better than those in which the relaxation incident to the constant immersion causes cardiovascular and muscular depression. In the latter a combination of the wet and dry methods is often more efficacious than either one alone. In those cases in which the burned surface becomes infected this latter combined method is very efficacious.

**The Late Local Treatment of the Burned Area.**—This is largely dependent upon the area involved and includes practically all the expedients of plastic surgery devised to correct and relieve deformities, skin grafting, strapping with adhesive plaster, or the use of rubber tissue strips laid over the granulating area. If the area is near a joint or over an important muscular area, skin grafting should be resorted to as soon as possible. Cicatrices which break down and ulcerate should be excised and the area covered by skin grafts.

**The General Treatment.**—Morphin should be given hypodermically to relieve the pain. The shock should be combated by such measures as hot saline solution, water or coffee by rectum, or saline by hypodermoclysis.

In extensive burns water should be given freely by mouth preferably slightly acidulated by lemon or orange juice. In cases which cannot be made to take water in this way it should be given by proctoclysis by the Murphy drip. In many cases the two methods may be advantageously combined. It is important that the patient receive a large volume of fluid throughout the early stages of the treatment. The nourishment should be fluid with a high caloric value.

## Burns Due to Chemicals

**Burns Due to Acids.**—The action of carbolic acid may be neutralized by alcohol.

The caustic acids, sulphuric, nitric, hydrochloric, etc., are best neutralized by dilute alkalies. Care should be taken not to allow this process of neutralization to occur too rapidly as the heat generated may increase the degree of the burn.

**The Burns Due to Caustic Alkalies.**—The burned area should be washed with a dilute acid (vinegar or acetic acid preferably). After the process of neutralization of the chemical substance the treatment should be that advised under the local and general treatment of burns in general.

## Burns Due to Light Rays

**Sunburn.**—Mild degrees of solar burns may be treated by evaporating lotions or any of the lubricating jellies.

The severe forms should be treated by cold compresses of sodium bicarbonate or aluminum acetate solutions until the intense burning has subsided. Skin blebs should then be opened and the area covered by silver foil or weak picric acid solutions.

The late irritating itching may be relieved by a bland oil or a toilet cream.

**X-ray Burns** occur in two forms: (1) an actual burn, and (2) X-ray dermatitis.

The chief treatment should be preventive and all individuals repeatedly exposed to the action of the X-ray should be properly protected.

The operator should not expose himself to the direct rays unless his hands are protected by specially prepared gloves. **Preferably he should work behind a lead screen.**

Patients exposed to the X-ray for diagnostic purposes should not be submitted to long exposures. When patients are exposed to the X-ray for therapeutic purposes the rays should be administered through a suitable filter and the exposures made at suitable intervals.

When a burn occurs no further treatments should be given. The burned area may be treated by various light rays, as red light rays (Bar), and blue light rays (Kaiser).

The burns are painful. For the pain, aspirin, the bromids, codein, and morphin may be necessary. Due to the chronicity of the local process the opium alkaloids must be used with considerable caution. In 2 cases under the writer's care the involved area was excised and the raw surface skin grafted with most satisfactory results.

The X-ray dermatitis is best treated by excision of the involved skin area and skin grafting. Should the involved area show signs of epitheliomatous change amputation may be necessary.

Radium burns are similar to those produced by the X-ray but extend more deeply into the tissues and are more difficult to handle. The same treatment outlined for the X-ray burns is indicated.

### Injuries Due to Electricity. Electric Shocks, Burns, and Injuries Due to Lightning

Death after exposure to the high tension electric currents is usually due to the inhibition of the respiratory center. The affected individual should therefore be freed from contact with the current, the mouth opened and the tongue pulled out, and artificial respiration done. This should be kept up as long as the heart continues to beat. (In electric plants, or wherever high tension currents are in constant use, a pulmotor should be kept for this purpose.)

In shocks due to low tension currents, especially alternating currents, death is due to cardiac paralysis due to fibrillary tremor of the heart muscle and when this occurs treatment avails little.

Burns due to electricity depend upon the duration and degree of contact, dampness of the skin, etc., usually extend deeply into the tissues and, at the point of exit, frequently cause complete charring of the tissues, that is, a dry gangrene.

The treatment is substantially that of third degree burns. Amputation is indicated for those cases in which the part is killed by the current.

The constitutional and local effects of lightning are similar to those produced by the commercial currents, and the same statements apply to their treatment as to those given above.

For the late general symptoms, such as the psychoses, functional neuroses, epileptiform attacks, eye symptoms, etc., the reader is referred to the various works dealing with these diseases.

## THE EFFECTS OF COLD ON THE TISSUE

**The Treatment of Individuals Exposed to Low Temperature or Submersion in Cold Water.**—The patient should be placed in a cold room, artificial respiration performed, and the extremities rubbed with dilute alcohol solutions containing a little camphor. (Alcohol 50 per cent. with 1 per cent. camphor.) When the patient begins to react (reaction should be brought about slowly), the temperature of the room should be slowly raised and the patient given warm drinks of coffee, tea, or whiskey.

The local results of cold are divided into first, second, and third degree injuries as given under burns.

The essential features of the treatment for frozen tissues is to bring about a gradual thawing of the part and a slow return of the circulation in the affected extremity. This may be done by gentle friction with snow or the immersion of the part in ice water and gentle friction. As the circulation returns the temperature of the water should be slowly raised.

The resulting conditions after the thawing process are due to the reaction in the involved tissues.

The erythema (chilblain) must be protected from changes of temperature by warm covering. This may also be satisfactorily supplemented by the use of a protective coating of vaselin containing about 2 per cent. camphor. Fordyce ("Keen's Surgery," Vol. II) advises the use of a hot saturated solution of alum to relieve the venous congestion and itching.

When bullæ form (second degree) the part may be dressed with alcohol or 1 per cent. alcoholic solution of picric acid. The bullæ should not be opened until the second dressing. Should infection occur the part should be dressed with the above solution and kept moist. When gangrene seems imminent the extremities should be suspended.

In third degree frost bites with slough formation desiccation should be encouraged by dry heat, absolute alcohol, or dilute formalin solution and the part amputated when a line of demarcation has developed.

## THE TREATMENT OF ILLUMINATING GAS POISONING; CARBON MONOXID AND CARBON BISULPHID POISONING

Carbon monoxid poisoning occurs in two forms, each of which needs separate treatment, i. e., the acute form and the chronic form. Illuminating gas poisoning requires practically the same treatment and is included under this heading.

**Acute Carbon Monoxid Poisoning.**—The patient should be removed from the room or area which contains the gas, and artificial respiration done. A pulmotor should be used for this purpose if accessible. Oxygen inhalation should be given and generous doses of strychnin, caffein, etc., should be given hypodermatically.

Saline solution should be given intravenously and, in plethoric individuals, bleeding may be practiced from the distal end of the vein into which the saline solution is being injected.

In desperate cases blood transfusion may be done.

The chronic forms of poisoning such as occur in workers about electric furnaces, in brick and tile workers, the "miner's disease," etc., are treated by removing the patient from exposure to the gas, the use of hematinics to overcome the anemia, and an outdoor life in the fresh air and sunshine.

**Chronic Carbon Bisulphid Poisoning.**—This occurs in workers employed in making rubber goods.

The treatment should be largely preventive and workmen should be taught to use instruments for dipping the material into the bisulphid solution. Special means for ventilation should be employed to carry off the fumes from the bisulphid tanks and the workmen should be cautioned against inhaling the vapor.

When symptoms of chronic poisoning develop, complete removal from exposure to the bisulphid is indicated. An outdoor life with mild exercise and a generous diet, very largely fluid, are probably of the greatest value. Alcohol should be prohibited. The treatment otherwise should be symptomatic for the headache, constipation, and nervous symptoms. The local eczema should be treated by appropriate measures.

## THE TREATMENT OF ACCIDENT CASES, RAILROAD INJURIES AND OTHER FORMS OF MECHANICAL VIOLENCE PRODUCING MULTIPLE INJURIES

The detailed features of the treatment of such injuries will be found scattered throughout the entire work and such information as is not given here will be found under the various regional chapters and in Vol. II, Chapters I and II, Postoperative Care and Postoperative Complications.

The essential factor in the treatment of such injuries is the establishment of a temporary dressing station or the application of sufficient first aid dressings to protect the injured areas until suitable medical aid can be obtained or until the patient can be transported to proper surroundings for the proper surgical treatment.

It would seem wise to have workmen employed in pursuits which are inherently dangerous properly instructed, as are soldiers, in the application of first-aid dressings, the methods of stopping hemorrhage, and in the ways and means of immobilizing injured parts so that the patient may be transported without increasing the extent of the injury, and with a minimum degree of pain.

The first-aid treatment often determines the outcome of the injury and, as pointed out in the chapters devoted to the treatment of wounds and of fractures, meddlesome interference under improper surroundings with insufficient materials or experience usually means disaster to the injured individual.

It should be stated as axiomatic that no operative procedures should be attempted until the patient has been removed to suitable surroundings. Such treatment as is undertaken, whether it be lay or medical, should be limited to the protection of the wound, the stopping of hemorrhage, the temporary immobilization of the part, and the combating of the shock. This latter, the combating of the shock, must needs be largely medical in that drugs such as morphin, etc., given hypodermatically cannot safely be entrusted to the laity. The introduction of hot coffee, tea, or water into the rectum, surrounding the patient by hot water in such containers as are accessible or by anything that can be heated are matters necessarily subject to medical direction.

In general in accident cases of the severe type received in railroad accidents, crushing injuries, etc., the chief aim, after the patient is received into a proper place for treatment, should be treatment directed toward the shock. This consists in using all the methods elaborated in the chapter devoted to that subject, Vol. II, Chap. I, Postoperative Care, etc., and in many other chapters.

Hemorrhage should be stopped and where a tourniquet has been applied elsewhere this should be inspected and adjusted if necessary. A tourniquet should be placed close to the injured area or on the injured tissue if possible rather than at too great a distance from it, especially if it must be left in position for any length of time.

**In severe injuries with internal hemorrhage, the hemorrhage must of necessity be sought for by operation and only such operative steps carried out as are necessary to check the hemorrhage and prevent infection.**

**Idealism has a definite field in other realms of surgery, but any time-consuming operation, no matter what its theoretical merits may be, has no place in this particular field.** The urgency of haste and of as little interference as possible should always be kept before the surgeon. When the stage of reaction has set in and the patient has sufficiently recovered to bear the operation, then the ideal may be attempted if the existing conditions warrant it.

The above applies with special significance to traumatic amputations and to those complicated lacerating or crushing injuries of the extremities in which a surgical amputation is necessary. See also Vol. I, Chap. V, Contra-indications, etc.

It is wiser to tide such patients over their first crisis before shoving them into a state of further depression by additional traumatism no matter how skillfully conducted as to the surgical technic or equipment.

In accident cases into which street dirt, manure, etc., are ground into the wound a prophylactic dose of tetanus antitoxin should be given. (This is especially indicated in localities known to be infected by the tetanus bacillus.)

In all severe traumatic injuries special care should be taken to prevent infection, to drain all dead spaces, and to avoid any form of compression either by suture or dressing which will interfere with a free circulation through the part. Extremities should be elevated and exposed muscles, etc., protected by sterile saline dressings to protect them from the drying action of the air.

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# PREPARATION AND APPLICATION OF PLASTER-OF-PARIS DRESSINGS

# CHAPTER XVII

## PREPARATION AND APPLICATION OF PLASTER-OF-PARIS DRESSINGS

J. F. Cowan

### INTRODUCTION

Because of the ease and accuracy with which it can be moulded to the body, and because of its lightness, firmness, and rapidity of setting, plaster-of-Paris is the best material for use in making splints, casts, and jackets. For these reasons it is the most frequently employed material in the treatment of fractures. There are few fractures which cannot be treated satisfactorily at some period by the proper use of this material.

It has an extensive application in orthopedic surgery in the treatment of tuberculous disease of the bones and joints and after the correction of deformities. It is applied in the form of plaster-of-Paris bandages, which are employed in making the following forms of dressings: (1) moulded plaster splints; (2) circular plaster dressings.

### PREPARATION OF PLASTER-OF-PARIS BANDAGES

These may be purchased ready for use from various surgical dressing manufacturers, or may be easily and cheaply made by the surgeon, an assistant, or nurse. The plaster-of-Paris should be of good quality, dental casting plaster being the best. Good plaster will set in from 5 to 10 minutes. High-grade commercial plaster-of-Paris may be used, but is slower in setting.

The best material to use as a foundation for the plaster is crinoline. Ordinary commercial crinoline contains considerable sizing or glue, which makes it quite stiff. To render it more serviceable, this should be washed in lukewarm water, thoroughly rinsed and dried. Crinoline sized with starch is preferable. The crinoline is cut into strips, 4 to 6 yards in length, with widths of 3, 4, 5, and 6 inches respectively. In order to avoid frayed edges, threads may be pulled, and the crinoline cut along the space of the pulled threads. Loose threads at the edges of the crinoline strips should be pulled, as they interfere materially with the smooth rolling of the bandage.

The crinoline strip is now laid upon a flat, smooth surface. A handful of plaster is placed upon it and swept along with the hand or a light piece of wood with a straight edge, the plaster being thoroughly worked into the meshes of the crinoline. It is important in preparing the bandages to put just sufficient plaster into the crinoline to fill the meshes and to have it evenly distributed. This amount can only be learned by experience in making and applying the bandages. As the meshes of the crinoline are filled with the plaster, the bandage is loosely rolled. Tight rolling of a bandage prevents the water from reaching the inner layers.

The bandages are wrapped in papers, which are folded over the ends, and held by means of strings or rubber bands. They are then placed in an ordinary tin bread-box, or other can with a tightly fitting cap. If kept in a dry place, many bandages may be made at a time, and their efficiency preserved for a long period. Should the plaster become damp, the bandages are placed in a warm oven till thoroughly dry. Special apparatus have been devised for rolling plaster bandages, but the above method is equally easy and satisfactory. By the preparation of his own plaster bandages the surgeon can always get bandages of the desired length and width, and with the proper amount of plaster. They will be fresh and therefore set more rapidly.

## MATERIALS NECESSARY FOR THE APPLICATION OF PLASTER DRESSINGS

The following materials are required for the application of plaster-of-Paris dressings: (1) plaster-of-Paris; (2) plaster-of-Paris roller bandages; (3) crinoline; (4) sheet-wadding in large sheets; (5) sheet-wadding made into roller bandages; (6) flannel roller bandages, or seamless tricot material; (7) muslin roller bandages; (8) muslin for slings; (9) bass-wood splints, or strips of perforated tin; (10) strips of malleable iron; (11) adhesive plaster; oxid of zinc and moleskin; (12) knife with short stout blade for cutting plaster, and saw; (13) pair of heavy bandage scissors; (14) spica stand.

## PLASTER-OF-PARIS DRESSING FOR FRACTURES

After reduction of a fracture, some form of retentive dressing is applied to maintain the fragments in proper position. Plaster, properly applied, is the best retaining material. Whether applied in the form of moulded plaster splints or circular plaster dressings, certain general principles should be observed:

**General Principles to be Observed.**—(1) In all cases the skin should be cleansed with soap and water, followed with alcohol and a dusting powder. If blebs are present, they should be punctured and the exudate pressed out. These areas and abrasions should be dusted with boric acid powder, and an aseptic gauze pad applied.

(2) In general, the joint above and below the site of fracture should be immobilized, **care being exercised to prevent stiffness of the joint and atrophy of the muscles by early massage and passive motion.**

(3) The dressing should not interfere with the circulation of the limb, nor cause undue pressure on prominent parts of bones or prominent tendons. **Allowance should always be made for swelling, especially during the first few days after injury.**

(4) The patient and his attendants should be warned of these dangers, and should be instructed to watch the color, temperature and freedom of motion of the distal portions of the limb, which should always be left exposed by the dressing.

(5) After reduction of displacement and the application of a properly fitting plaster dressing, with immobilization of the fragments, pain is greatly relieved. Should the patient continue to complain of pain, especially if this is not at the point of fracture, but at the site of a bony prominence, or prominent tendons, the dressing should be loosened or removed at once. Ulcers, the result of pressure, may cause considerable trouble, and furnish atria for pyogenic organisms.

(6) The surgeon should see the case at least once a day for the first 3 or 4 days.

(7) A radiograph, while not essential for diagnosis of fracture in the majority of cases, should, whenever possible, be taken immediately after the application of the dressing, and a second one 10 days or 2 weeks later, to determine the result of reduction and retention.

**Preparation for Plaster Work.**—An objection to plaster-of-Paris is that it soils objects with which it comes in contact. To avoid this, certain preparations for plaster work should be made. This is especially important in private practice.

Above all the surgeon and assistants should do their work neatly as well as rapidly. They should have their forearms bared, and should be protected by gowns or rubber aprons. If these are not at hand, a sheet draped about the body will serve the purpose. The patient and bed should be protected by rubber sheets or bed sheets, and the floor by rubber sheets, bed sheets or newspapers. If the bandages are properly made, and wrung until they cease to drip, there will be little cause for soiling the surroundings. If, however, the plaster has been spattered on clothing or carpets, it should be left until it is dry before attempting to remove it. Spots on woodwork or furniture are removed while moist, or moistened if dry.

**Moulded Plaster Splints.**—If plaster-of-Paris is used as a primary dressing, it should, as a rule, be in the form of moulded splints which can be easily loosened or removed. Moulded splints are especially serviceable in the treatment of fractures of the arm, elbow, wrist, and ankle.

PREPARATION.—A flannel or sheet-wadding bandage, about 2 inches longer, and a little wider than the desired plaster splint is measured off on the part to which the dressing is to be applied. By having the length and breadth of the flannel or sheet-wadding bandage a little in excess of the plaster, the ends and sides of the latter are prevented from coming in contact with the skin and causing irritation. **A plaster roller bandage is then placed in warm water, without**

**the addition of alum or salt.** There should be sufficient water to cover the bandage when set up on end. Only one bandage should be immersed at a time. When all the air bubbles have ceased to escape, it is carefully lifted from the water by holding an end with each hand so as to prevent as far as possible the escape of the plaster.

The bandage is wrung until it ceases to drip. It is then rapidly and evenly spread upon a smooth surface to the desired length, and brought back and forth, each turn being smoothed by the hand, and the plaster thoroughly worked into it. From eight to fifteen turns are usually required, but the number will depend upon the thickness of the material used and the part to which it is to be applied. The flannel or sheet-wadding strip is placed upon the plaster splint, and the ends of the former folded over the ends of the latter. It is best not to spread the plaster upon the flannel or sheet-wadding bandage, as the latter should be dry when applied to the skin. Plaster splints may be reënforced by thin strips of basswood, or perforated tin, cut in proper dimensions and incorporated between the layers of the plaster bandages. By the use of these the weight of the splint may be reduced, while the strength is maintained. Reënforcement can best be used in parts where the plaster will not require much moulding.

APPLICATION.—The part is firmly held by assistants, and the fragments maintained in the correct position by traction and counter-pressure. The plaster splints are rapidly applied, moulded to the part by gentle pressure, and held in position by a muslin roller bandage. The part is carefully supported by the assistant, or by sand bags, until the plaster hardens. This dressing can be easily loosened to allow for swelling, thus lessening the danger of constriction, and can be readily removed when massage and passive motion are desired. As a general rule, a roller bandage should not be applied to the limb previous to the application of a plaster dressing, as it may interfere with swelling and do harm. Moulded splints may also be made by first applying a circular plaster dressing. When the plaster is set, it is cut through the entire length, laterally, or anteriorly and posteriorly. Anterior and posterior or lateral splints are thus made.

**Circular Plaster Dressings.**—A circular plaster dressing should rarely be used as a primary dressing in the treatment of fractures.

**Complete encasement of a part in plaster before swelling has occurred, exposes it to the dangers of constriction and subsequent gangrene or ischemic contracture, if swelling takes place after the application.** If applied while the limb is swollen, the subsidence of the swelling will leave the dressing loose, so that the fragments are not properly immobilized. Such conditions call for the removal of the dressing. The circular plaster dressing is the most serviceable dressing for fractures after swelling has subsided, and at a later period in cases of fracture in which treatment by continuous traction has resulted in a fair degree of union. It is also applied after open operations for fractures.

APPLICATION.—The limb is carefully raised by two assistants, one of whom makes steady traction in order to secure the full length and proper alignment;

the other supports the limb at the site of fracture. The surgeon applies a roller of sheet-wadding smoothing about the limb. This is made thicker over points of pressure and about bony prominences, and is made to extend beyond the limits of the cast, so as to prevent irritation of the skin by the ends of the plaster.

The first plaster roller should be carried from below upward, in spiral turns, never reverses, as far as it will go, completing the dressing once. Tucks are taken in the bandage posteriorly, so that the spirals will be evenly applied. The succeeding turns should go over this from beginning to end, care being taken to have the dressing of equal thickness throughout. In certain cases the dressing will require reënforcement at particular places. This will be described in the application of special dressings. The turns of the first layer of the plaster roller should be drawn just tight enough to retain them in place, and the succeeding turns applied without increasing the pressure. The turns, as they are made, are smoothed with the hand, always in the same direction, and the plaster thoroughly worked into them. They are accurately moulded to the prominences and depressions of the limb, thereby preventing subsequent movement of the limb within the dressing. Rubbing a large quantity of plaster cream into the turns as they are applied adds to the weight.

A plaster dressing should be as light as is compatible with strength. The weight of the dressing may be reduced by the use of strips of basswood, or perforated tin, incorporated between the layers of the plaster bandages.

After the completion of the dressing, the limb should be properly supported by the hands, or by sand-bags, until the plaster has become firm. This usually requires from 10 to 15 minutes. The dressing should not be covered with the bed clothing, but should be left exposed to the air, in order to effect a thorough hardening. The ends of the flannel or sheet-wadding bandage are brought over the plaster like a cuff, and are held by means of adhesive plaster, or by the last turns of the plaster as they are made. A circular dressing should always extend well above and below the site of fracture, and the fingers and toes should always be left exposed and carefully watched for signs of interference with circulation.

