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ILITARY MEDICAL MANUALS

GENERAL EDITOR:
RGEON-GEN. SIR ALFRED KEOGH
G.C.B., M.D., F.R.C.P.

# WOUNDS OF THE VESSELS

L. SENCERT

EDITED BY

F. F. BURGHARD

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# WOUNDS OF THE VESSELS

BY

L. SENCERT

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EDITED WITH A PREFACE BY

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SURGEON TO KING'S COLLEGE HOSPITAL, AND LATELY CONSULTING SURGEON TO THE BRITISH ARMIES IN FRANCE

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# GENERAL INTRODUCTION

The infinite variety of injuries which any war presents to the surgeon gives to military surgery a special interest and importance. The special interest and importance, in a surgical sense, of the great European War lies not so much in the fact that examples of every form of gross lesion of organs and limbs have been seen, for if we read the older writers we find little in the moderns that is new in this respect but is to be found in the enormous mass of clinical material which has been presented to us and in the production of evidence sufficient to eliminate sources of error in determining important conclusions. For the first time also in any campaign the labours of the surgeon and the physician have had the aid of the bacteriologist, the pathologist, the physiologist, and indeed of every form of scientific assistance, in the solution of their respective problems. The clinician entered upon the great war armed with all the resources which the advances of fifty years had made available. If the surgical problems of modern war can be said not to differ sensibly from the campaigns of the past, the form in which they have been presented is certainly as different as are the methods of their solution. The achievements in the field of discovery of the chemist, the physicist and the biologist have given the military surgeon an advantage in diagnosis and treatment which was denied to his predecessors, and we are able to measure the effects of these advantages when we come to appraise the results which have been attained.

But although we may admit the general truth of these statements, it would be wrong to assume that modern scientific knowledge was, on the outbreak

of the war, immediately useful to those to whom the wounded were to be confided. Fixed principles existed in all the sciences auxiliary to the work of the surgeon, but our scientific resources were not immediately available at the outset of the great campaign ; scientific work bearing on wound problems had not been arranged in a manner adapted to the requirements—indeed, the requirements were not fully foreseen ; the workers in the various fields were isolated, or isolated themselves, pursuing new researches rather than concentrating their powerful forces upon the one great quest.

However brilliant the triumphs of surgery may be —and that they have been of surpassing splendour no one will be found to deny—experiences of the war have already produced a mass of facts sufficient to suggest the complete remodelling of our methods of education and research.

The series of manuals, which it is my pleasant duty to introduce to English readers, consists of translations of the principal volumes of the " Horizon " Collection, which has been appropriately named after the uniform of the French soldier.

The authors, who are all well-known specialists in the subjects which they represent, have given a concise but eminently readable account of the recent acquisitions to the medicine and surgery of war which had hitherto been disseminated in periodical literature.

No higher praise can be given to the Editors than to say that the clearness of exposition characteristic of the French original has not been lost in the rendering into English.

## MEDICAL SERIES

The medical volumes which have been translated for this series may be divided into two main groups, the first dealing with certain epidemic diseases, including syphilis, which are most liable to attack soldiers, and the second with various aspects of the

neurology of war. The last word on *Typhoid Fever*, hitherto "the greatest scourge of armies in time of war," as it has been truly called, will be found in the monograph by MM. Vincent and Muratet, which contains a full account of recent progress in bacteriology and epidemiology as well as the clinical features of typhoid and paratyphoid fevers. The writers combat a belief in the comparatively harmless nature of paratyphoid and state that in the present war hæmorrhage and perforation have been as frequent in paratyphoid, as in typhoid fever. In their chapter on diagnosis they show that the serum test is of no value in the case of those who have undergone anti-typhoid or anti-paratyphoid vaccination, and that precise information can be gained by blood cultures only. The relative advantages of a restricted and liberal diet are discussed in the chapter on treatment, which also contains a description of serum-therapy and vaccine-therapy and the general management of the patient.

Considerable space is devoted to the important question of the carrier of infection. A special chapter is devoted to the prophylaxis of typhoid fever in the army. The work concludes with a chapter on preventive inoculation, in which its value is conclusively proved by the statistics of all countries in which it has been employed.

MM. Vincent and Muratet have also contributed to the series a work on *Dysentery, Cholera and Typhus* which will be of special interest to those whose duties take them to the Eastern Mediterranean or Mesopotamia. The carrier problem in relation to dysentery and cholera is fully discussed, and special stress is laid on the epidemiological importance of mild or abortive cases of these two diseases.