It is quite important that a radiograph shall be taken immediately after the application of a circular dressing for fracture, and a second one 10 days or 2 weeks later to determine the position of the fragments. If this is not possible, the dressing should be cut down and removed, and a careful examination of the limb made. The position of the fragments may be improved and the dressing readjusted, or a new one applied. If the dressing is to be replaced, the limb is protected by another flannel or sheet-wadding bandage, the dressing readjusted and held in position by several strips of adhesive plaster applied circularly about it. If swelling has subsided so that the dressing is loose, a greater thickness of protecting material is necessary. Whenever the dressing is removed the skin should be thoroughly cleansed.

**Fenestrated Plaster Dressings.**—In cases of laceration of the skin, compound fractures, or after operation, e. g. fracture of the patella, where dressing or inspection of the part is necessary; or when it is desired to relieve the pressure at a certain point, as in plaster dressings applied after the correction of club-foot, an opening or fenestrum is cut in the dressing before the plaster is dry. To make provision for the cutting of an opening a gauze compress, the size of the desired fenestrum, is applied over the wound. When the dressing is completed, an elevation on the surface marks the position of the wound and enables the surgeon to make the fenestrum in the proper position and of the proper size, and at the same time protects the wound. The edges of the fenestrum may be protected from the wound discharge by dental rubber or oiled silk.

**Interrupted Plaster Dressings.**—If the skin or soft parts have been extensively injured, as in certain compound fractures, or in cases of an infected joint, such as the knee, where the wound cannot be dressed through a fenestrum without weakening the dressing, or where injury to the deeper structures forbids any constriction or pressure, the dressing may be interrupted. This is done by incorporating one or two curved iron bands (Fig. 1) into the plaster in the following manner: The limb is covered with sheet-wadding or flannel bandage up to the lower limit of the part which is to be left exposed. The same material is then applied from the upper limit of the part to be exposed as far as may be desired. To these covered portions of the limb a few turns of a plaster roller are applied. A straight iron band, sufficiently long to extend well above and below the area at which the dressing is to be interrupted, is placed on the plaster opposite the wounded area, and is fixed in place by a few turns of the plaster bandage. One or two stout iron bands bent in the form shown above are next incorporated in the subsequent turns of the plaster, and the dressing completed. The limb is held in the desired position till the plaster hardens.

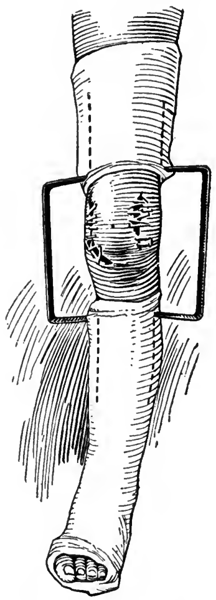


Fig. 1.—Treatment of Compound Fracture (Infected), Involving the Knee-joint. Two plaster casts, inclosing the thigh and leg, connected by U-shaped pieces of iron incorporated into the plaster.

**Plaster-of-Paris Spica for the Hip.**—The plaster-of-Paris spica is employed in the treatment of fractures of the femur, either as a primary dressing or after union has become fairly firm by treatment with continuous traction. It is used as a retentive dressing after the open method, in which the fragments are fixed by plate or wire. It has an extensive application in the treatment of tuberculous disease of the hip, and after reduction of congenital dislocation of that joint. The details are as follows:

Application.—The patient is placed upon a box or stand about 6 inches in height, and of sufficient size to support the head and upper portion of the trunk. A spica stand, well padded with layers of sheet-wadding, is placed beneath the sacrum. The extremities are supported by assistants. A folded towel, or several thicknesses of sheet-wadding, the so-called "dinner pad" is placed over the abdomen. The entire abdomen, pelvis, and whole or part of the extremity, depending upon the case, are covered with several thicknesses of sheet-wadding in the form of 4 or 6-inch roller bandages. Extra pads of the same material are placed over the crests of the ilia and symphysis pubis, the sacrum being protected by the pad on the arm of the spica stand. This pad remains in position after the removal of the stand.

With the limb held in the desired position by an assistant, the surgeon applies the plaster rollers, beginning at the pelvis. The bandage is carried around the pelvis, over the hip to the thigh, around the latter, and brought back to the pelvis in a figure-of-eight. After several figures-of-eight have been made about the hip, the bandage is carried down to the extremity in spiral turns. Spiral

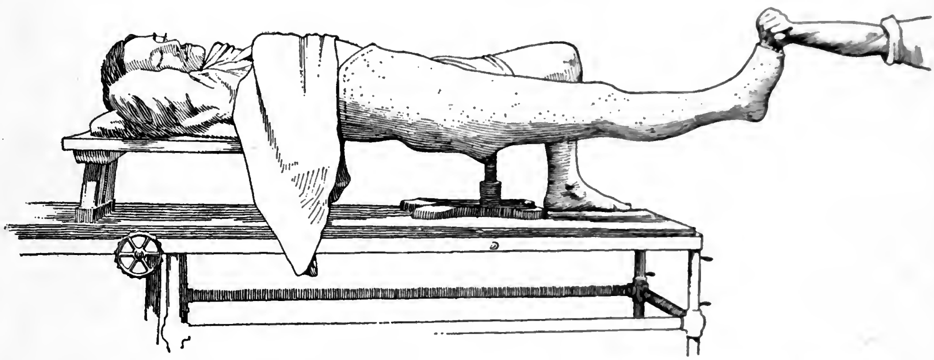


FIG. 2.—LONG PLASTER SPICA INCLUDING THE FOOT. Dressing for fractures of the femur.

turns, beginning at the pelvis, are carried upward about the abdomen, returned to the pelvis, and carried down the extremity. This is continued with spiral turns to the abdomen and extremity, and figures-of-eight about the hip until the dressing is of the desired strength.

The weak portion of the spica, over the groin, is reënforced anteriorly and laterally by layers of plaster rollers extending from well above the pelvis to the knee and incorporated between the layers of the spiral turns. Strips of basswood may be used in the same manner. The turns, as they are made, are smoothed with the hand, and the plaster thoroughly worked into them. After completing the application of the plaster, a semi-circular portion is removed in front by making a cut extending from the upper border at the sides to the level of the umbilicus. This, with the removal of the abdominal pad, gives more freedom to the respiratory movements. The edges of the dressing above and about the perineum are now trimmed. If the foot is included in this dressing, it should be well padded on the dorsum, and held in the right-angled position. If flexion is less, drop-foot will result, causing considerable difficulty in walking after the removal of the dressing.

**Removal of Circular Plaster Dressings.**—Several instruments have been devised for cutting plaster dressings. Of these, Stille's shears are most useful. The ordinary knife with a short, stout blade is, however, quite efficient. The plaster is moistened along a straight line with hot water, or $H_2O_2$, and cut through with a knife. There is diminished resistance to the knife when the lower layers of the plaster are reached. These with the sheet-wadding are cut with heavy bandage scissors and the sides of the dressing forcibly pulled apart.

**Removal of Plaster from the Hands.**—To prevent the plaster from sticking to the skin, one may thoroughly anoint the hands with vaselin before beginning the plaster work. After completion of the work, the hands are washed with soap and warm water, which leaves the skin soft and clean. If the hands have not been previously anointed with vaselin, they may be washed in a solution of sodium carbonate, a teaspoonful to a basin of water. Friction with granulated sugar or corn-meal may be used in removing the plaster. Rubber gloves may be worn.

## PLASTER-OF-PARIS DRESSING FOR SPECIAL FRACTURES

In the application of plaster dressings for fractures, it must be borne in mind that the function of the dressing is only to retain the fragments in the corrected position, and not to reduce displacement. Replacement of the fragments should therefore be made as complete as possible, and the limb should be held firmly in the corrected position both during the application of the dressing and the hardening of the plaster.

### EPIPHYSEAL FRACTURE OF THE UPPER END OF THE HUMERUS

The muscles inserted into the tuberosities draw the upper fragment upward and forward, so that the articular surface of the head looks downward. Further elevation is prevented by the impinging of the greater tuberosity on the acromion process. Codman (5) has shown that when the arm is rotated inward and abducted to the horizontal, the greater tuberosity impinges on the acromion process and prevents further elevation of the arm on the scapula, and that for further abduction, it is necessary to rotate the arm outward. The upper fragment, being rotated inward and drawn forward, is anatomically fixed in this position by the contraction of the muscles inserted into the tuberosity, and by the counter-impinging of the greater tuberosity on the acromion process.

In an open operation on one of these fractures, Albee (1), after wiring the fragments and attempting to bring the arm to the side, noticed that the upper fragment was so firmly fixed that it would not rotate downward, and the wire began to cut through. He therefore elevated the arm forward and slightly outward, with slight inward rotation of the humerus, and flexed the elbow at a right angle.

**Dressing.**—With the shoulder, arm, and forearm in the above position, a plaster-of-Paris spica is applied, reaching from the wrist to the waist. The patient is kept in bed during the first week after the application of the dressing, the weight of the dressing and the arm being supported by suspension. At the end of 3 weeks the dressing is removed, and massage and passive motion begun.

Fig. 3.—Plaster-of-Paris Spica Applied to Arm and Thorax.

### FRACTURE OF THE SURGICAL NECK OF THE HUMERUS

The action of the muscles tends to displace the lower fragment upward and inward, and to flex, abduct, and externally rotate the upper fragment. As in the epiphyseal fracture, the capital fragment is too small to be directly influenced by the splints. The lower fragment must therefore be brought into alignment with the upper. The dressing applied by Albee in the treatment of fracture of the upper epiphysis may be used in this fracture. Anterior and posterior moulded splints (Hitzrot, 8) forming a cap for the shoulder, with axillary pad, may be used also.

**Application.**—The forearm is flexed and supported at the wrist by a sling. A modified Stromeyer cushion is placed in the axilla and firmly held in position by a bandage over the opposite shoulder, and about the waist. The cushion should extend from the apex of the axilla to just above the internal condyle of the humerus, and should be broad enough at its base to bring the lower fragment into proper alignment. If the cushion is too short, there is danger of causing angulation of the fragments. It should be sufficiently firm to maintain its shape under pressure of the arm.

Strips of adhesive plaster are applied to the arm, extending from the level of the deltoid insertion to 6 inches below the elbow. These are held by an assistant, who applies traction, or a weight of from 5 to 10 pounds is attached to the ends. The posterior splint begins at the base of the neck and extends down the arm and forearm to the wrist. The anterior splint begins at the vertebral column, passes over the scapula and posterior splint above the shoulder joint, and down the arm and forearm to the wrist, the latter joint being left free. With the lower fragment appropriately abducted, traction is made upon the adhesive strips, and the corrected position carefully maintained by an assistant, while the surgeon applies and gently moulds the splints to the limb.

The splints are held in position by a muslin bandage extending from the wrist, with a spica to the shoulder. The latter aids immobilization and opposes overriding. If overriding occurs, the shoulder cap formed by the crossing of the 2 splints rises above the shoulder, so that the finger may be introduced beneath it. A weight attached to the adhesive strips or to a bandage over the elbow is useful to prevent overriding, or to overcome shortening which may have occurred. As the action of the muscles tends constantly to produce displacement, and as it is difficult to fix the upper end of the splints so as to prevent overriding, the dressing should be examined at frequent intervals and readjustment made when necessary. Points of pressure should be carefully watched, especially the nerves and vessels of the axilla, and the inner aspect of the arm. Massage is begun during the third week. The splints are removed at the end of the fourth week, and active and passive motion begun. The forearm is supported at the wrist by a sling for a week after the removal of the splints.

### FRACTURE OF THE SHAFT OF THE HUMERUS

Displacement of the fragments varies with the site of fracture. If the fracture is in the upper third of the shaft, the upper fragment is displaced inward by the action of the pectoralis major, and the lower fragment is drawn upward by the deltoid. In the middle and lower thirds, the upper fragment is drawn forward and outward by the deltoid, while the lower fragment is displaced upward and backward by the triceps. Reduction is accomplished by traction upon the flexed forearm and manipulation of the fragments.

**Dressing.**—The above described anterior and posterior moulded splints with axillary pad is an efficient dressing for these fractures, especially if there is a tendency to displacement of the fragments. The Stromeyer cushion should be about 3 inches wide at its base, so that the arm is but slightly abducted. A moulded plaster-of-Paris splint forming a cap for the shoulder may be used.

This dressing is prepared in the following manner: A pattern corresponding to the dimensions of the splint is made by placing a piece of muslin upon the shoulder, anterior, and posterior aspects of the chest, and outer side of the arm and forearm, and cutting it to fit the parts. The pattern is then laid upon the table, and from 6 to 8 thicknesses of crinoline are cut to correspond. These are soaked in plaster cream and laid one upon the other, the plaster being thoroughly worked into the meshes by the hands. Six-inch plaster rollers may be used instead of the pieces of crinoline. These are unrolled back and forth over the pattern until the desired thickness has been secured. The edges are trimmed with scissors to correspond to the pattern. Several layers of sheet-wadding, a little larger than the pattern, are prepared, and the splint placed upon these. A firm axillary pad, giving slight abduction to the arm, is applied, and the forearm is supported by a sling at the wrist.

With the limb firmly supported by an assistant, the surgeon applies the splint and gently moulds it to the parts. It is held in position by a muslin bandage about the forearm, arm, and chest, the opposite axilla being protected by sheet-wadding. *This* dressing does not exert active traction upon the lower fragment and its application is therefore limited to cases in which there is little tendency to displacement. The dressing should be removed once a week, and the parts carefully examined. If displacement has occurred, it should be corrected if possible. As the swelling subsides it is necessary to replace the splint with a new one. The fluoroscope is a valuable adjuvant in the application of the dressing to these fractures.

Massage is begun during the third week. Union is usually firm in from 3 to 4 weeks in children, and in from 5 to 6 weeks in adults. Removal of the splints will depend upon the solidity of the callus. Delayed union, the result of improper fixation of the fragments, is quite apt to occur in these fractures.

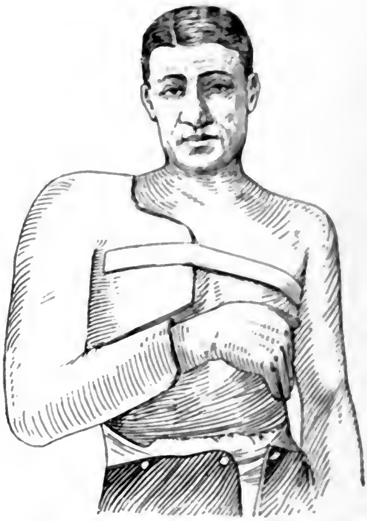


Fig. 4.—Moulded Plaster-of-Paris Splint for Use in Treatment of Fractures of Shaft of Humerus.

After the removal of the moulded splints, coaptation splints of basswood are applied, or those portions of the moulded splints applied to the arm are left. Coaptation splints are worn for one week, the sling used for one week after all dressing has been removed.

In fractures of the shaft of the humerus, a careful examination should be made to determine whether injury to the musculo-spiral nerve has occurred. This injury is most common in fractures of the middle third. If the injury is not determined at the time of the application of the splints, but later upon their removal, the cause of the paralysis cannot be readily determined, and the patient may attribute the result of injury to faulty application of the splints.

## FRACTURES OF THE LOWER END OF THE HUMERUS

Because of the proximity to the joint, it is most important to secure accurate reduction of the fragments, and to fix these, so as to prevent the two common forms of displacement, viz., overriding and lateral angular deformity. There is considerable diversity of opinion among surgeons as to the position in which the elbow should be placed in the treatment of these fractures. As a general rule, however, the position of the forearm on the arm, in a given fracture, should be that in which it is found by manipulation that the fragments are best retained in position after reduction. The following positions are employed: (1) acute flexion; (2) flexion at a right angle, or slightly beyond; (3) extension.

In supracondyloid fracture, fractures of the internal epicondyle, fracture of internal and external condyles, acute flexion reduces and retains the fragments in position.

**Supracondyloid Fracture.**—Of the two varieties, flexion and extension fractures, the latter is the most common. In this fracture the lower fragment is displaced backward and upward. Reduction is accomplished, under anesthesia, by hyperextension of the elbow, traction on the forearm, counter-traction and pressure backward on the upper fragment, and flexion of the elbow.

In the acutely flexed position, the untorn periosteum on the posterior surface of the humerus, and the triceps, together with the fasciæ posteriorly and laterally, hold the fragments reduced. In this position also the forearm prevents forward riding of the upper fragment by the pressure exerted on the latter by the parts within the flexure of the elbow. Lusk (11) has shown in an X-ray of one of these fractures that, in extreme flexion, the coronoid process of the ulna can impinge against the anterior margin of the lower end of the upper fragment and prevent anterior displacement. The degree of flexion which can be used will depend upon the amount of swelling of the soft parts. If this is marked, the flexion must be less.

DRESSING.—The circular plaster dressing described by Lusk is applied in the following manner: A layer of absorbent cotton is placed between the skin surfaces at the flexure of the elbow. A flannel bandage is applied to the lower portion of the forearm and upper portion of the arm, the flexure of the elbow remaining free so as not to interfere with extreme flexion. A few turns of a plaster roller are applied about the wrist and upper portion of the arm separately, then about the two together, and made to include the elbow, which is protected laterally and posteriorly by sheet-wadding. The circular turns applied to the wrist and upper portion of the arm prevent the dressing from slipping; the turns including these two maintain flexion and prevent lateral displacement.

The *limb* should be inspected frequently during the first few days. The radial pulse is carefully watched for signs of compression of the vessels at the flexure of the elbow. The position gives some discomfort, but should not cause actual pain. The latter symptom indicates too great pressure, and calls for a decrease in the angle of flexion.

This dressing holds the fragments firmly in position, but acute flexion may itself cause an angular displacement by a tilting forward of the lower fragment. In cases where the swelling is marked, the angle of flexion must be decreased. Some surgeons prefer the position of flexion at a right angle, or slightly beyond it.

APPLICATION OF SPLINTS.—In this position, anterior and posterior splints may be applied. These are well padded with sheet-wadding and extend from the level of the axilla to the middle of the palm and dorsum of the hand. They are held in position by adhesive strips and a muslin bandage. The forearm is supported at the wrist by a sling. A posterior moulded splint combined with a U-shaped splint about the elbow (Hitzrot, 9) may be used. To prevent the gunstock deformity, the arm of the U over the inner side of the forearm is placed a little more upward than the posterior limb of the splint. The forearm is supported at the wrist by a sling.

The position of extension is an uncomfortable one. In some cases, however, because of the tendency to recurrence of displacement, it may be necessary. After a week or 10 days in this position, the elbow may be flexed to a right angle. Internal and external moulded splints are applied, extending from the axilla to the webs of the fingers. These are held in position by adhesive strips, and the entire extremity bandaged with a muslin bandage.

In the treatment of these fractures it is most essential to preserve the normal carrying angle, and in the application of splints the proper degree of abduction of the forearm must be maintained. If the normal angle is destroyed, it should be restored. A circular dressing extending from the axilla to the middle of the hand may be used also. Splints are removed once a week and re-applied. Massage is begun after subsidence of the swelling, the posterior splint being left in

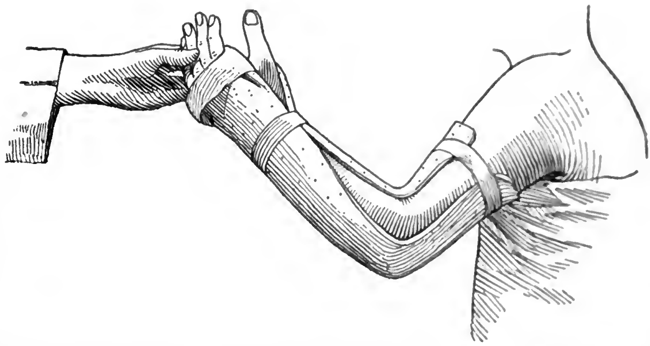


**Fig. 5.—Anterior and Posterior Plaster Splints Applied.** Dressing for fractures high up the forearm and at the elbow and lower portion of the arm.

position meanwhile. The splints are removed at the end of the fourth or fifth week, and passive motion begun. Function is usually restored, especially in children. In children, where there is no displacement, union is sufficiently firm in two weeks to permit of the removal of the splints. The forearm is supported in a sling at the wrist for another week. After removal of the splints, a firm bandage is applied to the elbow for support.

**Fracture of the Internal Epicondyle.**—Immobilization with the elbow in hyperflexion to relax the pronator radii teres and the superficial flexor muscles of the forearm, which tend to draw it forward and downward. This position is maintained until union is firm. Union is firm, as a rule, in 2 weeks in children. The forearm is carried in a sling for another week.

**Fracture of the Internal Condyle.**—In this fracture the principal point to be considered in the application of the dressing is the prevention of displacement upward of the lower fragment, thereby causing adduction of the forearm. In as much as the lower fragment is too small to be influenced directly by the splint, its position must be controlled through the ulna to which it is attached.

In applying moulded splints, the surgeon must exercise care to keep the fragment well down in position while the plaster is setting. If the right-angled position is used, the forearm is supported at the wrist by a sling. No pressure upward on the elbow is permitted. Union usually results in 3 weeks. The sling is used for 1 week after the splints are removed. Care should be taken not to force passive motion.

**Fracture of the External Condyle.**—It is often more difficult to reduce displacement of the fragments than to maintain them in the correct position after reduction has been accomplished. After reduction is made as complete as possible, the forearm is hyperflexed and a posterior moulded splint extending from the shoulder to the wrist is applied and held in position with strips of adhesive. If the right-angled position is used, anterior and posterior moulded splints are applied as in supracondyloid fractures.

**T- or Y-shaped Fracture.**—Because of comminution and displacement of the fragments, these fractures are quite certain to result in marked limitation of motion in the elbow joint. Reduction should be done under anesthesia. As a rule, the fragments are best held reduced by the acutely flexed position. In cases where there are considerable comminution and displacement, deformity, such as a widening of the joint, with anteroposterior thickening, is quite liable to occur. This results in limitation of motion. In these cases the forearm should be placed in the position which will give the best functional result if stiffness occurs. The elbow is flexed to a right angle, or slightly beyond, and anterior and posterior moulded splints, described above in the treatment of fracture of the surgical neck, are applied.

In applying these, they should be carefully moulded to the elbow joint and held firmly at and above the condyles while the plaster is setting. Splints are removed once a week and re-applied. Gentle massage is begun at the end of the second week, with the posterior splint in position. Splints are removed at the end of the fourth week, and the forearm is supported by a sling. The patient is encouraged to make slight active movements increasing the range of motion a little each day. Forced movements should not be made until the end of 5 or 6 weeks. Full use of the arm is not permitted until the tenth week.

**Separation of the Lower Epiphysis of the Humerus.**—The elbow is placed in the right-angled position, and anterior and posterior moulded splints, used in the treatment of supracondyloid fractures, are applied. Special precaution should be taken to prevent inward displacement of the lower fragment.

## FRACTURE OF THE OLECRANON PROCESS

As a rule, there is little separation of the fragments in this fracture. The periosteum, the lateral aponeurotic attachments and ligaments, and the extension of the insertion of the triceps along the lateral and posterior surfaces of the olecranon prevent this. Two positions of the forearm are used in the treatment of this fracture, viz., full extension and partial flexion.

Full extension gives closer apposition of the fragments, because, as Stimson (13) observes, the triceps cannot draw the fragment above the position which it takes in complete extension unless the ligaments binding it to the humerus are torn, a complication which happens only rarely. In cases where this is separation of the fragments, which is increased by flexing the elbow, this position must be used.

The degree of flexion which may be used will depend upon the amount of separation of the fragments. If this is slight, and is not increased by flexion, or if the fragments can be easily approximated by gentle downward pressure on

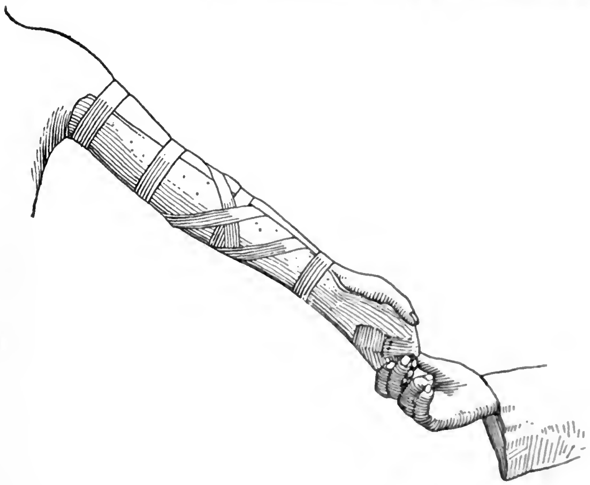


FIG. 6.—MOULDED PLASTER SPLINT FOR FRACTURE OF THE OLECRANON. Arm in extension. Splint held in position by adhesive straps. Note strap applied obliquely so as to drag downward on the loose upper fragment. Fingers are slightly flexed.

the upper fragment, this position, which is the more comfortable one, may be employed.

In either position an internal moulded splint extending from the axilla to the tips of the fingers is applied. The fingers are slightly flexed and pieces of sheet-wadding are placed between them to prevent chafing. The splint is held in position by 4 strips of adhesive, placed circularly about the limb, two above and two below the elbow. An obliquely placed strip of adhesive is so adjusted as to draw downward on the upper fragment. A muslin roller bandage is applied from the fingers to the axilla to prevent swelling of the hand. If the position of partial flexion is used, the splint is reinforced at the angle by additional layers of a plaster roller.

Massage is begun at the end of the second week, and slight active and passive movements during the third week. Union occurs usually in 4 weeks, the splints are removed, and the elbow is supported by a bandage.

## FRACTURE OF THE CORONOID PROCESS

With the forearm semipronated, the elbow is immobilized at a right angle, or an acute angle, depending upon the degree of displacement of the fragment by the brachialis anticus. Anterior and posterior moulded splints extending from the axilla to the wrist are applied and held in position with strips of adhesive. Light passive and active movements are begun during the third week, at the end of which splints are removed. The forearm is supported in a sling for another week.

### FRACTURE OF THE HEAD AND NECK OF THE RADIUS

If there is no marked displacement of the fragments, the elbow is flexed to a right angle or beyond, the forearm is placed in the position midway between pronation and supination, and anterior and posterior moulded splints, extend-

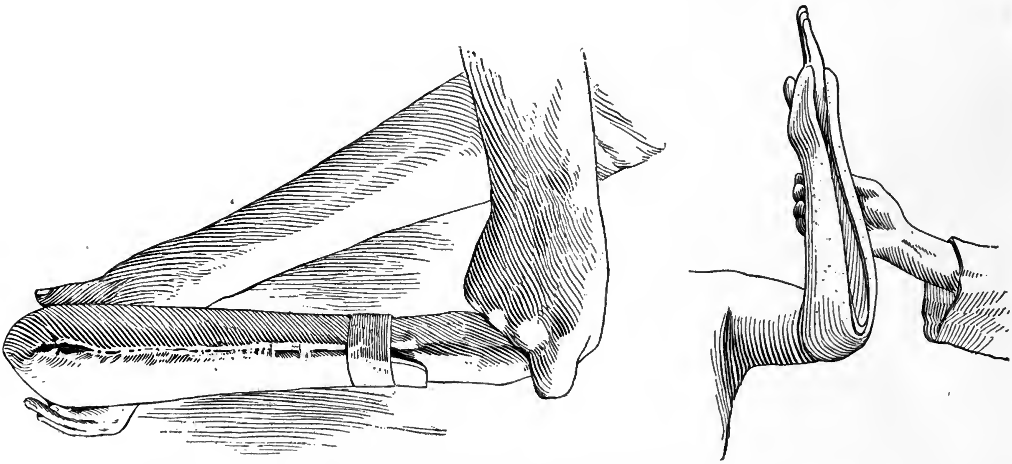


Fig. 7.—U-Shaped Moulded Plaster Splint for Fracture of Forearm.

ing from the axilla to the middle of the palm and dorsum of the hand are applied. The U-shaped splint may be used, as in fractures of the shaft of the radius and the ulna. The forearm is supported at the wrist by a sling.

Massage is begun in 10 days or two weeks. Union occurs, as a rule, in three or four weeks. The splints are then removed and the sling continued for another week. Attention must be paid to the movements of pronation and supination. They should be made passively at the end of the third week.

### FRACTURE OF BOTH BONES OF THE FOREARM

In these fractures it is quite essential to secure accurate reduction and retention of the fragments, for the movements of pronation and supination are easily interfered with, or lost by displacement or failure of union. Reduction is effected by traction, counter-traction and direct manipulation of the fragments near the seat of fracture, with the thumbs in front and the fingers behind.

The position of the forearm in most cases is that which is midway between supination and pronation. This is the most favorable for the following reasons: (1) When the radius is brought into semipronation (so that the thumb will point upward), the bones are most nearly parallel, and at the greatest possible distance from each other. (2) It is the natural position assumed when the forearm is suspended beside the body, with the elbow flexed at a right angle. (3) It is the position which affords most comfort.

With the forearm held in the above position, anterior and posterior moulded splints, extending from well above the elbow to the middle of the palm and dorsum of the hand, are applied. These are held in position by adhesive strips and a muslin bandage. The extension of the splints above the elbow joint gives better fixation and opposes shortening. A U-shaped moulded splint (Stimson) beginning at the middle of the palm, extending up the flexor surface of the forearm, about the back of the elbow, and down the extensor surface of the forearm to the dorsum of the hand, is an efficient dressing for these fractures.

The splints should be as wide as the most muscular portion of the forearm. Although union of the callus of one bone to that of the other is infrequent, it is most apt to occur if the splints are narrower than the forearm, thus pressing the bones together. A circular plaster dressing should not be used during the first week after injury. When swelling has subsided, this dressing may be used, special care being taken not to exert any lateral pressure. Gangrene or ischemic contracture is very apt to follow too tight application of splints in these fractures.

With the subsidence of the swelling, the splints may be made narrower by cutting away a strip along the entire length of the edge. The entire forearm is supported by a sling, the hand being left free.

The splints are removed once a week and readjusted. Massage is begun during the third week. At the end of the fourth or fifth week union is usually firm and the splints are removed. Passive and active movements are begun, special attention being given to the movements of pronation and supination.

### FRACTURE OF THE SHAFT OF THE ULNA

Reduction is made by pressure on the displaced fragments, traction being practically without value. Lateral displacement toward the radius is the most important, and this is corrected by pressing the thumb and fingers between the bones. As the radius acts as a splint to prevent overriding, the forearm is placed in the position of semipronation, and anterior and posterior moulded splints, like those used in fractures of both bones of the forearm, are applied. The forearm is supported in a sling, care being taken to avoid too great pressure upon the ulna. The after-treatment is the same as in fractures of both bones.

### FRACTURE OF THE SHAFT OF THE RADIUS

Displacement varies according to the seat of the fracture. Angular displacement, with the apex of the angle directed forward and inward, is the more common form. If the fracture is in the upper third, i. e., above the insertion of the pronator radii teres, the upper fragment is completely supinated by the biceps, while the pronator muscles displace the lower fragment inward and fully pronate it.

In fractures at or below the middle of the shaft, the upper fragment is drawn forward by the biceps and inward by the pronator radii teres, while the lower fragment is drawn toward the ulna by the pronator quadratus. Reduction is made by traction upon the wrist and by exerting pressure over the ends of the fragments. Pressure with the fingers and thumb between the bones may help to bring the fragments into the correct position. If the fracture is in the lower third, and the lower fragment is displaced inward, traction on the hand downward and toward the ulnar side may bring the fragment back into position.

If the fracture is above the middle of the bone, the forearm is held in the supinated position. If the fracture is below the middle third, the forearm is held in the position of semipronation. In each case the elbow is flexed to a right angle, and the forearm is firmly held by an assistant, while anterior and posterior moulded splints, used in treatment of fractures of both bones, are applied. The after-treatment is the same as in fractures of both bones. In fracture of the shaft of the ulna or radius alone, the same precautions as to the width of the splints should be observed as with fractures of both bones.

## COLLES' FRACTURE

In this fracture, the following displacements of the lower fragment may occur: (1) Toward the dorsal or extensor surface of the forearm, (2) toward the radial side of the forearm, and (3) there is often an axial rotation on an anteroposterior axis. Complete reduction is essential to prevent permanent deformity, and this is carried out in the following ways: (1) In the simpler cases, the surgeon grasps the patient's hand with his corresponding hand and makes traction, at the same time making direct pressure upon the dorsum of the lower fragment. (2) If impaction has occurred, a general anesthetic will be required for reduction. The fragments are grasped firmly between the thumb and fingers and the lower fragment freed from the upper by traction, backward, forward, and lateral movements, and pressed into place. Pressure is made upon the radial side of the lower fragment in order to correct the elevation of the styloid process of the radius, which is brought about by the rotation of the lower fragment on an anteroposterior axis. With the hand and forearm in semipronation, the assistant makes traction on the hand and holds the fragments in the corrected position while the surgeon applies anterior and posterior moulded splints.

These should be a little wider than the forearm in its most muscular portion and should extend from a little below the elbow to the metacarpophalangeal joint. A crescentic piece is removed from the outer edge of the anterior splint for the thenar eminence; a small wedge-shaped piece is cut from the inner edge of the posterior splint over the prominent head of the ulna. The splints are well padded with sheet-wadding.

Small retentive pads of gauze are sometimes necessary. The anterior of these is placed over the lower end of the upper fragment, the posterior over the dorsum of the lower fragment. While the plaster is setting, the splints are held firmly against the sides of the wrist so as to keep the radius and ulna together. These splints, accurately moulded to the forearm hand, retain the fragments and carpus in the corrected position better than any other.

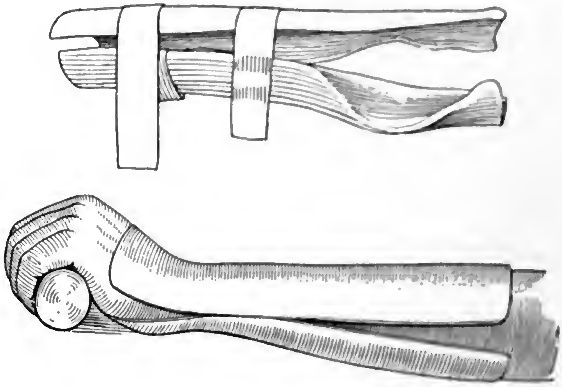


Fig. 8.—Moulded Plaster Splints for Colles' Fracture. (Stimson.) Note grooves for thenar eminence and head of ulna. Splints applied with adhesive plaster.

The forearm is carried in a sling adjusted to bear its whole weight. The hand rests free from upward pressure. The patient should be encouraged to exercise the fingers frequently, to prevent stiffness due to tenosynovitis. The splints are removed once a week and reapplied. Massage is begun during the second week, only one splint at a time being removed during this. Passive motion of the wrist is begun during the second week. Union is firm at the end of three weeks, and the splints are removed. The wrist is supported by a bandage or a leather bracelet.

In the treatment of a reversed Colles' fracture, the same splints are applied. There is a reversal of the retentive pads, the anterior one being placed over the lower fragment, and the posterior one over the lower end of the upper fragment.

## FRACTURE OF THE BONES OF THE HAND

A circular plaster dressing may be used in fractures of the carpal bones, or of the base or shaft of the metacarpals, but it is most efficient for fractures of the thumb. In fractures of the carpal or metacarpal bones, a circular plaster dressing extending from the webs of the fingers to two inches above the wrist is applied. In fractures of the bones of the thumb, the hand is covered with a cotton glove or flannel bandage, the thumb is extended and abducted and a plaster spica is applied. This should reach from the head of the metacarpal bones below to one inch above the wrist. Dressing is removed in 10 days or 2 weeks. Massage, douching and active motion should be used after this time.

## FRACTURES OF THE FEMUR

In fractures of the femur, complete encasement in plaster-of-Paris is used, as a rule, at some time during the course of treatment. The plaster spica may be applied after union has become well advanced by treatment with continuous traction, as in the older methods. It may be applied as a primary dressing in fractures of the neck, as recommended by Whitman, or in cases of fractures of the shaft, in which there is no displacement, or in which displacement can be corrected by traction, counter-traction, and manipulation at the time of the application of the plaster dressing. It is also used after the open method, in which the fragments are fixed by plate or wire.

**Fractures of the Neck of the Femur.**—That fractures of the neck of the femur are the most difficult fractures to treat is evidenced by the unsatisfactory results following the ordinary methods of treatment.

TREATMENT BY EXTENSION AND COUNTER EXTENSION: HODGEN'S SPLINT.—In this method of treatment, displacement caused by the weight of the limb and the action of the muscles is corrected by support equivalent to that destroyed by the injury. To this end, several forms of apparatus have been devised. Of these, the Hodgen's splint is the most convenient and satisfactory, for it gives more freedom of motion and is more comfortable to the patient. It is an especially serviceable splint in the treatment of fractures of the neck in elderly people who are too weak for the ambulatory method of treatment. It is used also in the treatment of fractures of the shaft close above the condyles, and in fractures of the middle portion of the shaft in muscular subjects.

The Hodgen's splint combines the principles of the double inclined plane and Buck's extension. It consists of a rigid iron or steel frame made in the form of the letter U. The outer bar is a little longer than the inner, and extends from the level of the anterior-superior iliac spine to 3 inches beyond the sole of the foot. The inner bar extends from the adductor longus tendon to the same level where the two are connected by a cross-bar. Above, the two bars are connected by a semicircular rod, which passes over the anterior surface of the thigh and is so placed that it is parallel to Poupart's ligament. The side-bars taper with the limb and should be 3/4 inch farther apart than the diameter of the limb at any point. The bars are bent at the knee to an angle of 130°. Two hooks are attached to each bar, one above, the other below. To these cords are fastened and brought over the limb to a traction cord which passes through a pulley attached to an upright at the foot of the bed. To the traction cord a weight is attached. The adjustable Hodgen's splint shown in the figure is so constructed that the length of the side bars, the width between them, and the angle at the knee can be varied. The splint can therefore be adjusted to any limb and applied to either right or left side.

PREPARATION OF THE SPLINT.—Strips of flannel bandage 6 inches wide are cut in lengths, a little in excess of the circumference of the limb at the levels to which they are to be applied. These are applied to the side-bars in the following manner: The strips are passed over the bars with the free ends external. The lower end of the strip is brought up over the bar for an inch or more. The upper end is then folded over the lower, and the 4 thicknesses of bandage are made fast with safety pins. This makes a trough in which the limb rests. The strips should be so adjusted that the side bars will be a little below the level of the anterior surface of the limb.

Application of the Splint to the Limb.—The limb is shaved, and the skin thoroughly cleansed with soap and water followed by alcohol. Strips of moleskin adhesive plaster, which is stronger and less irritating to the skin than the ordinary adhesive plaster, are cut 3 inches in width and long enough to reach from just above the knee to four inches beyond the sole of the foot. Oblique cuts are made along the edges of these, so that they may be applied more readily to the part.

About 3 inches above the malleoli, the strips are cut obliquely on each side for one-third the width, and the sides below this are folded over each other so as to cover completely the adhesive surface. Similar strips are prepared for the thigh and made sufficiently long to reach from the trochanter on the outside and the adductor longus tendon on the inner side to one foot beyond the knee. Oblique cuts are made also along the edges of these strips. The adhesive surface of the strips is now heated over an alcohol lamp or moistened with ether, and the strips are applied to the leg and thigh respectively. A flannel or muslin roller bandage, beginning at the toes, is applied to the foot, ankle and lower 3 inches of the leg. It is then made to include the adhesive strips and carried up over the knee. About 3 inches above the knee it includes the adhesive strips applied to the thigh, and is carried to the upper portion of the latter.

The limb is now placed in the trough of the splint, and the sides adjusted. The traction strips applied to the leg are fixed to the cross bar at its junction with the side bar, care being taken to have the width of the cross bar sufficient to protect the malleoli from pressure by the strips. The ends of the strips applied to the thigh are brought over a spreader of sufficient width to prevent pressure of the strips on the condyles. A cord is attached to the spreader. The cords attached to the hooks on the side bars above and below are brought over the limb to the traction cord. The latter should be arranged so that it is 15° to 30° from the vertical, and the weight should be sufficient to lift the limb free from the bed.

The cord fastened to the spreader below the knee is passed over a pulley and a weight applied. To the suspension and traction afforded by the splint, there is additional traction in the line of the femur. The upright which supports the splint is fixed to the foot of the bed and arranged so that it may be swung outward to give the desired amount of abduction. When the limb is properly suspended in this apparatus, there are traction in the line of the femur, flexion at the hip and knee joints, and abduction of the thigh.

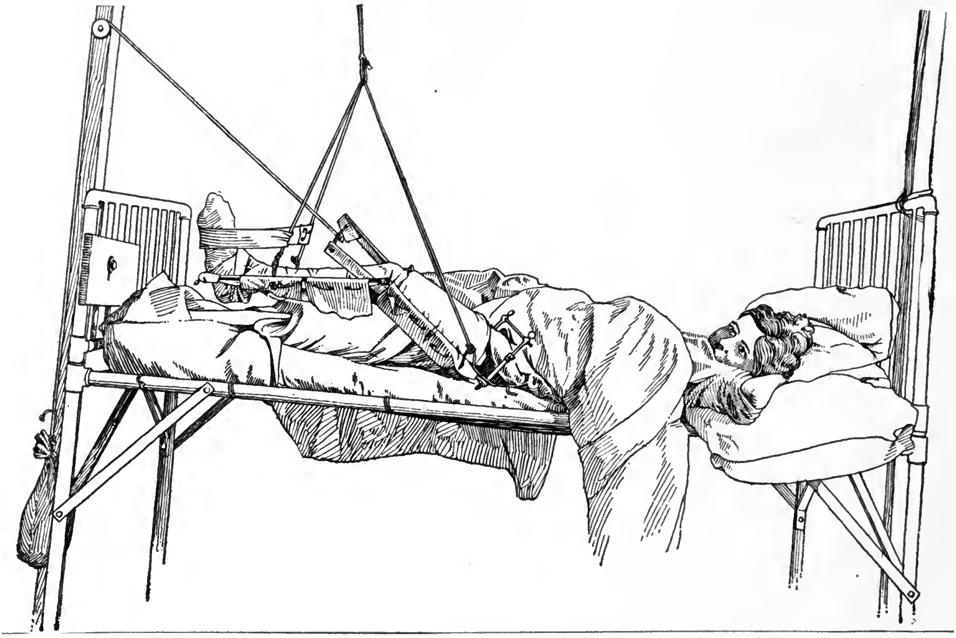


Fig. 9A.

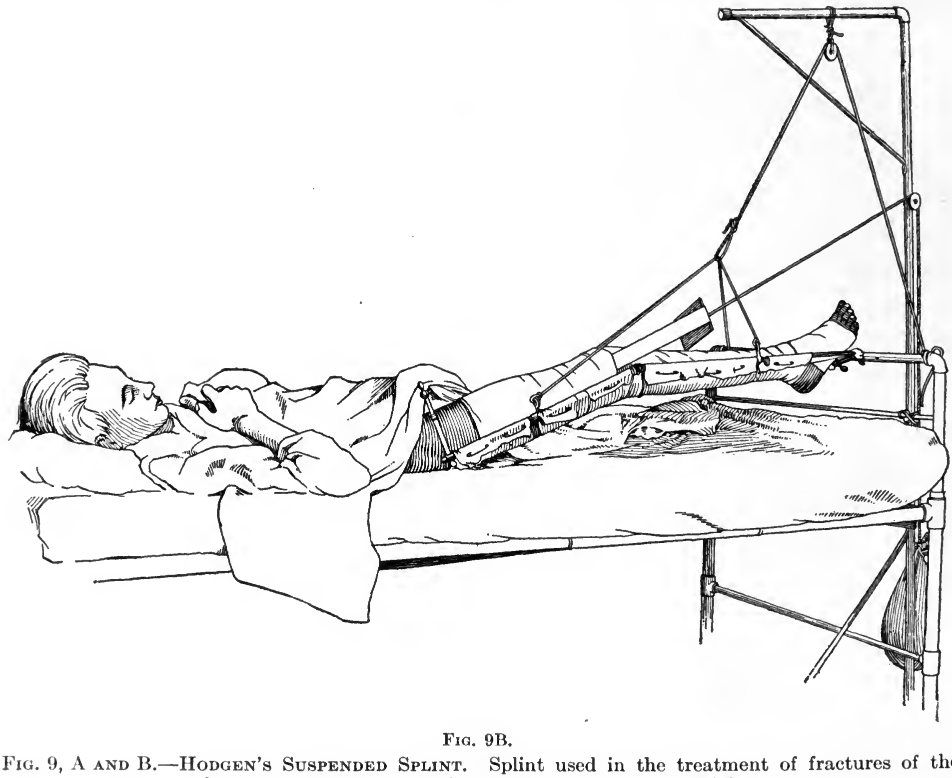


Fig. 9B.

Fig. 9, A and B.—Hodgen's Suspended Splint. Splint used in the treatment of fractures of the femur. Note traction on lower fragment in line of thigh.

Traction is measured and constantly maintained. The foot should be kept in the right-angled position, and the patient encouraged to exercise it daily. The splint requires watching and readjustment from time to time. The traction cords should be taut. Laxity of these indicates slipping of the splint. The bed should have a firm hair mattress and be supported by fracture boards beneath it to prevent sagging. The foot of the bed is raised 6 inches by blocks to secure counter extension. The draw sheet must be kept smooth, and the patient's back rubbed with alcohol and dusted with powder twice daily.

After 5 or 6 weeks, when union is fairly well advanced, the splint is removed, and a long plaster spica including the foot is applied. This is worn for 5 or 6 weeks. After the removal of the spica, a long external lateral moulded splint is applied. Massage and passive motion are begun with the removal of the spica. This is given every other day, and the knee and hip joints moved. At the end of the fifteenth week all dressings are removed, and the patient is permitted to bear light weight on the injured limb.

Unimpacted fractures of the neck may unite, but often remain ununited. Impacted fractures unite readily, but with deformity. In these latter cases, the neck of the femur is depressed, giving rise to the condition of traumatic coxa vara and, as impaction is most marked on the posterior surface, there is external rotation. The effects of the elevation of the trochanter are shortening, external rotation, and limitation of abduction and flexion. In the older methods of treatment, viz., by extension or immobilization, no special attempt was made to reduce the deformity, hence the resulting functional disability.

TREATMENT BY REDUCTION AND RETENTION: WHITMAN'S METHOD. —In fractures of the neck of the femur, in adults as well as in early life, Whitman (16) has recommended and employed the following method of reduction and retention, in which the affected limb is placed in the position of abduction, which as nearly as possible corresponds to the normal abduction of 45°.

CASES WITH IMPACTION.—The patient is anesthetized, and the pelvis supported by a spica stand. The sound limb is abducted to the normal limit to serve as a guide and to fix the pelvis. The assistant holds the injured limb and with gentle traction slowly abducts it. The surgeon, at the same time, supports the joint with his hands and presses gently downward upon the trochanter. When the normal limit has been approximately reached, a long, closely fitting plaster spica is applied, including the foot. In this method, the abducted position serves to reduce the deformity, without altogether separating the fragments and completely breaking up the impaction.

CASES WITHOUT IMPACTION.—If the fracture is complete, there is a marked tendency toward separation of the fragments. As a rule, the shaft is drawn upward, rotated outward, and displaced backward.

The patient is anesthetized and placed in the position described above. The limb on the injured side is slightly flexed and rotated inward to disengage the folds of the capsule that may have fallen between the fragments. Traction and counter-traction are made till the limbs are shown by measurement to be of equal length. The assistant then abducts the extended limb on the pelvis, which is fixed by full abduction of the opposite limb. The operator at the same time supports the joint and presses the thigh upward from beneath to force the fragments forward against the tense anterior wall of the capsule. When the trochanter is firmly fixed against the side of the pelvis, the long plaster spica is applied. "This is strengthened beneath the joint by a bar of steel or aluminum shaped like the Thomas' splint, in order to support the femur in a plane

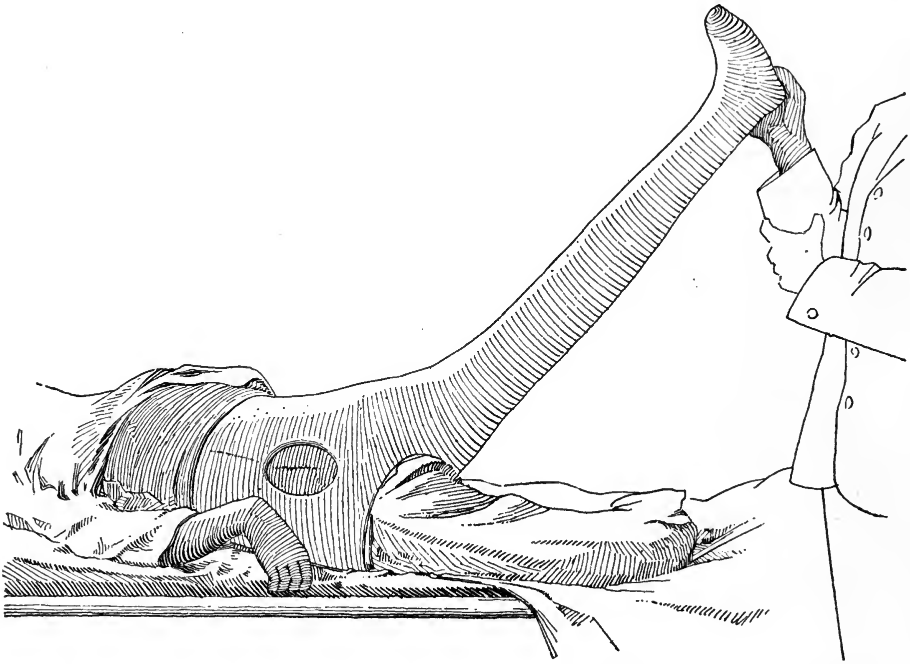


FIG. 9, C.—PLASTER SPICA FOR FRACTURE OF NECK OF FEMUR, LIMB IN ABDUCTION.

somewhat above that of the trunk, and to prevent it from sinking backward below the inner fragment." The outward rotation is corrected at the same time.

In complete and unimpacted fractures the abducted position adjusts the fragments and fixes them. The particular advantages of this position are:

(1) "When the extended limb is placed in complete abduction, the trochanter is firmly apposed to the side of the pelvis, so that upward displacement of the femur is impossible."

(2) "In this attitude the capsule is made tense; thus it should serve to direct the fragments toward one another."

(3) "The deforming influence of muscular contraction is removed, since

the abductor group is relaxed, while the contraction of the iliopsoas muscle in this position would draw the fragments toward one another."

**Subtrochanteric Fracture of the Femur.**—Displacement of the fragments in these fractures occurs as follows: The upper fragment is flexed and abducted, while the lower fragment overrides the upper and is slightly *adducted.* Because of the position and shortness of the capital fragment, it cannot be directly influenced by the splint, and the lower fragment must therefore be brought into alignment with it, i. e., must be placed in the position of flexion and abduction with traction. This alignment is most satisfactorily accomplished by the use of the Hodgen's splint, traction being made in the line of the elevated thigh. If this proves inefficient, open operation is indicated. After the splint has been used for from 4 to 6 weeks, or after the open operation, a long plaster spica is applied with slight flexion and abduction of the thigh and with slight flexion at the knee.

**Fracture of the Shaft of the Femur.**—In fractures of the shaft of the femur, without displacement, or in cases where displacement can be corrected by traction with the patient anesthetized, the spica may be applied at once. To effect reduction, and to maintain the fragments in apposition while the spica is being applied, the method described by Huntington (10) is quite serviceable.

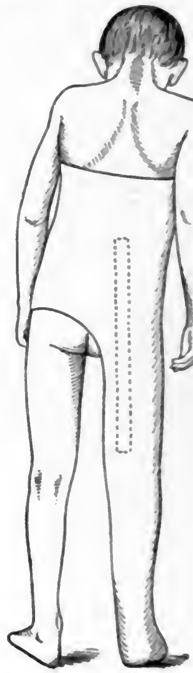


Fig. 10. — Plaster Spica for Fracture of Shaft of Femur.

"A skein of heavy woolen yarn is passed over each leg to serve as a medium for perineal traction. To each of these is attached a cord whose distal ends are tied to a ring in the end wall of the room. Another similar skein is applied to the ankle of the affected limb with a clove hitch. To this is attached a small set of pulleys, which in turn are anchored to the wall at the foot of the operating-table, and the pulley rope intrusted to an assistant."

While the steady pull is being made by the assistant, the surgeon manipulates the fragments to effect reduction. If satisfactory reduction is accomplished, a long spica is applied.

When the foot is to be included in the plaster dressing, adhesive strips may be used instead of the yarn. These are applied to the sides of the leg and thigh as high as the seat of fracture, and traction made upon them. They are included in the plaster and are cut off at the points of emergence upon completion of the dressing. In applying the long plaster spica, care should be exercised to have the anterior-superior iliac spine, mid-patella, and middle of the ankle in the same alignment as on the normal side. In cases where the above method fails to overcome muscular contraction, continuous traction must be applied.

For fractures of the middle two-fourths of the femur, Buck's extension with the Volkmann sliding rest is generally employed. If lateral displacement of the fragments is present, the lateral traction advised by Bardenheuer and Graessnera may be added.

In the application of Buck's extension, the adhesive straps are applied to the leg in the same manner as described for the Hodgen's splint, but are carried up to the seat of fracture. These are held in position by strips of adhesive placed circularly and spirally about the leg and lower fragment, or by a muslin bandage beginning at the toes. Beyond the sole of the foot, the ends of the traction strips are attached to a spreader with a weighted cord, the cord passing over a pulley at the foot of the bed.

Fig. 11.—Plaster-of-Paris Used for Fractures of the Shaft of the Femur or of the Neck of the Femur. (Davidson.)

While steady traction is being maintained, a long posterior gutter splint of plaster-of-Paris is applied to the thigh, and three coaptation splints, one placed anteriorly, one internally, and one externally, are added, and the whole held firmly in place by strips of adhesive plaster passed circularly about the thigh. A Volkmann sliding rest is next adjusted. The foot of the bed is raised six inches by blocks to provide counter-extension. The foot is kept in right-angled position by the footpiece of the rest, and sand bags may be placed along the inner and outer sides of the limb to give additional support.

Traction by sufficient weight prevents shortening. The weight must necessarily vary with the individual, the amount of resistance to be overcome, and the degree of longitudinal displacement to be corrected. The weight is increased gradually as the comfort of the patient will permit. Usually 15 to 25 pounds is required for adults. The effect of extension should be noted from day to day, and measurements made, until shortening has disappeared or has been reduced to a minimum. Slight abduction prevents outward bowing of the thigh, and the pulley over which the cord makes extension must correspond with the axis of the limb in this position. The Volkmann sliding rest prevents eversion of the foot, and therefore outward rotation of the leg with the lower fragment. The posterior gutter and coaptation splints prevent backward displacement of the fragments.

If lateral displacement of the fragments is present, traction in opposite directions upon the ends of the fragments is made by attaching bands to weighted cords which pass over pulleys, one on each side of the bed. At the end of 5 or 6 weeks, when displacements are no longer to be feared, the apparatus is removed and a long plaster spica, including the foot, is applied to furnish the necessary immobilization till union is complete. This is worn for 5 or 6 weeks, and the patient is then permitted the use of crutches. Massage and passive motion are begun with the removal of the spica.

**Supracondyloid Fracture of the Femur.**—In this fracture the upper end of the lower fragment is displaced backward, chiefly through the action of the gastrocnemius muscle. Because of this, treatment in the extended position is usually unsatisfactory. To relax the gastrocnemius, the leg is flexed, and the Hodgen's splint applied. The degree of flexion should be sufficient to bring the fragments into proper alignment. A pad placed behind the upper end of the lower fragment will assist in keeping the lower fragment lifted forward. After 4 or 5 weeks the apparatus is removed and a long plaster spica, including the foot, is applied. In the application of the spica, care should be taken to have the alignment the same as on the sound side. The patient is permitted the use of crutches. At the end of eight or nine weeks, union will usually be firm; the spica is removed, and massage, active and passive movements, are given daily.

**Fractures of the Shaft of the Femur in Young Children.**—Vertical suspension suggested by Schede is the most convenient and satisfactory method of treatment. Adhesive straps are applied to each limb as in Buck's extension and then attached to a spreader beyond the sole of the foot. The spreader is attached by means of a cord to a right-angled upright. Traction should be sufficient to lift the nates free from the bed. The counterweight of the body acts to correct overriding, and the sound limb serves as a splint to prevent angulation of the fragments. After 3 weeks, union is fairly firm, and a light plaster spica is applied, the foot being left free. This is worn for 2 or 3 weeks.

**Fractures of the Lower End of the Femur.**—These are (a) intercondyloid fractures, (b) fracture of either condyle, and (c) separation of the lower epiphysis. As in fractures of the lower end of the humerus, the chief objects to be sought are accurate reduction of the fragments and prevention of ankylosis of the knee joint.

INTERCONDYLOID FRACTURES.—These are T- or Y-shaped and extend into the joint. If the main fracture is not oblique, the tendency to overriding and angular displacement is not so marked, and the limb may be immobilized in the extended position by a long circular plaster dressing, extending from Poupart's ligament and including the foot. The plaster should be carefully moulded about the knee joint. If the main fracture is oblique, it may be necessary to employ traction. This is accomplished by the use of the Hodgen's splint, with the leg slightly flexed.

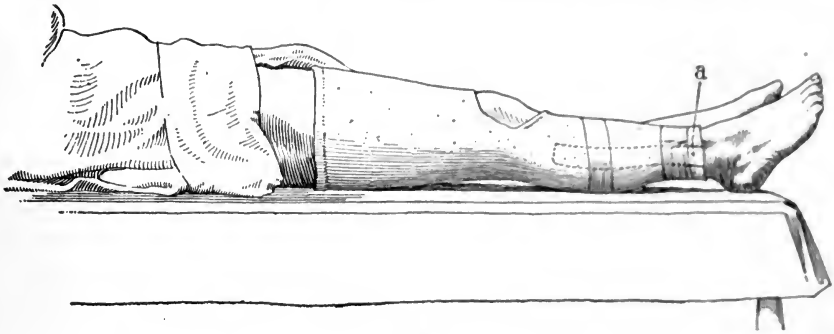
FRACTURE OF EITHER CONDYLE.—Displacement is usually slight. As the lateral ligaments are tense when the leg is extended, this position gives more security to retention. A circular plaster dressing is applied as in the intercondyloid fractures. In the application of the dressing in these fractures, special care should be taken to have the anterior-superior spine, middle of the patella, and middle of the ankle in the same line as on the opposite side. Early massage is an important factor in the treatment. To provide for this, a removable plaster dressing is made. Passive motion should be begun at the end of 4 weeks. The plaster dressing is used 8 or 10 weeks.

SEPARATION OF THE LOWER EPIPHYSIS.—If separation of the fragments is closed, every effort should be made to reduce the fragments without incision. As a rule, the lower fragment is displaced forward, the lower end of the upper fragment being drawn backward into the popliteal space by the gastrocnemius. Reduction may be accomplished by the method suggested by Reisman. The leg is strongly flexed, and traction is made upon the calf by an assistant, while the surgeon makes traction upward on the thigh and at the same time pushes downward with the thumbs upon the upper border of the displaced epiphysis. If reduction is successful, the leg should be flexed at a right angle, or an acute angle, and immobilized in a circular plaster dressing, extending from Poupart's ligament and including the foot. At the end of 4 weeks, the leg is gradually extended and a new dressing applied. This is removed at the end of the eighth week, and massage and light passive movements begun.

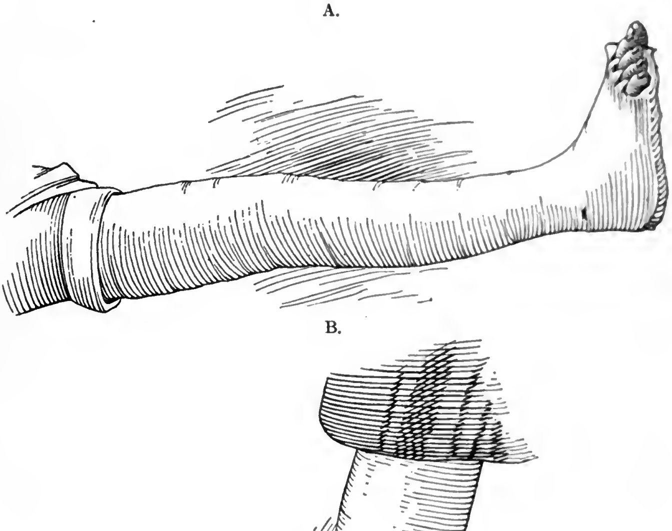
## FRACTURE OF THE PATELLA

The degree of separation of the fragments depends upon the contraction of the quadriceps extensor cruris, the extent of the rupture of the lateral aponeuroses, and the amount of distention of the joint by blood and synovial fluid. After absorption of the hemorrhage and effusion, the interposition of aponeurotic and periosteal shreds may prevent complete apposition of the fragments. An attempt to reduce the fragments should not be made until nearly all the fluid has been absorbed from the joint. In order to hasten absorption, the knee-joint is immobilized with the leg in the extended position upon a posterior moulded splint, extending from just above the ankle to the fold of the buttock. This should be wide enough to extend for a short way on to the sides of the thigh and leg, and should be moulded to the parts and held in place by a muslin bandage about the foot, leg, and thigh, the knee being left exposed. About the knee, an elastic bandage is firmly applied. If the limb is to be treated with massage, the muslin bandage is removed after the plaster has hardened, and the splint is held in position by adhesive straps passed circularly about the limb.

When the swelling has subsided, the limb is elevated in order to relax the quadriceps extensor muscle, and the lower fragment is fixed by an adhesive strap, an inch or more in width, placed across the lower margin with the ends carried upward and backward on either side to the back of the splint. The upper fragment is then drawn downward by traction with a similar strap passed across the upper margin and fixed to the posterior surface of the splint. This strap will need frequent adjustment. Adhesive straps cut in the form of a broad U will fit the part more accurately. To prevent tilting forward of the fragments, a third strap is placed across the knee over the line of fracture. As an auxiliary to the straps, the quadriceps is held firmly by coaptation splints. These are fixed in position by adhesive straps encircling the limb and posterior splint. When massage is given, the coaptation splints alone are removed.




A.



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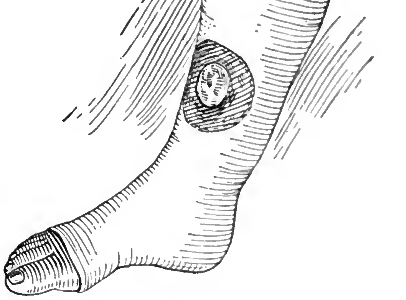

C.

FIG. 12.—CIRCULAR PLASTER DRESSING FOR FRACTURE OF BONES OF THE LEG. A, Fracture of the patella. Applied after open operation or after union has occurred by treatment with posterior splint and adhesive strap. Fenestrum over patella. Note adhesive strap, a, shown by dotted line to prevent slipping of dressing. B, Fracture of bones of leg. (Scudder.) C, Compound fracture of bones of leg. Fenestrum for dressing wound. (Scudder.)

At the end of 5 weeks union will be found and this dressing is removed. A light circular plaster dressing is now applied and the patient permitted the use of crutches. The circular plaster dressing applied in these cases, as well as after operation, should extend from the upper part of the thigh to about three inches above the ankle joint. To prevent slipping of the dressing, two straps of moleskin adhesive plaster, extending from above the knee to the sole of the foot, are applied to the sides of the limb. After several layers of plaster bandages have been applied, the lower ends of these straps are folded back over the end of the plaster and fixed by the subsequent turns of the plaster bandages.

This dressing should not be too heavy and should fit snugly. In the plaster dressing applied after operation, a fenestrum is made over the patella. In these cases, it is well to reinforce the dressing posteriorly by extra layers of plaster bandages applied longitudinally and incorporated between the spiral turns. If massage is to be given, a removable dressing is made by cutting the plaster along the median line in front before it hardens, and sponging it off the limb. Strips of leather supplied with lacing hooks are stitched to the edges. Passive movements are begun at the end of the sixth week. The circular dressing is removed at the end of the eighth week, and a light posterior moulded splint applied as protection against sudden accidental flexion of the knee. The knee should be protected for 6 months.

## FRACTURES OF THE TIBIA AND FIBULA OR OF THE TIBIA ALONE

In the treatment of simple fractures of these bones, the choice of a dressing will depend upon (1) the degree of swelling, (2) the amount of displacement, and (3) the ability to retain fragments in the corrected position after reduction.

In fracture of either bone without displacement, and with but slight swelling, a circular plaster dressing extending from the toes to the middle of the thigh may be applied. Before the plaster has hardened, it is cut down along the median line in front and held by means of adhesive straps passed circularly about the dressing. The toes should be watched carefully for signs of interference with the circulation.

If subsidence of swelling renders the dressing loose, a new one must be applied. At the end of 5 or 6 weeks union will be sufficiently firm to permit removal of the dressing. Massage, active and passive movements are begun.

In cases with swelling and displacement, reduction of deformity should be effected as early as possible, preferably under an anesthetic, by traction on the foot, counter traction on the thigh, with the knee slightly flexed, and by manipulation of the fragments at the seat of fracture. The subcutaneous crest of the tibia should be brought into line and the fragments carefully held in the corrected position while a posterior and a U-shaped moulded splint are applied.

The posterior splint begins at the toes, extends along the sole of the foot and posterior surface of the leg and thigh to the middle of the latter. The U-shaped splint extends from the middle of the thigh on one side, along the side of the limb around the sole of the foot, and along the opposite side of the limb to the same height. These are carefully moulded to the limb and held in position by a muslin bandage. After the plaster has hardened, the bandage is removed and the splints are held in position by adhesive straps or circular bandages, the crest of the tibia in the region of the fracture being left exposed so that examinations can be made.

At the end of 2 weeks the splints are cut so that the knee joint can be moved and massage is begun. These splints can be loosened to permit swelling, tightened as swelling subsides, and are easily removed when massage and passive motion are to be given.

In applying the circular plaster dressing or moulded splints, the patient is

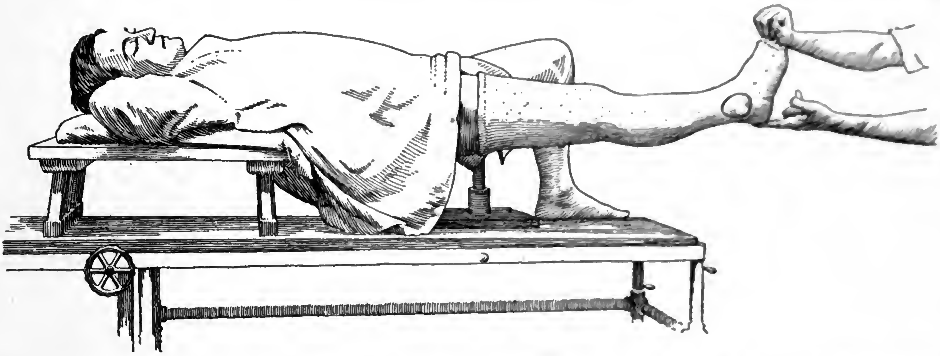

FIG. 13.—CIRCULAR PLASTER DRESSING FOR FRACTURE OF BONES OF THE LEG. Fenestrum over external malleolus.

placed so that the hips rest at the edge of the table, with the normal limb resting on a stool or chair. One assistant supports the heel with one hand, maintains right-angle flexion and slight adduction with the other and makes traction. A second assistant flexes the knee and supports the limb by placing one hand beneath the lower portion of the thigh and the other hand beneath the upper portion of the leg.

In cases in which there is comminution of the upper end of the tibia or in oblique fractures with displacement, where it is difficult to retain the fragments in position after reduction, continuous traction may be employed.

Instead of the fracture box and the dressing suggested by Niell, a plaster-of-Paris dressing with extension and counter-extension (Lovett, 12) may be employed.

The plaster dressing is applied in the following manner: The limb is shaved and the skin thoroughly cleansed. Moleskin adhesive straps are applied to the sides of the limb, extending upward and downward from the seat of the fracture. These are held in place by strips of adhesive passed circularly and spirally about the limb. The foot, leg and lower half of the thigh are inclosed in sheet wadding and a pad 2 or 3 inches in thickness is placed below the sole of the foot. A circular plaster dressing is now applied from the toes to the middle of the

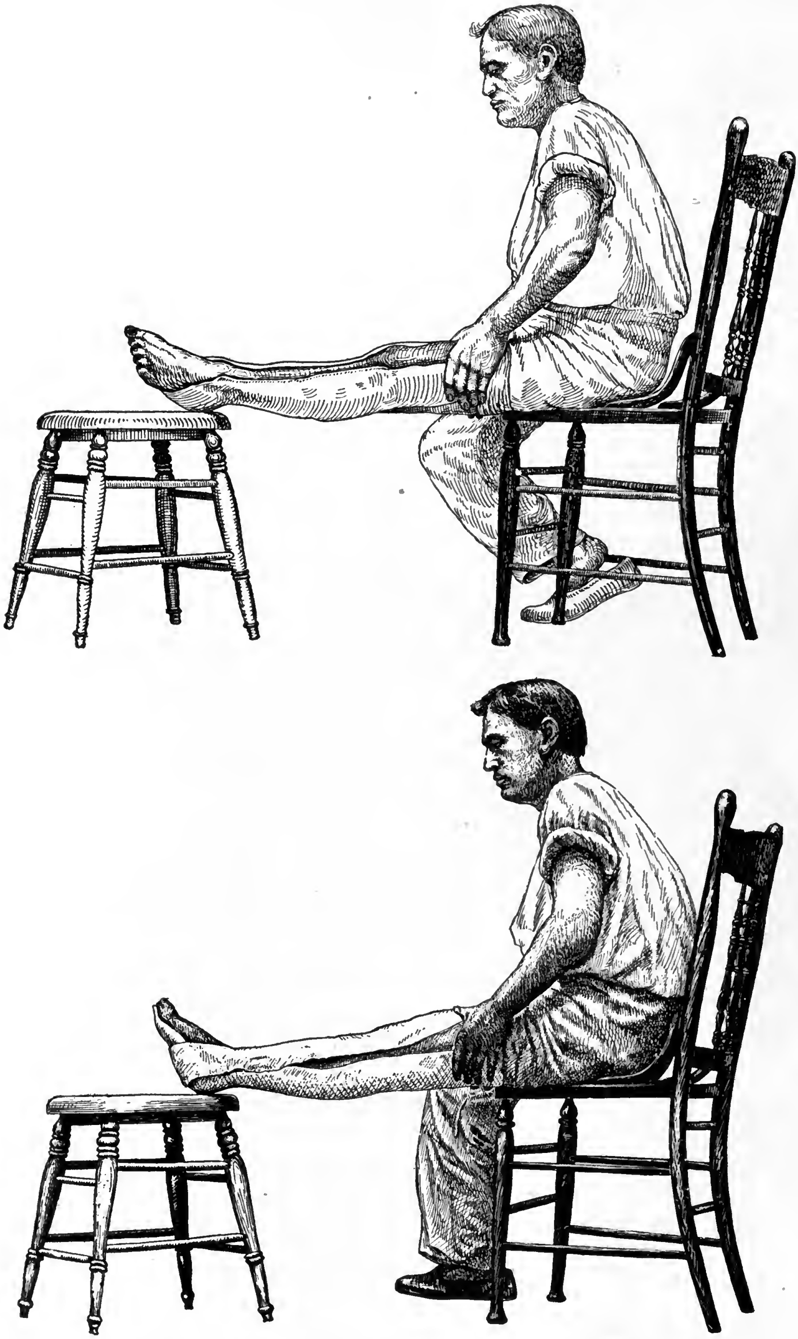

Fig. 14.—Posterior and U-shaped Plaster Splints for Fracture of Bones of the Leg.

thigh and straps supplied with buckles are incorporated in the sides about 3 inches from the upper edge. The lower straps are brought out above the malleoli. Before the plaster has hardened, a slit is cut on each side of the ankle for the lower straps and a fenestrum is made over the seat of fracture. After the plaster has hardened, the upper straps are brought over the edge of the dressing and firmly attached to the buckles. The lower straps are fixed to a spreader with a cord attached for traction. The pad below the foot is removed. After 2 weeks, this dressing is removed and a circular plaster dressing applied.

In fractures with considerable swelling and associated injuries to the soft parts, a temporary dressing is indicated.

As a substitute for the fracture box or Volkmann's trough splint, the stocking or bivalve plaster splint of Stimson (14) is quite useful. It is prepared in

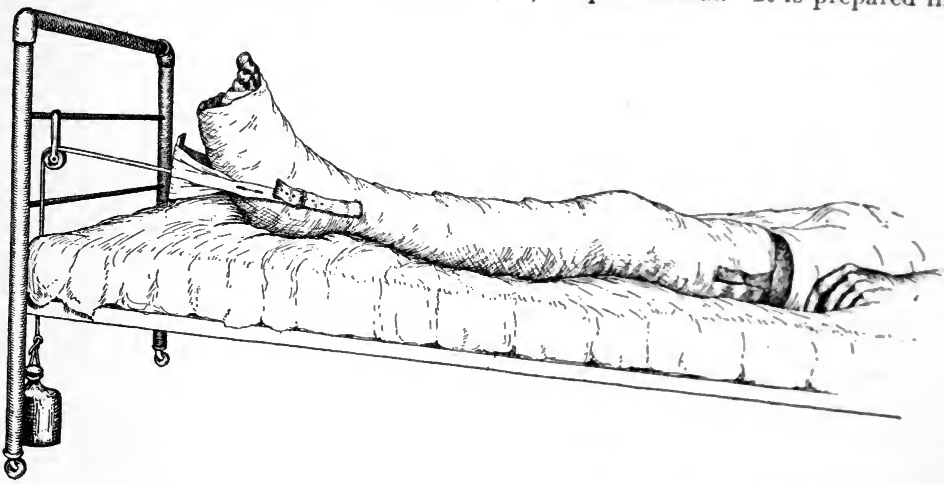

Fig. 15.—Plaster Traction Splint for Fracture of Bones of Leg. Note adhesive straps for traction and space below sole of foot to allow for traction.

the following way: Two pieces of muslin are cut in the shape shown in the figure, and of a size to fit the limb. These are stitched together along the median line. Twelve or fifteen pieces of crinolin, each a little smaller than a lateral half of the muslin pattern are prepared, soaked in plaster cream and placed in each half of the pattern, between the two layers. The splint is then applied smoothly to the limb and held by means of a muslin bandage.

When the plaster has hardened, the muslin bandage is removed and the splint held in position by strips of muslin bandage applied circularly and tied.

This splint combines the advantages of the Volkmann splint and later encasement. It can be loosened or tightened as needs arise, permits easy inspection to detect and correct deformity, and permits dressing of associated wounds.

Marked displacement of the fragments should be corrected as far as possible before the application of the splint. Blebs are opened under aseptic precautions and dusted with an antiseptic powder. Associated wounds are cleansed and sterile gauze applied.

After swelling has subsided, a more accurate reduction of the fragments is attempted under anesthesia, and a permanent dressing is applied. If wounds of the soft parts have not healed, and a circular plaster dressing is applied, a fenestrum is cut over the site of the wound.

## FRACTURES OF THE FIBULA ALONE

In these fractures, displacement, as a rule, is slight for the tibia serves as a splint to prevent this. A circular plaster dressing is applied to prevent movement of the lower fragment by twisting of the foot.

In fractures of the upper end of the fibula the knee is slightly flexed to relax the biceps femoris.

## POTT'S FRACTURE

With the spreading apart of the malleoli, there are lateral displacement of the foot outward and anterior posterior displacement of the foot backward.

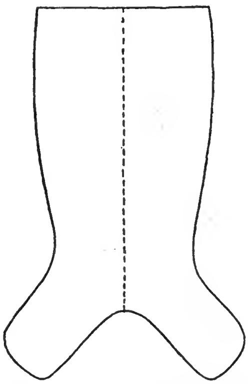

Fig. 16.—Stocking or Bivalve Splint for Fracture of Bones of Leg with Considerable Swelling of Soft Parts. A substitute for Volkmann's trough splint or the fracture box. (Stimson.)

Reduction is best effected under anesthesia by making lateral outward pressure upon the internal malleolus, lateral inward pressure upon the foot, and forward pressure upon the heel. Retention is most satisfactorily maintained by the use of the posterior and external lateral moulded splints of Stimson.

These are made of 4-inch plaster rollers. The posterior extends from the toes, along the sole of the foot and up the calf nearly to the knee.

The lateral splint begins just in front of the external malleolus, passes over the dorsum of the foot to the inner side, under the sole, and up along the outer side of the leg to the same height.

These are snugly moulded to the limb and held in position by a muslin bandage and, while the plaster is setting, the foot is maintained in right angle flexion, inversion, and adduction. After the plaster has hardened, the bandage may be removed and the splint held in position by adhesive straps or circular bandages about the foot, just above the ankle, and at the upper part of the leg. If there has been considerable displacement, the splints are carried to the middle of the thigh.

These splints are preferable to complete encasement in plaster because they permit inspection of the inner side of the ankle, can be easily loosened to allow for swelling and can be tightened as swelling subsides without disturbing the position of the fragments.

Massage of the exposed parts is begun during the third week. Splints are removed in 5 or 6 weeks.

### FRACTURE OF BONES OF THE FOOT

The skin of the foot and leg should be thoroughly cleansed and covered with a sterile dressing. The heel and ankle should be well protected by sheet-wadding and a posterior moulded splint extending from the toes to the knee may be applied and held in position with a bandage.

After swelling has subsided, a removable circular plaster dressing is applied

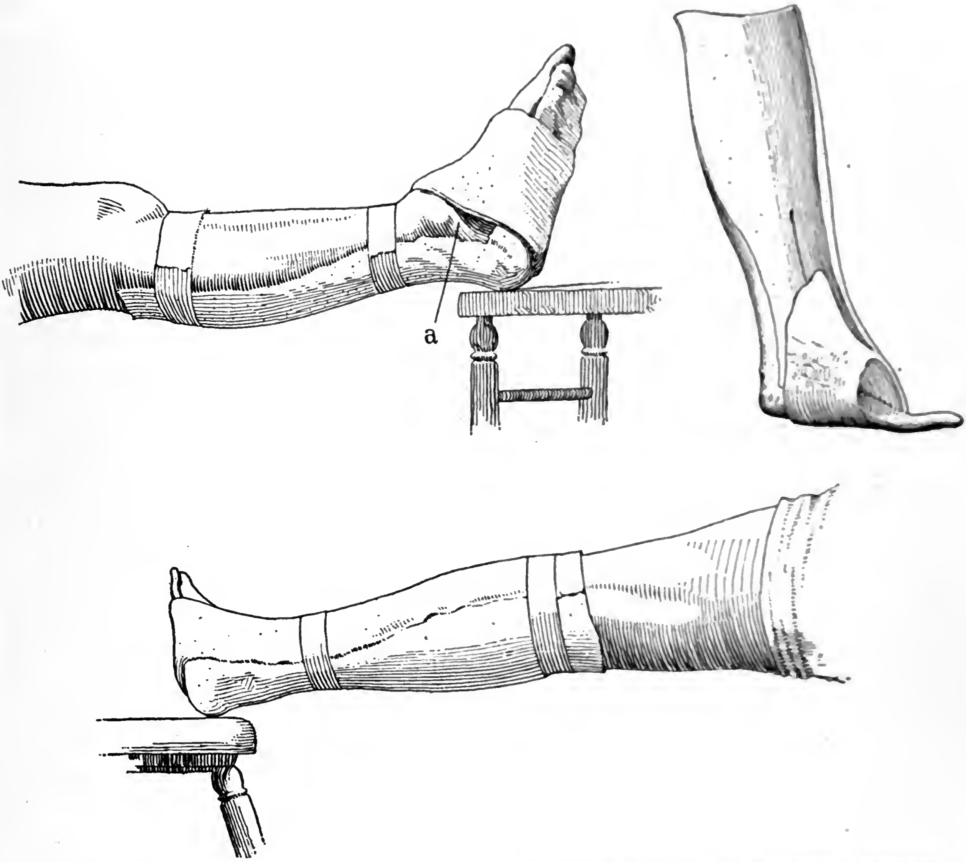


**Fig. 17.—Posterior and External Lateral Plaster Splints for Pott's Fracture.** (Stimson.) Note (a)—exposure of inner side of ankle.

to the foot and leg with the foot in the right-angle position. Special care should be taken to have the heel and malleoli well padded.

For the application of this dressing an anesthetic should be given and displacement corrected.

In fractures of the metatarsal bones, a felt pad should be placed on the plantar surface to assist in supporting the transverse arch.

In fractures of the tarsal bones, the circular dressing should be worn for 6 or 8 weeks. In fractures of the metatarsal bones, the dressing is worn for 4 weeks. If pain persists when the patient begins to walk a metal insole should be worn.

## PLASTER JACKETS

The plaster jacket has its widest application in the treatment of tuberculous disease of the spine. It is used also in the treatment of lateral curvature, in cases in which the deformed spine is painful, and in fractures of the vertebræ. As with splints applied for fractures, the jacket is not used to correct deformity, but to immobilize the spine, and thus protect the affected vertebræ from injury during the process of repair, and to limit any increase of deformity. Again, as in fractures, the plaster jacket should extend sufficiently above and below the affected part to secure complete immobilization, and all bony prominences, including the deformity, should be protected from pressure by proper padding.

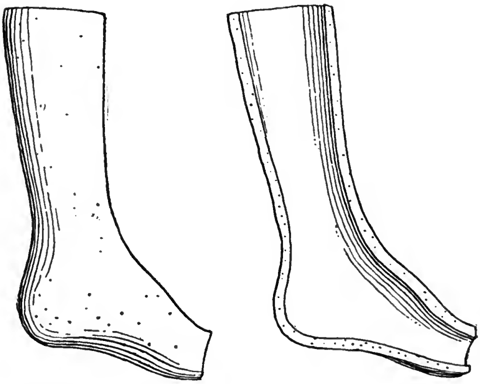

Fig. 18.—Lateral Plaster Splints for Fracture of Bones of Leg. Prepared by first applying a circular plaster dressing and cutting it in the median line anteriorly and posteriorly.

Jackets are made by applying layers of plaster bandages around the trunk, after the improved position of the spine has been secured by traction or hyperextension. During the application of the jacket, the patient is either in the upright or the recumbent position. In the recumbent position, he may be placed either prone or supine.

### APPLICATION OF JACKET WITH PATIENT SUSPENDED (SAYER)

The patient's clothes are removed, and the skin thoroughly cleansed with soap and water, followed by an alcohol rub and a dusting powder. A snugly fitting seamless undershirt, or tricot hose, is slipped over the head or feet. If the tricot hose is used, cuts are made in the mid-axillary lines and the ends brought up over the shoulders and tied. It is fastened beneath the perineum with a safety pin. The shirting should reach from the neck to the ankles. Inside this, two strips of muslin bandage, the "scratch bandages of Lorenz" are placed, one in front, the other behind.

The head sling devised by Calot (12) is now adjusted. This consists of a circular piece of canvas 6 cm. wide (2.4 inches) and 168 cm. (67.2 inches) in circumference, to which is sewed a tailpiece 104 cm. (416.6 inches) long. The occipitofrontal circumference of the patient's head is measured, and 2 cm. added to this. This length is measured off on the circular part of the sling, and safety pins are inserted in such a way that the tailpiece comes in the middle behind the occiput. The sling is adjusted to the chin and occiput, and the two loops are fixed to the notches at the ends of the iron cross bar. The tailpiece is attached to the center of the bar and prevents the head from tilting backward. To the center of the bar is attached a system of ropes and pulleys, fastened to a crane, swung from the wall, or to a wooden tripod, or two ladders hinged at their upper ends.

The arms are extended, and the hands grasp the cross bar. This aids extension of the spine, and diminishes the strain upon the neck. The patient is then raised so that the tips of the toes touch the floor or a stool. The patient's trunk should be on a level with the arms of the surgeon, seated and applying the bandages. An assistant steadies the legs, to prevent swaying of the body and inadvertent flexion of the thighs.

Before beginning the application of the plaster, all wrinkles are smoothed out of the shirt, and pads of felt are prepared for the anterior-superior spines and crests of the ilia. Two strips of felt, each 6 inches long, one inch wide, and of sufficient thickness to prevent pressure of the plaster on the protruding spine, are also prepared. These are to be placed longitudinally at the sides of the kyphosis, and to press upon the lateral masses of the vertebræ.

The surgeon, seated behind the patient, applies the plaster rollers, beginning below the great trochanters and extending upward under the axilla and over the top of the sternum, fixing each pad in position as the turns of the bandage reach it. Several thicknesses of sheet wadding or gauze are placed in the axillæ to protect the skin from friction of the finished jacket.

The bandages are applied smoothly, in circular and spiral turns, the plaster thoroughly worked into them by the hand, and the whole carefully moulded over the bony prominences. It is important to have the jacket strong in front as well as behind, and it should extend as high as possible in front in order to secure the necessary extension. While the plaster is hardening, and while the patient is still suspended, the edges of the jacket are trimmed. Below, a crescentic piece is removed on each side at Poupart's ligament to permit flexion of the thighs, a tongue-shaped piece being left over the symphysis pubis. At the sides, the jacket is cut away until it conforms with the upper limit of the great trochanters, and posteriorly it is trimmed so that it will not interfere with the sitting posture. Above, a crescentic piece is removed from each axilla to permit adduction of the arms. Anteriorly it must not be cut below the level of the suprasternal notch, and posteriorly it is cut across from the upper limits of the axillary folds.

After trimming is complete, the lower portion of the shirting is turned up over the jacket and sewed to the upper part along the edge of the jacket. This prevents the edges of the jacket from irritating the skin. The ends of the "scratch bandages" are brought together over the jacket and tied.

With good plaster sufficient hardening will have occurred by the time the jacket has been completed to permit the release of the patient from the apparatus. The patient is lifted out of the apparatus by placing the hands in the axillæ. He should either stand or lie upon his side for several hours. The sitting posture should not be assumed until the plaster has thoroughly hardened.

R. Tunstall Taylor adds to the suspension forward pressure at the seat of deformity by an instrument called the kyphotone. In this method the patient is seated on a bicycle saddle, and while strong traction is applied to the head, forward pressure is made over the kyphosis.

### APPLICATION OF THE JACKET WITH PATIENT IN THE RECUMBENT POSITION (PRONE)

In the application of the jacket, with the patient in the prone position, the gas pipe frame (Bradford) is used. This is a rectangular frame made of gas

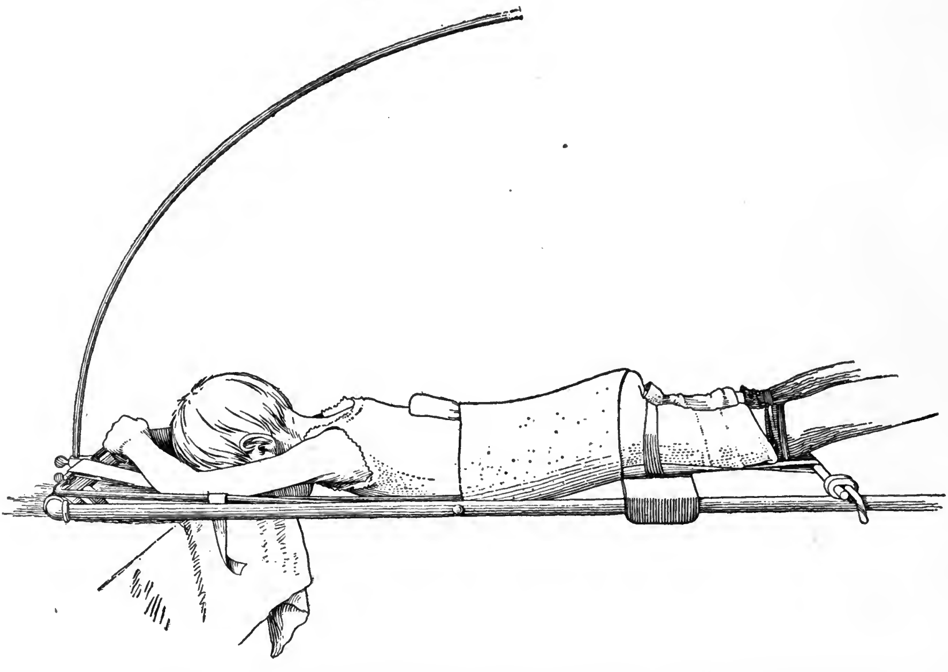

Fig. 19.—Application of Jacket with Patient in the Recumbent Position. Patient placed prone on the gas pipe frame. (Bradford.) Plaster rollers applied as far as the apex of the kyphosis.

pipe, within which, at the head end, there is a smaller frame fixed to the side bars by hinges. The inner frame can be elevated, and its position fixed on a curved upright as shown in the figure. To the cross bar of the inner frame is attached one end of a hammock, made of stout cloth or canvas. The other end of the hammock is fixed to a movable bar, connected by ropes to a ratchet at the foot end of the frame. By turning the ratchet the hammock is tightened. The patient is prepared, as described above, and placed (face down) on the hammock, with the kyphosis on a line with the hinge of the inner frame.

The hammock cloth is cut longitudinally along the sides of the patient's body, and the parts not under the body are removed. A circular opening is cut for the face, and the forehead is supported on a strap placed between the bars. A cross-piece about 8 inches in width is placed beneath the hammock at the upper portion of the thighs, and to this the patient is fixed by a strap. The bony prominences are padded, and strips of felt of sufficient thickness to prevent pressure of the plaster on the spines are placed at the sides of the deformity.

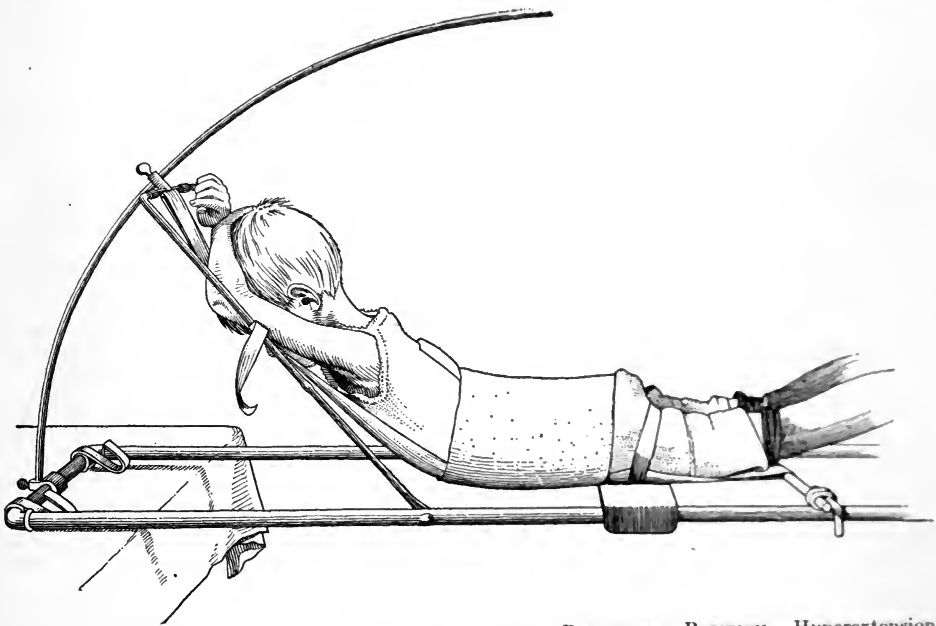

Fig. 20.—Application of Jacket with Patient in the Recumbent Position. Hyperextension secured by raising the inner frame. Jacket is now to be completed.

The plaster rollers are applied beginning below and are carried upward as far as the apex of the kyphosis and allowed to harden. The desired amount of hyperextension is secured by raising the inner frame. Hyperextension is carried to the point of slight discomfort, and the jacket completed. In this way hyperextension is secured at the seat of the disease. The jacket is trimmed in the manner described above.

## APPLICATION OF JACKET WITH PATIENT IN RECUMBENT POSITION (SUPINE)

To avoid compression of the chest and flattening of the abdomen, which occur, to some extent, when the jacket is applied with the patient in the prone position, the jacket may be applied with the patient lying on his back.

To secure the necessary hyperextension of the spine, Goldthwait has devised the following apparatus: An upright steel rod is arranged with a forked top, on which two attachable pad plates can be placed. The rod fits on a frame, and can be raised or lowered by means of a screw. The patient is so placed that while the shoulders and pelvis are supported on cross-pieces of the frame, the kyphosis rests upon the pad plates. By raising the bar, the counterweight of the body acts to hyperextend the spine at the seat of deformity. Exaggerated lordosis is prevented by flexing the thighs. The jacket is applied in the usual manner, and after its completion, the rods within are withdrawn.

In the absence of one of these forms of apparatus, the jacket may be applied in one of the following ways:

(1) The patient is placed between two tables, so that his shoulders rest on one, while his thighs rest upon the other. The thighs are held firmly by one

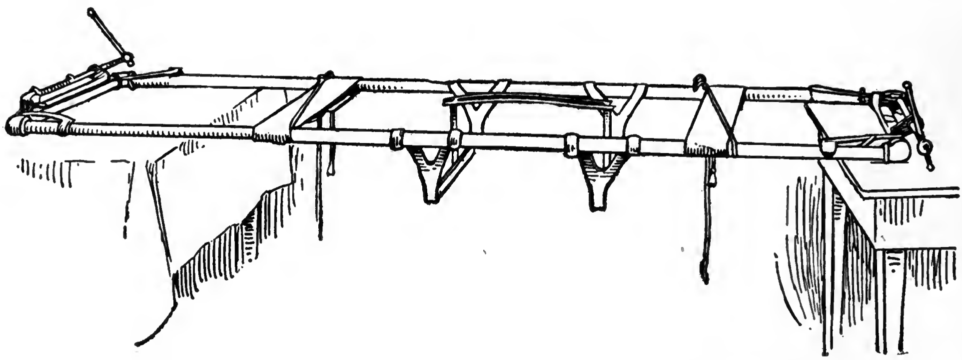

Fig. 21.—Frame for the Application of Plaster Jacket in Dorsal Position.

assistant, who makes steady traction, while counter-traction is made by a second assistant, who grasps the patient's arms close to the axilla. The weight of the trunk gives the necessary hyperextension to overcome the deformity.

(2) A hammock may be made of muslin or canvas and suspended between two walls. The patient is placed on the hammock, face downward, with arms and legs extended. The hammock may be made taut or allowed to sag, and in this way the desired degree of hyperextension is secured. The plaster bandages include the hammock, the excess of which is cut away after the plaster has hardened.

The ordinary jacket is most serviceable for diseases below the ninth dorsal vertebra. For diseases of the cervical and upper dorsal vertebræ, a jury mast, or head sling, is incorporated in the dorsal portion of the jacket in order to relieve the spine fom the pressure of the superimposed weight of the head. This is unsatisfactory, because it is difficult to adjust and to keep adjusted, and is uncomfortable to the patient. For disease of these parts of the spine, for disease with much deformity, and for cases of Pott's paraplegia, the jacket devised by Calot is the most efficient.

### THE CALOT JACKET (7)

The patient is prepared and suspended as described above. If the "grand jacket" is to be applied, a piece of stockinette, reaching over the top of the head, and with a hole cut out for the nose, is applied, and the patient's chin and occiput are carefully padded. For the jacket with military collar, a collar of felt is sewed to the top of the shirt. An assistant steadies the patient by holding the arms at an angle of 45° with the body. A large triangular pad of non absorbent cotton is placed provisionally over the sternum and anterior aspect of the ribs, and the bony prominences protected by pieces of felt in the usual manner.

Fig. 22.—Steps in Application of Grand Jacket. (Cabot.)

Calot uses plaster bandages, *freshly prepared,* by immersing crinoline bandages in plaster cream, unrolling and rerolling them rapidly. The plaster bandages prepared in the ordinary way are preferable.

The plaster bandages are applied smoothly, beginning below as in the ordinary jackets, but passing upward, the turns include the shoulders and axillæ and encircle the neck if the jacket is to be one with the military collar, or include the head, avoiding the hole cut for the nose in case of the "grand jacket." After several layers of the plaster bandages have been completed, the auxiliary pieces are applied. These consist of several sheets of crinoline, previously measured to fit the parts, and impregnated with fresh plaster cream. For the jacket with military collar there are three, two aprons, front and back, and a collar; for the grand jacket, two aprons, a chin-piece, and a piece for the occiput. The aprons are the length of the trunk plus one-half, and the width of each is equal to one-half the circumference of the trunk. Each apron is slit at its upper end for one-third its length, and the slit ends are passed over the shoulders and into the axillæ, the ends from the front and back being superimposed. The lower ends of the aprons are folded upon themselves and worked in with the circular turns. These are nicked with the scissors if necessary in order to make them fit smoothly. The collar is made about the height of the patient's neck, and one and a half of its circumference. The pieces for the chin and occiput in the grand jacket should be about 4 by 6 inches, and should extend downward from these points.

After the auxiliary pieces have been placed in position, the jacket is completed as quickly as possible by circular and spiral turns of the plaster bandages outside of these, and the whole carefully moulded to the pelvic and shoulder girdles. The jacket is now trimmed. A small triangular opening, apex upward, is made over the sternum, and the cotton pad removed. The jacket is trimmed below as in ordinary jackets. Above, the jacket with the military collar is trimmed at the junction of the chin and neck, while the grand jacket includes the chin and occiput, leaving the ears free. The shoulders are exposed, and the crescentic piece is removed from each axilla to permit free range of motion to the arms. The patient is now released from the sling and placed face downward over the edge of the bed. He is watched for a while to see that his breathing is not impeded.

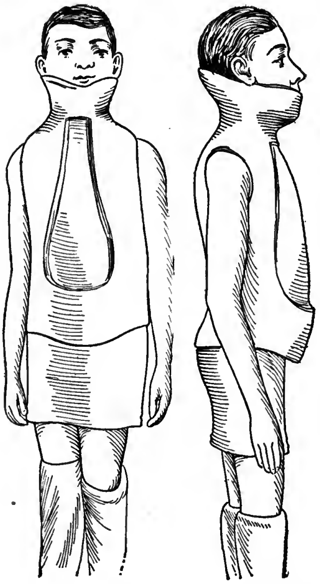

FIG. 23.—GRAND JACKET COMPLETED. (Cabot.) Front view.

At the end of 48 hours, a larger window is cut anteriorly as shown in the figure. Posteriorly over the kyphosis another window 6 by 3 inches is made. The shirt is opened by two cross cuts, the skin anointed with vaselin, and pieces of cotton a little larger than the window are wedged under the shirting by means of a spatula. The edges of the opening in the shirt are folded back in place, and successive layers of cotton are placed over the kyphosis until they project beyond the level of the jacket. These are held in place and pressed upon by circular turns of plaster bandages. This procedure drives the kyphosis forward, and the large window anteriorly permits the chest to yield under pressure from behind. At intervals of two months, as the kyphosis recedes, additional layers of cotton are applied.

The jacket should be well padded, fit snugly and be comfortable. It should be of uniform thickness throughout, and should be as light as is compatible with strength. Parents should be instructed in the use of the "scratch bandages," and these should be used daily in order to keep the skin in good condition. Parents should be cautioned against letting any object fall inside the jacket, and should be instructed to watch carefully for any foul odor emanating from the jacket. This indicates excoriation of the skin, and calls for the immediate removal of the jacket.

The jacket is removed by cutting it along the median line in front. By making a fenestrum over the site of the excoriation, the pressure is relieved and treatment made possible. The jacket is readjusted and held by adhesive straps till the wound has healed, after which a new jacket is applied. A good jacket will last from 2 to 6 months. If the "scratch bandages" are properly used, the skin will remain in good condition.

E. REMOVABLE JACKETS: After the jacket has been applied, it is cut down in front, and straps provided with lacing holes are sewed to the edges. These jackets do not furnish such efficient support as the fixed jackets during the acute stage of the disease, but are most suitable for use in convalescent cases, or cases where sloughs or excoriations are present.

### APPLICATION OF JACKET FOR FRACTURE OF THE VERTEBRÆ

A plaster-of-Paris jacket is employed in cases of fracture of the spinous processes alone, in cases of fracture of the bodies without recognizable displacement or symptoms of injury to the cord, and in cases of recognizable displacement without cord symptoms. It is also indicated in cases with recognizable displacement with symptoms of injury to the cord, if correction of deformity and relief of symptoms can be secured by manipulation or operation.

In the reduction of deformity and the application of the jacket, the utmost care should be exercised to prevent further displacement of the fragments and increased injury to the cord. Young patients may be suspended and the grand jacket applied. With large and heavy patients, the jacket is applied in the following way: A buttonless shirt, or sheet wadding is applied, and the bony prominences padded in the usual manner. The patient is placed upon his back with a support under the pelvis, and pillows under his head and shoulders. The deformity is protected by pads of felt placed over the lateral masses of the vertebræ, a sling is passed around the back under the pads at the seat of the deformity, and the ends of the sling are attached to the horizontal bar of a suspension apparatus. As the bar is slowly and gently raised, the counterweight of the body operates to correct the deformity.

When the deformity has been corrected, the plaster bandages are applied. These include the sling, the excess of which is cut away at the points of emergence after the plaster has hardened. After operation the jacket may be applied with the patient in the prone position on two tables. With the arms and thighs extended and firmly secured by assistants, the tables are slowly separated, thus permitting the trunk to remain unsupported between them. The weight of the body gives the necessary extension. The jacket is applied in the usual manner.

## SPICAS FOR CASES OF CONGENITAL DISLOCATION OF THE HIP

In cases of congenital dislocation, the rudimentary acetabulum is not of sufficient capacity to retain the head of the femur when the limb is in the normal attitude. After reduction has been secured by manipulation, the thigh is placed in right-angled flexion and hyperabduction, with the leg flexed, and this position is maintained by a short spica encircling the lower portion of the abdomen and the pelvis and reaching the knee joint. It is essential in the treatment of these cases to have a well-fitting plaster dressing, which will retain the head of the femur in the acetabulum while the patient walks about, for the acetabulum enlarges by the presence of the head, and the use of the muscles in walking prevents their atrophy.

**Application of Spica.**—After reduction, and while the child is still under the anesthetic, it is placed upon a pelvic support and the thighs are held in the hyperabducted position with the legs flexed, by an assistant. The scratch bandage is placed over the abdomen and thigh, and the abdomen, pelvis, and one or both thighs and knees (depending on the case) are covered with sheet wadding in the form of roller bandages. The perineum is entirely covered by figure-of-eight turns, and extra pads of the same material are placed over the anterior-superior spines and crests of the ilia and the sacrum. The method of applying the plaster rollers varies somewhat in unilateral and bilateral cases.

UNILATERAL CASES.—In the unilateral cases, the plaster roller begins at the anterior-superior spine of the sound side, is carried across the pelvis, down the inner surface of the thigh, and round the knee of the affected side, then along the posterior surface of the thigh and pelvis to the starting point. This is repeated several times and when the bandage reaches the knee, spiral turns are applied to the thigh till the pelvis is reached, when this part is covered by figure-of-eight turns, and the lower portion of the abdomen with spiral turns. This is repeated with spiral turns to the thigh and lower abdomen, and figure-of-eight turns for the pelvis until the dressing is of the desired thickness.

BILATERAL CASES.—In the bilateral cases the plaster roller begins at the knee of one side, passes along the inner surface of the thigh, across the pelvis, along the inner surface of the opposite thigh, around the knee, and is then carried posteriorly to the starting point. Several complete turns are made, and when the knee is reached, spiral turns to the thigh are begun. These are carried upward to the pelvis, when figure-of-eight turns are applied to the latter and spiral turns are carried down the opposite thigh to the knee. The dressing is reinforced anteriorly by several layers of plaster bandages extending from knee to knee, and completed with spiral turns to the thigh and lower abdomen, and figure-of-eight turns to the pelvis.

After the application of the plaster bandages is complete, a large fenestrum is cut from the perineal region, and the dressing trimmed about the knee to permit walking. Above in front, the dressing is cut down to the level of the umbilicus. The ends of the scratch bandage are brought over the spica and tied. As soon as soreness and discomfort have disappeared (in about a week or 10 days) the patient is encouraged to walk. Such efforts force the replaced head deeper into the acetabulum, stimulate its growth and thus increase the stability of the reposition. In unilateral cases a shoe with a high sole is used on the affected side; in bilateral cases, a small stool on wheels has been devised, by means of which the patient propels himself and thus makes use of the muscles.

The spica is worn 3 months, after which it is removed. Abduction is lessened, and a new dressing applied with the limb in the new position. After the removal of the last dressing, massage and passive motion are begun, and a hip splint is worn for several months. The scratch bandage should be used daily. The same general rules for the use of the X-ray, given under fractures, are to be followed in these cases to determine the results of reduction and retention.

## CIRCULAR PLASTER DRESSING FOR CLUB-FOOT

For the treatment of club-foot, plaster-of-Paris is the best dressing in ordinary hands. Here again, it must be remembered that the plaster is employed only to retain the foot in corrected position after deformity has been reduced by manipulation or open operation, and is not, in any case, used to overcome the deformity.

Correction of deformity should be made shortly after birth (second or third

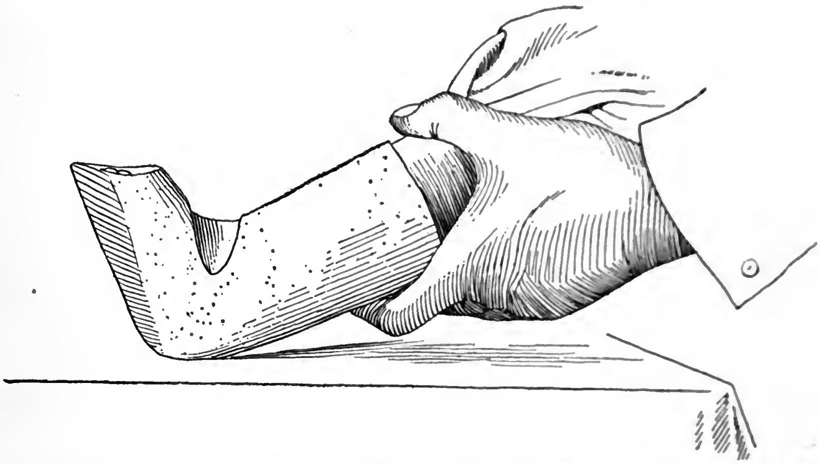

Fig. 24.—Plaster Dressing Applied After Correction of Club-foot. Note triangular fenestrum over instep. Sole flattened to permit walking.

week) for the plastic tissues of infants are easily moulded and results are more readily obtained.

By manipulation, the foot is brought from the equinus position into that of a right-angle flexion with the leg, and adduction (varus) and inward rotation are overcome.

After a thorough reduction of all the abnormal positions, so that the foot can be placed in an overcorrected position, the foot and leg are well covered with sheet wadding in the form of roller bandages.

The plaster rollers are snugly applied, beginning at the ankle. For the left foot, the plaster roller passes from right to left over the sole, and for the right foot in the reverse direction.

The dressing invests the foot and extends up the leg to the tuberosities of the tibia.

The foot is held in the over-corrected position till the plaster hardens. After the plaster has become firm, preparation for swelling is made by cutting a triangular fenestrum over the instep in front of the external malleolus and the toes are exposed. The circulation of the toes is carefully watched after the application of the dressing. In small children, it is difficult to prevent the dressing from slipping. To guard against this, strips of moleskin adhesive are applied to the leg. The lower ends of these are brought through the sheet wadding above the ankle and the plaster roller applied over them.

If the child is ready to walk, a thick sole of plaster is applied. This is flattened with a board.

If the deformity cannot be entirely corrected by the first manipulation, it is repeated in two or three weeks and a new plaster dressing is applied. With each renewal of the dressing, an attempt is made to improve the position of the foot.

## CIRCULAR PLASTER DRESSING FOR FLAT-FOOT

To correct the deformity of a rigid flat-foot, an anesthetic is administered and the foot is forcibly manipulated into an exaggerated adducted and inverted position and held at a right angle. It is maintained in this position by a plaster-of-Paris dressing extending from the toes to the tuberosities of the tibia. The dressing is worn for 4 weeks.

After the removal of the dressing, a plaster mould is made directly from the foot in the corrected position, and a steel insole prepared from this for the shoe.

## MANIPULATIONS FOR REDUCTION OF COMMON DISLOCATIONS

### DISLOCATION OF THE LOWER JAW

The common dislocation of the inferior maxilla is forward.

The following methods are used in reduction:

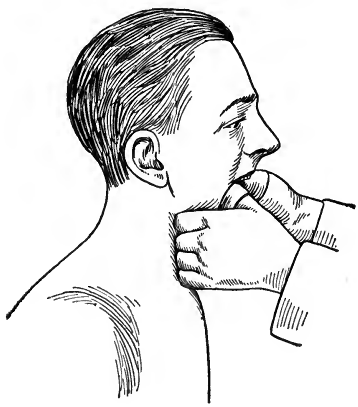

Fig. 25.—Method of Reduction in Dislocation of Lower Jaw.

(1) The thumbs are covered with gauze and inserted over the molar teeth upon either side of the jaw. The lower border of the jaw is grasped by the remaining fingers. Backward and slightly downward pressure is made upon the molar teeth by the thumbs, and the chin is lifted up and pressed backward by the remaining fingers. As soon as the condyles are felt to pass over the articular eminence, the thumbs are quickly withdrawn, and the teeth permitted to come together.

(2) In order to relax the lateral ligaments of the joint, the mouth is still farther opened by downward pressure upon the incisor teeth. With the lateral ligaments somewhat relaxed, direct pressure backward will effect a reduction.

**After-care.**—The jaw is immobilized with a Barton bandage for two weeks during which time only liquid food is given. After the removal of the bandage, the patient is cautioned against opening the mouth too widely.

### DISLOCATION OF THE SHOULDER

The common dislocation of the shoulder is the subcoracoid. Reduction is effected (1) by manipulation; and (2) by traction.

**Reduction by Manipulation: Kocher's Method.**—The patient lies upon his back and the surgeon stands on the side of the dislocated shoulder. The manipulations are carried out in four steps.

(1) The surgeon firmly grasps the injured arm above the condyle of the humerus with one hand, and the patient's wrist with the other. The forearm is flexed at a right angle and the elbow is slowly carried to the side of the body. (2) The humerus is externally rotated until the forearm points directly outward, when a distinct resistance can be felt. This movement relaxes the rent in the capsule through which the head of the humerus left the joint. (3) With the humerus strongly rotated outward, the elbow is gradually adducted by moving it forward, or forward and slightly inward until the arm is nearly in the horizontal position. (4) When the elbow has been raised as high as it will go, the hand is placed upon the opposite shoulder, thus rotating the humerus inward.

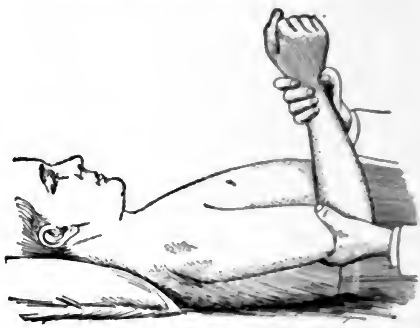

FIG. 26.—KOCHER'S METHOD OF REDUCTION IN SUBCORACOID DISLOCATION OF SHOULDER. First step.

Reduction is indicated by a click as the head slips into the glenoid cavity.

All steps should be carried out gradually and steady traction downward in the direction of the long axis of the humerus should be maintained by the surgeon.

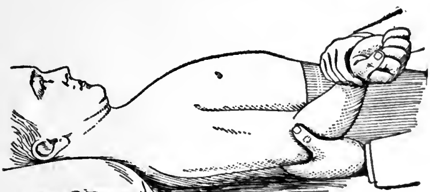

FIG. 27.—KOCHER'S METHOD OF REDUCTION IN SUBCORACOID DISLOCATION OF SHOULDER. Second step.

**Traction: Stimson's Method (15).** — The patient lies on his side upon a canvas cot, in which an opening is made, through which the injured arm is passed so as to hang vertically downward. The cot is raised upon blocks or chairs so that the arm will hang free of the floor. A weight of 10 pounds is attached to the wrist or elbow. In from 5 to 15 minutes the parts are sufficiently relaxed and the head slips into the glenoid cavity.

It may be necessary in some cases to increase the weight attached to the arm, and also to advance the head toward the glenoid cavity by adducting the arm against the fist placed in the axilla. Instead of the cot, the patient may be put upon two tables, placed end to end with the body resting on one and the head on the other, the arm hanging down between.

A simple method which will often suffice is the following: The arm is grasped above the elbow and steady traction is made in a downward and outward direction. The arm is now gradually abducted until it is nearly or quite at right angles with the body. An assistant manipulates, by pressure, the head of the humerus while traction is being made.

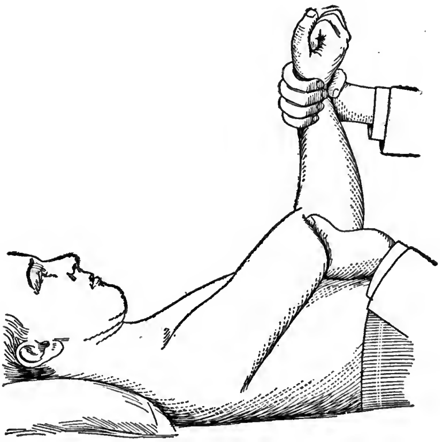

Fig. 28.—Kocher's Method of Reduction in Subcoracoid Dislocation of Shoulder. Third step.

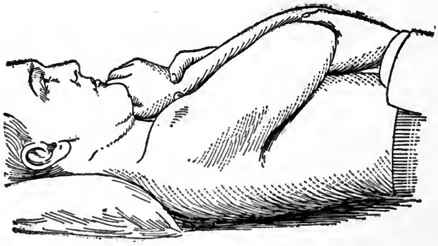

Fig. 29.—Kocher's Method of Reduction in Subcoracoid Dislocation of Shoulder. Fourth step.

**After-treatment.**—After-treatment consists in partially immobilizing the shoulder joint by an arm and chest bandage, the forearm being supported at the wrist by a sling. In a day or two after reduction, gentle passive movements are begun. These are continued daily and the range of motion gradually increased. Active movements are begun during the third week.

## DISLOCATION OF THE ELBOW

The common dislocation of the elbow is that of both bones of the forearm backward.

Reduction, in uncomplicated cases, is effected by hyperextending the forearm, thus freeing the coronoid process from the olecranon fossa and the posterior surface of the humerus, followed by direct traction on and flexion of the forearm.

The method suggested by Sir Astley Cooper (6) is as follows: The surgeon places his knee in front of the elbow joint, grasps the patient's wrist, presses upon the radius and ulna with his knee. and slowly but forcibly bends the forearm.

**After-treatment.**—The after-treatment consists in immobilization of the elbow with the forearm flexed to a right angle. A firm bandage is applied to the elbow and the forearm is supported in a sling. Light passive movements are begun during the third week and active movements during the fourth week.

## DISLOCATION OF THE THUMB

Complete backward dislocation of the first phalanx of the thumb is the common form. Reduction is made by hyperextending the thumb while traction is

FIG. 30.—REDUCTION OF DISLOCATION OF SHOULDER BY TRACTION. Stimson's method.

made upon it, pressing the base of the phalanx forward and finally quickly flexing the thumb into the palm.

If the ligament has caught behind the head, it may sometimes be freed by rotating the phalanx while pressing it forward.

Reduction of forward dislocation of the thumb is easily effected by traction and forced flexion with downward pressure on the base of the phalanx. The thumb is immobilized in the straight position for one week, after which gentle passive and active motion is begun.

## DISLOCATION OF THE HIP

For the reduction of a dislocation of the hip an anesthetic should always be administered.

**Reduction of Dorsal Dislocation: Stimson's Method** (13).—The patient is placed face downward upon a table with his legs projecting so far beyond the edge that the injured thigh hangs directly downward. The sound limb is held in line with the body by an assistant. The surgeon grasps the ankle of the dislocated limb and flexes the knee to a right angle. The weight of the limb now makes the needed traction in the desired direction and the surgeon has only to wait for the muscles to relax and the bone to resume its place without further effort on his part than a slight rocking or rotation of the limb. The added weight of a small sand-bag at the knee or sudden slight pressure at the same point may facilitate reduction.

The everted dorsal dislocations are reduced by first converting them into the dorsal form by flexion and inward rotation with adduction if necessary.

BIGELOW'S (4) METHOD OF REDUCTION OF A DORSAL OR POSTERIOR DISLOCATION.—The patient lies on his back upon a blanket on the floor. The pelvis is steadied by an assistant who exerts pressure upon the anterior-posterior spines. The leg is flexed upon the thigh, and the thigh upon the abdomen, the position of adduction and slight inversion being still maintained so that the knee extends beyond the midline of the body. This position with traction upward is maintained for some moments and the limb is then freely circumducted outward and brought down into the position of extension.

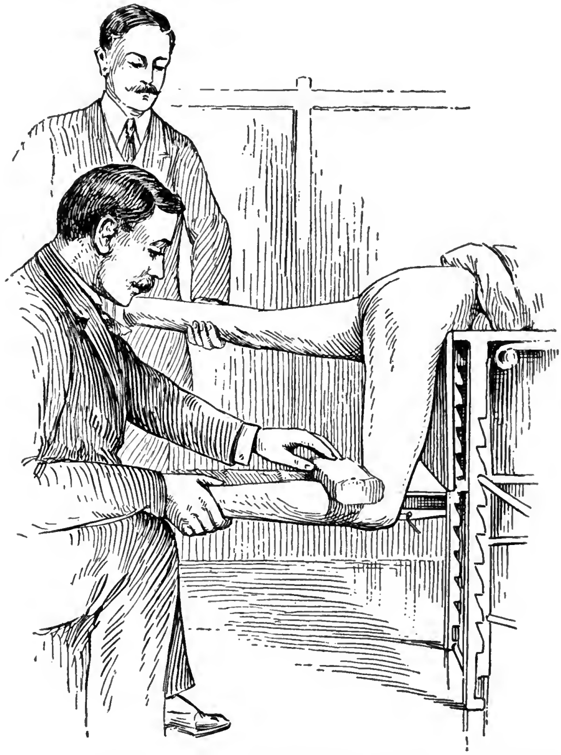

FIG. 31.—REDUCTION OF DISLOCATION OF HIP BY TRACTION. Stimson's method.

ALLIS' (2) METHOD.—The patient is placed in the same position as described above in Bigelow's method. The surgeon kneels by the patient's side and, if the right femur is dislocated, he grasps the patient's ankle with his right hand and places the bent elbow of his left arm beneath the flexure of the knee. He now turns the bent leg outward and lifts upward (skyward), then turns the bent leg inward and brings the thigh down in extension.

**Reduction of an Inward or Anterior Dislocation.**—1. ALLIS' DIRECT METHOD. —(1) Flex and abduct the femur; (2) make traction outward; (3) fix the head by digital pressure and adduct.

2. ALLIS' INDIRECT METHOD.—The patient lies upon his back with the femur flexed. The surgeon places his bent elbow beneath the flexed knee and grasps the ankle with his other hand; he then extends with traction in the line of the long axis of the femur, adducts, and rotates outward.

BIGELOW'S METHOD OF REDUCTION OF A THYROID OR ANTERIOR DISLOCATION.—"Flex the limb toward a perpendicular and abduct it a little to disengage the head of the bone. Then rotate the thigh strongly inward, adducting it, and carrying the knee to the floor." After reduction, the patient is required to remain in bed for three weeks, after which massage and passive motion are begun. The use of the limb is permitted during the fourth week.

### DISLOCATION OF THE KNEE JOINT

Dislocation of the tibia forward is the most frequent form. Reduction is effected by traction on the leg while the thigh is flexed, combined with manipulation in order to guide the head of the tibia into its normal position.

The limb is placed on a posterior splint for three weeks, after which passive movements are carefully made. A knee support is worn for several months.

### DISLOCATION OF THE ANKLE JOINT

These dislocations are quite rare and are often associated with fracture of one or both bones of the leg.

**1. Backward Dislocation.**—Backward dislocation is more frequent than the forward variety.

Reduction is made by forced plantar flexion, the foot being pulled forward and the lower end of the tibia pressed backward. Dorsal flexion of the foot completes reduction.

**2. Forward Dislocation.**—Reduction is made by marked dorsal flexion of the foot, pressure forward on the lower end of the tibia, and pressure backward on the foot. Plantar flexion completes reduction.

The foot is immobilized by a posterior splint for three weeks. Light passive motion is begun at the end of the third week.

### DISLOCATIONS AT THE WRIST

These dislocations are rare:

**Dislocations at the Lower Radio-ulnar Joint.**—Dislocation of the ulna may be forward or backward.

DISLOCATION FORWARD.—Reduction is effected by direct pressure upon the ulna with counter pressure on the radius.

DISLOCATION BACKWARD.—Reduction is effected by direct pressure on the radius, aided sometimes by abduction or supination of the hand.

**Dislocation of the Radiocarpal Joint.**—BACKWARD DISLOCATION.—Reduction is effected by traction upon the hand and direct pressure on the carpus.

FORWARD DISLOCATION.—Reduction is effected by traction upon the hand, counter traction on the forearm, while direct pressure is made upon the displaced carpus.

**Dislocation of the Carpal Bones.**—DISLOCATION OF THE MEDIOCARPAL JOINT.—Dislocation between the first and second rows of carpal bones is extremely rare and may be forward or backward. Reduction in these cases is effected by flexion or extension of the hand aided by traction and pressure over the distal carpal row.

DISLOCATION OF THE SEMILUNAR BONE.—Reduction of anterior dislocation of the semilunar bone is effected by hyperextension followed by hyperflexion over the thumbs of an assistant, held firmly in the flexure of the wrist on the semilunar.

**Dislocation of the Carpometacarpal Joints.**—The joint most frequently involved is that of the thumb and the displacement is almost always backward. Reduction is effected by traction upon the hand while pressure is made over the base of the dislocated bone.

## DRESSING FOR FRACTURE OF THE CLAVICLE

HOWARD D. COLLINS

In cases of extreme deformity an open operation may be necessary for the retention of the fragments in good position. In other cases where the deformity is slight the Sayre dressing is efficient. This is too well known to require a separate description. In passing, however, it may be said that while the Sayre dressing is theoretically correct in that the lines of force operate in the proper direction, yet serious practical objections arise in regard to this method: namely, first, the zinc oxid plaster after a few days irritates the skin, more especially in stout subjects: second, in a short time the body adjusts itself to the dressing in such a way that the whole force of the traction is lost and the reduction is no longer maintained. This requires a renewal of the dressing, and such renewal is annoying and painful to the patient since the zinc oxid plaster during its removal pulls violently upon the skin and often leaves an excoriated or an irritated surface behind.

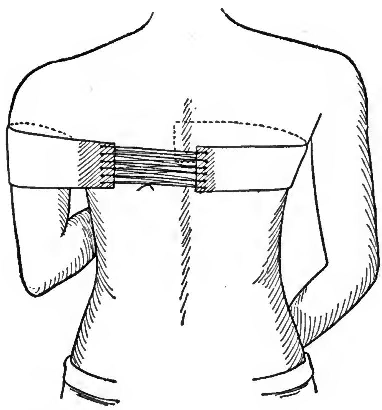

FIG. 32.—DRESSING FOR FRACTURE OF THE CLAVICLE. Posterior view, showing arm loop and body piece. Shaded area of bandage outlines portion reduplicated or lined, so that no adhesive surface is presented to the skin at those points.

The following dressing was devised by me to meet these objections. The material used consists of heavy moleskin adhesive plaster, which, while more troublesome to apply does not irritate the skin and firmly adheres thereto. The support and contraction resembles those of the Sayre dressing.

The dressing is applied as follows:

First, a piece of moleskin 4 or 5 inches wide is passed about the humerus as high up in the axilla as possible, and the ends, for about two inches of their length, caused to adhere to each other. This piece should be for the average about eighteen inches long. Before applying, the whole strip should be warmed so as to cause it to adhere to the circumference of the arm. At the posterior end of this loop, i. e., where the ends are adherent to each other, six holes are punched and eyelets inserted (these eyelets are similar to those through which the laces of shoes are passed and are made with a little hand punch devised for the purpose). A second strip of moleskin, the same width as the first, passed about the body, extending from the midline behind around the chest on the healthy side as far or even across the midline in front. The posterior end of this strip is turned over on itself for about two inches and a similar row of eyelets inserted. The two rows of eyelets should be about 6 inches apart and then an ordinary corset lace put in. With this lace the ends are drawn together with the result that the shoulder can be pulled back as far as desired. The second part of the dressing is applied as follows:

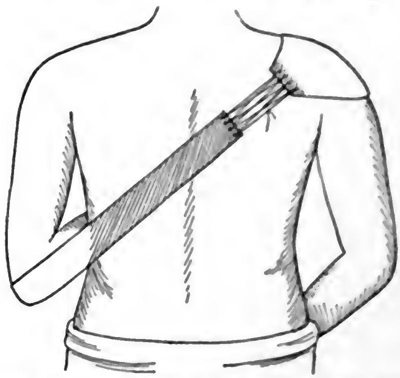

Fig. 33.—Dressing for Fracture of the Clavicle. Posterior view, showing shoulder cap and elbow sling.

A broad piece of moleskin about seven inches wide and a foot long is applied over the healthy shoulder in the form of a cap extending well down on the arm. (In order to secure a cap-like structure, it is necessary to cut a "dart" in the moleskin.) The free ends are turned back on themselves and cut to a taper, so that the margin is not more than three inches wide. A row of four eyelets is placed in each end. The last piece of the dressing consists of a long strip of moleskin three inches wide, passed around the forearm of the injured side close to the elbow, one end extending up the front of the chest, the other up the back. The ends of this strip are also turned back on themselves and each has a row of four eyelets. This strip should be lined with muslin so that there is no adhesive surface exposed except where the moleskin is in contact with the forearm and elbow. A lacing joins this elbow piece with the shoulder cap in front and another is placed behind. The front and back lacings between the elbow sling and shoulder cap permit the injured shoulder to be raised or, by

Fig. 34.—Dressing for Fracture of the Clavicle. Anterior view, showing shoulder cap and elbow sling.

tightening one lacing more than the other, the elbow may be brought forward or back as desired.

In applying this dressing, it should be borne in mind that the pieces should be carefully cut and fitted before the adhesive surface has become thoroughly secured to the skin.

The only disadvantage of this apparatus is the length of time required for its application. This disadvantage is more than offset by the advantages, which are: (1) a non-irritating dressing that may be worn three or four weeks; and (2) the chance to tighten the lines of traction as occasion may require without removing the adhesive.

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# CHAPTER XVIII

## RADIUM IN SURGERY

A. Schuyler Clark

Radio-activity was first demonstrated by Becquerel in 1896 in uranium salts by means of a photographic plate. In 1898 Madame Curie and M. Schmidt proved that thorium was also radio-active and, being struck by the fact that some samples of pitchblende were infinitely more radio-active than others, finally in 1903 developed from it polonium and radium.

Debierne, about this time, also isolated **actinium** which, though more radio-active than radium, cannot be used therapeutically owing to the difficulty of extraction. Other radio-active substances have been discovered but, up to the present time, **radium** has proven the most practical, owing to its possible isolation in the state of a pure salt. It is used in combination as a sulphate or bromid therapeutically, but we can quantitatively determine the amount of radium element in any specimen or apparatus.

Radium is found in **uranite** and **carnotite** ore deposits, of which those in southern Colorado are probably the most extensive in the world. It is recovered at great expense of time and ore, for it is present in infinitesimal amounts and at the present market value costs from $100 to $120 per mg. of the element.

The Standard Chemical Company of Pittsburg are the largest producers in this country. There is an international standard of measurement, determined by the rapidity with which a definite amount of air is ionized, and the stated amount of element in any preparation can now be verified at the Bureau of Standards, Washington, D. C.

**Radio-activity.**—The so-called radio-activity consists of a series of disintegrations of the radium element into gaseous emanations which in time decompose, resulting in the formation of different active products which it deposits on every substance it touches, rendering them radio-active. This induced activity, as in water, vaselin and other substances, is more or less varied and limited. When, however, it is confined in an hermetically sealed capsule or varnish, as in the various radium apparatus, radio-activity exists indefinitely and this explains the fact that several months must be allowed to pass before an apparatus reaches its full power, when it becomes a stable quantity with a duration of even thousands of years without appreciable loss of the original element or activity. These sealed deposits result in rays with various powers of penetration, the so-called Alpha, Beta and Gamma rays.

The Alpha rays are material particles charged with positive electricity—they have very slight powers of penetration and are lost in 1 in. of air space or are filtered out with even 2 layers of rubber tissue.

The Beta rays are charged with negative electricity and are comparatively soft and hard, the softer rays can be filtered out by 2½ to 3½ in. of air space or by ½ to 1 mm. of platinum foil.

The Gamma rays are believed to be due to the anatomic explosions which generate the Alpha and Beta particles and are caused by electromagnetic pulsations or disturbances transmitted through the ether in the same manner as the Hertzian waves, light and X-rays. They are ultrapenetrating up to 2 in. through living tissue and are not deflected by the magnetic field and some of them can penetrate even 2 in. of lead or many inches of stone or wood.

**Filtration.**—Radium in thin glass containers emits approximately 90 per cent. of Alpha rays, 9 per cent. of Beta rays and 1 per cent. of Gamma rays. Aluminum, silver, platinum and lead filter out varying proportions of these different rays and these screens are, therefore, of practical therapeutic value in varying the proportions of the rays.

Two layers of rubber tissue will filter out practically all the Alpha rays; 0.5 to 1 mm. of platinum or aluminum will filter out the Alpha rays and the softer Beta rays; 1 to 2 mm. will filter out also the medium Beta rays, and 4 to 5 mm. will filter out practically all of the Alpha and Beta rays, allowing the Gamma rays to pass through. It is in this way that one can determine a superficial or deep penetrating radio-activity with a single apparatus, naturally varying the time of exposure according to the amount of rays transmitted through the filter. All these varieties of rays are capable of producing a radiodermatitis and destruction of normal tissue, if a sufficient amount of them is administered.

Radium, to-day, is not only supplied in small glass and thin metal tubes and cells but can be incorporated in an especially prepared varnish, uniformly spread over definite areas for the treatment of more extended superficial lesions, and water can be activated to a more or less definite degree by exposure to radium emanations, developing an induced activity and so making it possible to employ radium rays internally in various ways and diseased conditions.

**Dosage.**—The dosage can be determined fairly accurately in radium therapeutics, owing to the practically constant amount and character of rays emitted from an hermetically sealed apparatus. Four main factors enter into consideration in determining this: 1. The degree of susceptibility of the tissues to the rays; 2. the amount and character of the radio-active source; 3. the screens employed or not; 4. the duration, methods and distance of the application.

In a general sense, younger tissues are progressively more susceptible and older tissues progressively less susceptible to the influence of the rays, and the dosage, therefore, must be varied in youth, adult life and adolescence.

**Action of Rays on Living Cells.**—Living cells exposed to rays of radium may be stimulated or depressed and retarded in their growth, or degenerated and completely destroyed, depending on the amount of rays absorbed. Besides this, the rays seem to have a selective action on certain tissues which, without destroying the cells, they have the power of changing back, as it were, to more nearly the embryonic type from which they developed. In diseased tissue these cellular reactions are much more promptly and easily produced than in normal tissue, and it is largely owing to this characteristic that radium has achieved what success it has in the treatment of the malignant diseases we commonly call cancer. Epitheliomatous tissue exposed to sufficient radium rays shows, after a few days, a cellular disorganization, going on to a softening and gradual disappearance by absorption. The connective tissue immediately surrounding the mass apparently is stimulated and regenerated by the invasion of embryonic nuclei dissociating and finally replacing the cancerous cells. Thus takes place a sort of embryonic fibrous transformation of the tumor, which eventually changes into a sclerotic mass, healing being produced with a minimum amount of scarring or deformity. This occurs with little or moderate inflammatory reaction of the surrounding or overlying healthy tissue necessarily included in the exposure, from which it regularly returns to a normal condition.

This selective action of radium, or particular susceptibility of the malignant tissue to the rays, is conceded to be even more pronounced in degenerations of connective tissue than in those of epithelial tissue. It is equally pronounced on embryonic vascular tissue—nevoid growths—and a specific alterative and restorative action in this tissue can be produced, resulting in a shrinking of the tissue and an obliteration of vessels and cavernous spaces with little or no real destruction of tissue.

The effects of an application of radium begin to make themselves demonstrable in from 2 or 3 to 10 days and are progressive up to 3 weeks, depending on the character and the amount of the irradiation. Radium rays are germicidal but act very slowly.

## THERAPEUTICS OF RADIUM IN SURGERY

Since Becquerel received his notorious burn from carrying some of this substance in his pocket, shortly after its discovery and isolation, Wickham and Degrais have been the leading investigators therapeutically, and it is largely due to their publications that others have resorted to its use in surgical affections and that we now have what working knowledge we possess in its various therapeutic applications. So comparatively little is yet understood of its physics and chemistry that it must necessarily still be in its infancy from a therapeutic point of view, but statistical reports, going up into the thousands, have demonstrated its peculiar qualifications and fitness for the treatment of certain surgical conditions and to-day it must be recognized as a useful and even essential part of a surgical armamentarium. That it has its limitations must be conceded, but that its use may become less limited in the future is within the realm of probability.

That it is a powerful force in any considerable quantity should be constantly remembered, and the greatest care should be exercised in its applications, both for the patient and for the operator. Severe dermatitis and extensive burns which may be very painful and slow in healing, may result from the careless handling of radium apparatus. Even keratoses and degenerative ulcerations may result from repeated exposures but, generally speaking, they are less to be feared and more easily controlled than similar conditions resulting from X-ray exposures.

**Warts and Papillomata, Senile and Seborrhoic Keratoses.**—Warts and papillomata, senile and seborrhoic keratoses yield readily to radium applications. The ordinary *papillomatous wart* will undergo a retrograde metamorphosis, returning to a normal tissue without apparent inflammatory reaction or the slightest scarring when exposed by contact to even small amounts of radium element filtered through 2 layers of rubber tissue for a sufficient length of time.

A cell, 2½ to 3 mg., of the element uniformly spread over an area of ¼ sq. cm. so applied for 30 minutes is satisfactory on such a lesion.

*Papillomata* of the hollow or tubular portions of the body, such as of the *larynx,* can be removed permanently without ulceration or contractures, but here it is necessary to use much larger amounts of the element, filtered through thin layers (½ to 1 mm.) of platinum or silver foil. It can be carried to its destination in the closed end of a tubular container or an applicator is inserted through an open incision made for the purpose. At least 50 mg. would be required here.

*Senile and seborrhoic keratoses,* so frequently found on the faces of older people, particularly those who have been exposed to the weather, fade away as if by magic, and even where a degeneration has become established, it is of such a low grade of malignancy that small non-inflammatory applications of lightly filtered radium permanently remove it without visible scarring.

*X-ray keratoses and ulcerations,* such as are seen to-day on the hands of the older X-ray operators, often respond kindly to radium irradiations and with less discomfort than usually follows applications of liquid air and carbonic snow.

**Fibromata** undergo a retrograde metamorphosis under the influence of radium and interesting reports are at hand of a considerable success with it in the treatment of fibromata of the uterus.

In the *interstitial variety,* frequently demanding a complete extirpation, radium has in a few instances spared the patient so extensive an operation. Very considerable amounts of well-filtered radium passed up into the cavity of the uterus and surface irradiations, through the abdominal wall from several locations directed toward the uterus, are said to be of advantage in combination. The metrorrhagia from the endometritis accompanying this condition is regularly favorably influenced.

**Keloids and Disfiguring Scars.**—Wickham and Degrais and other observers have removed most successfully deforming and painful keloids by means of radium irradiations. The so-called *spontaneous keloid* regularly responds to non-inflammatory doses, leaving in its place a pliable, level, whitish, shiny tissue that does not tend to relapse. Here again a selective action on tissue varying from the normal must explain these excellent results. In a similarly satisfactory way do *acne keloids* and *keloidal cicatrices* fade away, as it were, under its influence, with moderate doses of slightly filtered rays. The old hard, *fibrous keloids* and *fibrosclerotic bands* require more intensive applications, even to the production of an inflammatory reaction or a superficial ulceration, when healing is said to begin in the deep-seated tissue of the keloid in embryonic cells, which gradually replace the mass. When refractive to this method of treatment, surgical extirpation of these dense tissues can be resorted to with mild prophylactic irradiations directly healing is established. Excellent results have followed in my hands even after several recurrences following excision.

**Angiomata.**—The above-mentioned investigators, with Gaud, have seen microscopically in angiomatous tissue after radium applications "an alteration of the cells which lined the inner surface of the blood-vessels and connective tissue surrounding them, causing an obliteration of the small vessels and resulting in a sclerotic transformation and exsanguination of the tumor." In this way superficial level *port wine stains* are regularly decolorized by slightly filtered doses of radium with little or no inflammatory reaction or scarring. As these lesions usually are situated about the face and great care must, therefore, be used in determining the dosage, Kromayer light applications, with a thick blue glass filter and firm pressure, should be preferred, as they are equally effective and without danger of resulting scarring. In the lesions that are more or less infiltrated and in which it is difficult or impossible to press out the discoloration, radium alone or in combination with the Kromayer light seems to give the best results. Extensive, flexible, radiferous toiles, separated from the lesion by ½ to 2 mm. of foil, applied over prolonged and repeated periods, through their more penetrating rays, can produce the above-described changes in this tissue and often give most excellent cosmetic results.

*Extensive, cavernous, erectile angiomata* have been reported and pictured satisfactorily removed by repeated applications of considerable amounts of well-filtered radium, and equally brilliant results are to be attained in subcutaneous cavernous angiomatous tumors where surgery has heretofore been quite helpless. Surpenetrating rays from large amounts of the element well filtered (2 to 3 mm. of aluminum) are required, and the "cross-fire" method by irradiations from various points of vantage directed toward the tumor (from the mucous membrane out, also in lesions of the cheeks) is necessary in order to project enough rays into the tissues without destruction of the overlying skin or mucous membrane.

Often it is necessary, after a certain amount of sclerosis is established in the tumor, to surgically imbed tubes of moderately filtered radium throughout the mass. Naturally, inflammation, telangiectases and scarring can result from such strenuous but necessary methods of raying. It is here that radium has probably achieved its greatest success for, up to the present, no such uniformly good results have been attained by other methods.

**Malignant Neoplasms, Cutaneous Epitheliomata, etc.—It is in the treatment of this latter condition that radium has clinically demonstrated its wonderful power of changing and destroying cancer cells, more or less permanently, with the least possible inconvenience and deformity and the best possible end results.**—In lesions about the face, and particularly those at or near the eye, radium has proven to be at great advantage over other therapeutic agents, because of the ease and comfort of its application, its cosmetic results—the scar being a comparatively level, smooth and perfectly pliable one without contractures—and the comparative infrequence of recurrences.

The more recent reports of the Radium Institute of London and of the Vienna Institute concur with other opinions that, generally speaking, **radium even in moderate doses, if applied over a sufficient period of time, is preferable to other methods of treatment,** and Pinch, of the former institution, thinks it may be effective in this class of case because single doses with full-strength applicators unscreened can be used. Because of their situation these results would seem to be due to the ability to secure the penetration of rays in sufficient amount to all parts of the tumor.

The single or massive dose method would seem to be the method of choice with considerable amounts of unfiltered or slightly filtered rays, and this method is practicable because of the comparative susceptibility of these diseased tissues to radium irradiations, it being estimated that the margin of time exposure between the destruction of the cancer cells and up to a destruction of the adjacent normal tissue cells is at least a fifth of the whole time necessary to destroy the cancer, a pretty safe working margin for any slight error in over-exposure.

The *superficial epitheliomata of the rodent ulcer type* are the most easily influenced of the skin cancers, but radium is very effective in either the cicatricial, squamous, ulcerating or fungating variety, the length and strength of exposures varying according to the depth of the lesion. Flat varnish applicators of varying dimensions have an advantage in cutaneous epitheliomata, but a cell or tube may be used and irradiations made at a short distance (½ inch) from the lesion in order to cover a larger area at each application, remembering the law of inverse proportions in this latter method.

Extensive *indurated cutaneous epitheliomata in the region of the nares and eyes,* involving the subcutaneous and underlying tissue, even with bony involvement, are as successfully treated by massive doses of light and moderately filtered radium as by surgical intervention and, when successful, with far better cosmetic results. A cure, dating back a sufficient number of years to be so called, of a very extensive involvement of one naris and the corresponding maxillary sinus, is reported.

*Epitheliomata of the mucous membranes* have been notoriously less influenced and are more apt to recur after radium, than skin cancers. This may be due to their greater lymphatic supply with a consequent tendency to metastases, to a greater susceptibility of normal mucous membrane tissue than is the case with normal skin tissue, and to the inconvenient location of the lesion, often making prolonged application difficult.

*Inoperable lesions* can be regularly reduced and the pain and discharge diminished, and latterly, with the larger amounts of radium at our disposal, a total dissipation has occasionally resulted with a fair prospect of permanent relief. Generally speaking, up to the present writing, no operable case of mucous membrane cancer should be treated by radium before it is surgically removed, but radium should be resorted to in all inoperable cases and is recommended by several observers as a prophylactic measure of considerable value. *Metastatic glands,* when discovered or often even where suspected, should always be exposed and surgically extirpated.

*Epitheliomata of the lower lip* would seem to be more successfully treated, no matter how superficial or limited, by surgery than by radium, except as a prophylactic measure after operation. Should radium therapy for cosmetic reasons be demanded here, extensive applications of well-filtered radium could be employed both from the mucous membrane and skin surfaces directed toward the interior of the lip, and an accompanying surgical operation of the submaxillary glandular tissue should be advised. It is to be remembered that occasionally an **extensive, inoperable mucous membrane cancer can be made operable** by powerful radium applications and 1 or 2 such postoperations apparently have been successful.

*Inoperable carcinomas of the tonsil and pharynx* are reported improved and lately, since larger amounts of radium can be obtained, even more may be looked for, from the patient's point of view, by a combination of imbedation, cross-fire and surface irradiations.

*Cancer of the tongue,* with the usual involvement of the sublingual glandular tissue, even in the early cases, is a surgical indication, but recurrences and inoperable lesions should be intensively irradiated, for occasionally a startling amelioration of the lesion and symptoms intervenes.

**Deep-seated Cancers, Carcinoma, Sarcoma, etc.**—Wickham, in his book published in 1913, sums up his experience with radium from the Laboratoire Biologique du Radium in these classes of cases as follows: **"Acknowledging their special and very selective susceptibility to the influence of radium, I do not consider this action complete enough to warrant the use of radium as a primary therapeutic agent in any form of operable cancer with the single exception of cancer of the skin."** And the Radium Institutes of both London and Vienna, after a big experience, absolutely concur with him in this opinion. Marvelous improvement has resulted and even apparent cures in some inoperable cases following the more recent methods of irradiation, and the above authorities urge the use of radium in **inoperable cancers,** no matter how severe and extensive they may be. More or less relief of pain or of discharge or pressure symptoms through the reduction of the size of the mass can be expected, as after no other known means of treatment, in these inoperable cases.

Inoperable tumors can sometimes be made operable, and a cachectic general condition can often be greatly improved by radium applications to the offending mass or masses. The increasing success, as shown by results reported in the more recent years, undoubtedly has been due to a concerted effort to project greater masses of rays more equally distributed throughout the tumor and the immediately surrounding tissues. This is accomplished by the employment of far larger amounts of the element than were formerly used, by the "cross-fire" method of application of rays projected into the tumor from various parts of its circumference, and the imbedding into the mass, through surgical incision, of one or more strong tubes suitably distributed and well filtered with very prolonged exposures to get a greater penetration (2 to 4 mm. of platinum foil). In the irradiation of these cancers it is generally conceded that tubes containing less than 25 mg. of the element are inefficient, and larger tubes are proportionately more effective. The **dangers** of such extensive and powerful applications should always be borne in mind and with reasonable care can mostly be avoided. **Dermatitis, radium burns and ulceration** can result even though the Alpha and softer Beta rays are filtered out. Other dangers are **thrombosis or hemorrhage of an included vessel, ulceration of a hollow viscus, and sloughing and ulceration at the site of imbedded tubes, either from the breaking down of destroyed cells or a secondary infection,** which is exceedingly apt to occur, due to the lowered resistance against germ invasion of the irradiated cells, with a more or less severe or fatal toxic absorption from either source.

*Epithelial cancers of the uterus, rectum and breast* have seemed to be more influenced by radium treatment than the other inoperable or recurring epitheliomata.

*Carcinoma of the cervix and uterus* is anatomically well situated for radium applications, owing to its tendency to spread around the walls of the organ, leaving the cavity of the vagina, cervix and uterus patent for the insertion of radium tubes on various applicators or in catheters. A 50-mg. tube of the element filtered with 2 to 4 mm. of foil and left in place for 24 hours will relieve pain, hemorrhage and discharge and, in a few rare cases, the lesion has entirely disappeared over a period of months after radium treatment, the cervix and uterus tending to resume somewhat their original contour and appearance. In the more extensive cases, curettage of the fungating mass, involving the uterus or cervix and vagina, followed by severe irradiation and irradiation of the recto-vaginal septum by means of a well-filtered tube in the rectum, has been productive of a marked regeneration and relief.

Such applications to *inoperable carcinomata of the rectum* have occasionally prolonged life for months and even years and saved the patient the discomfort of an artificial anus. *Recurring nodules and inoperable carcinomata of the breast* have occasionally been dissipated by radium and, when this treatment has been combined with resection of diseased glands, a few cases have been free after many months. In most extensive cases well-filtered radium may be imbedded within the tumor—inserted beneath it by elevating the mass and passing the applicator along the chest wall—and may be applied from without by varnish applicators and tubes, over mapped-out areas of the surface, directed toward the center of the mass, thus, in so far as possible, insuring a sufficient and equal distribution of rays throughout the entire mass.

A striking percentage of *excisions, without recurrence of carcinomata of the breast,* prophylactically irradiated directly healing was established, are reported, and a few cases have been made operable by radium applications.

*Internal cancers involving or in the immediate vicinity of vessels and viscera* must be approached with care because of the possibility of a destruction of the walls of these organs; nevertheless, in these usually inoperable cases, something can be hoped for from a surgical exposure, with or without a partial extirpation of the malignant mass followed by irradiation by imbedation. Frequently severe shock and septic infection follow such an effort, but if survived, a very considerable prolongation of life can result.

*Inoperable carcinoma of the esophagus and stomach* can be irradiated by esophageal radium carriers or, in the case of the stomach, through a gastrotomy wound made for the purpose or for exploration, often with the amelioration of distressing symptoms and a prolongation of life.

*Cancers of the neck and groin,* involving the deep vessels, more or less have by irradiation after partial extirpation shown marvelous improvement up to an apparent resorption of the mass.

It is in the *malignant sarcomata* that radium seems to exert its greatest selective action. Several cases of *giant-celled sarcoma of the femur* have disappeared entirely after imbedding tubes of radium uniformly throughout the mass. One or 2 very extensive cases, dating back several years, are apparently free from disease. This method of treatment is to be considered in comparison with so serious and deforming a surgical procedure as amputation at the hip, often followed by extension of the disease in spite of so heroic an effort.

Even *extensive sarcomata of the parotid gland and tonsil* are sometimes marvelously influenced, and radium, by imbedation and surface irradiation, is here indicated when surgery has failed or is likely to fail.

*Inoperable sarcoma of the prostate* offers a field for radium therapy by imbedding tubes in the mass itself and irradiations directed toward the mass per bladder and per rectum.

*Epulis,* when it defines an *osteosarcoma,* is readily influenced by radium rays, and inoperable or borderline cases should be so treated; a preliminary curettement of the softer broken-down tissue is advantageous. Here again large amounts of well-filtered radium are essential.

The indications for radium treatment of *metastatic glandular involvement* in cancerous disease are the same as in cancer itself—extensive inoperable masses of enlarged matted glands are reduced and the consequent pain and swelling from pressure often present are more or less relieved.

Koenig and Gans, after a large clinical experience with considerable quantities of radium at their disposal, have formulated the following indications for the radium treatment of cancer:

1. When cancer is operable, but can be easily controlled by sight and touch, employ radium.

2. When cancer is operable and not easily controlled by sight and touch, operate, provided the postoperative mortality is not too high.

3. When inoperable, radiate.

4. After operation, when there is a probability of a recurrence, radiate.

These broad indications are in a fair way to be justified in the near future. In the face of the startling results that have been attained in the radium treatment of cancer, it is well to bear in mind that the disappearance of a cancer growth and the cure of cancer disease are far from synonymous terms.

A field for experimentation along these lines lies in the injection of soluble and insoluble salts of radium in and around the tumor, in water and oily media, respectively. The results in animal experimentation up to the present, while not very striking, are not yet condemning.

**Tuberculosis.**—*Lupus vulgaris and tuberculous nodules* are favorably influenced by radium but it is necessary to produce a considerable inflammatory reaction to get results, with more or less scarring and telangiectases resulting. Ultraviolet rays from the Kromayer or Finsen lights are equally effective, with better cosmetic results, and are, therefore, to be preferred. In *infiltrated, thick, granulomatous lupus vulgaris* lesions, inflammatory radium exposures followed by Kromayer light treatments after the inflammatory reaction has subsided are of advantage. Rather extensive and lightly filtered irradiations are here indicated.

In *lupus of the mucous membrane,* however, because of its inaccessibility, the various radium appliances are the most convenient and successful therapeutic agents. Radium has healed *tuberculous sinuses,* and *ulcers and tuberculous glands* are frequently reduced by ultrapenetrating radium rays from the surface. There seems to be no particular susceptibility on the part of tuberculous tissue over other tissues to rays of radium and they are not actively germicidal.

**Goiter.**—Several cases of exophthalmic goiter have been reduced and the nervous and other symptoms relieved by frequently repeated exposures to ultrapenetrating rays. The "cross-fire" method, with large amounts of the element, can be applied conveniently in these cases because of the anatomical situation and configuration of the tumor. Radium tubes may also be imbedded in the substance of the gland.

**Hodgkin's Disease.**—Some cases are temporarily relieved, the glandular and splenic swellings reduced and the anemia and blood picture improved by irradiations with large amounts of ultrapenetrating rays.

A case of *splenomegaly* is reported with a reduction from 300,000 to 6,000 in the white cell count and a greatly enlarged spleen reduced to normal in a few weeks, improvement still persisting after several months. Inflammatory glandular enlargements in general are more or less influenced by a decongestive action of radium rays without any inflammatory reaction.

**Leukoplakia.**—Leukoplakia, a condition prone to degenerate, notoriously rebellious to treatment and, because of the extent of the lesions, often not amenable to surgical methods, when thick, indurated, mammillated and cracked, can be reduced to a smooth, level, grayish membrane by slightly inflammatory irradiations, the pain and tenderness relieved and the liability to degeneration diminished. The level or slightly grayish, painless patches, show little improvement and are better treated with soothing or mildly astringent lotions and applications and the interdiction of tobacco, alcohol and irritating foods and drinks.

**Chronic, sluggish ulcerations,** such as are often seen on the lower legs, with a poor circulation and with varicose veins, can often be made to heal by repeated, mild, stimulating applications of radium.

**Neuralgic and Itching Conditions.**—The marvelous neurotrophic effect of radium in relieving indefinite neuralgic and itching conditions and its broad application in the field of dermatology should always be remembered.

Compared with the X-ray, radium in sufficient amounts will accomplish, therapeutically, anything that the former can do. Its Gamma rays are more penetrating than any of the X-rays so far produced, and its portability and the convenience of the method of application are important considerations.

The stability of the amount and character of rays emitted from an hermetically sealed apparatus is a very important advantage in radium therapy.

# INDEX

(2)