In their monograph on *The Abnormal Forms of Tetanus*, MM. Courtois-Suffit and Giroux treat of those varieties of the disease in which the spasm is confined to a limited group of muscles, *e.g.* those of the head, or one or more limbs, or of the abdomino-

thoracic muscles. The constitutional symptoms are less severe than in the generalized form of the disease, and the prognosis is more favourable.

The volume by Dr G. Thibierge on *Syphilis in the Army* is intended as a *vade mecum* for medical officers in the army.

Turning now to the works of neurological interest, we have two volumes dealing with lesions of the peripheral nerves by Mme. Athanassio-Benisty, who has been for several years assistant to Professor Pierre Marie at La Salpêtrière. The first volume contains an account of the anatomy and physiology of the peripheral nerves, together with the symptomatology of their lesions. The second volume is devoted to the prognosis and treatment of nerve lesions.

The monograph of MM. Babinski and Froment on *Hysteria or Pithiatism and Nervous Disorders of a Reflex Character* next claims attention. In the first part the old conception of hysteria, especially as it was built up by Charcot, is set forth, and is followed by a description of the modern conception of hysteria due to Babinski, who has suggested the substitution of the term "Pithiatism," *i.e.* a state curable by persuasion, for the old name hysteria. The second part deals with nervous disorders of a reflex character, consisting of contractures or paralysis following traumatism, which are frequently found in the neurology of war, and a variety of minor symptoms, such as muscular atrophy, exaggeration of the tendon reflexes, vasomotor, thermal and secretory changes, etc. An important section discusses the future of such men, especially as regards their disposal by medical boards.

An instructive companion volume to the above is to be found in the monograph of MM. Roussy and Lhermitte, which embodies a description of the psychoneuroses met with in war, starting with elementary motor disorders and concluding with the most complex represented by pure psychoses.

## SURGICAL SERIES

When the present war began, surgeons, under the influence of the immortal work of Lister, had for more than a quarter of a century concerned themselves almost exclusively with elaborations of technique designed to shorten the time occupied in or to improve the results obtained by the many complex operations that the genius of Lister had rendered possible. The good behaviour of the wound was taken for granted whenever it was made, as it nearly always was, through unbroken skin, and hence the study of the treatment of wounds had become largely restricted to the study of the aseptic variety. Septic wounds were rarely seen, and antiseptic surgery had been almost forgotten. Very few of those who were called upon to treat the wounded in the early autumn of 1914 were familiar with the treatment of grossly septic compound fractures and wounded joints, and none had any wide experience. To these men the conditions of the wounds came as a sinister and disheartening revelation. They were suddenly confronted with a state of affairs, as far as the physical conditions in the wounds were concerned, for which it was necessary to go back a hundred years or more to find a parallel.

Hence the early period of the war was one of earnest search after the correct principles that should be applied to the removal of the unusual difficulties with which surgeons and physicians were faced. It was necessary to discover where and why the treatment that sufficed for affections among the civil population failed when it was applied to military casualties, and then to originate adequate measures for the relief of the latter. For many reasons this was a slow and laborious process, in spite of the multitude of workers and the wealth of scientific resources at their disposal. The ruthlessness of war must necessarily hamper the work of the medical scientist in almost every direction except in that of

providing him with an abundance of material upon which to work. It limits the opportunity for deliberate critical observation and comparison that is so essential to the formation of an accurate estimation of values; it often compels work to be done under such high pressure and such unfavourable conditions that it becomes of little value for educative purposes. In all the armies, and on all the fronts, the pressure caused by the unprecedented number of casualties has necessitated rapid evacuation from the front along lines of communication, often of enormous length, and this means the transfer of cases through many hands, with its consequent division of responsibility, loss of continuity of treatment, and absence of prolonged observation by any one individual.

In addition to all this, it must be remembered that in this war the early conditions at the front were so uncertain that it was impossible to establish there the completely equipped scientific institutions for the treatment of the wounded that are now available under more assured circumstances, and that progress was thereby much hampered until definitive treatment could be undertaken at the early stage that is now possible.

But order has been steadily evolved out of chaos, and many things are now being done at the front that would have been deemed impossible not many months ago. As general principles of treatment are established it is found practicable to give effect to them to their full logical extent, and though there are still many obscure points to be elucidated and many methods in use that still call for improvements, it is now safe to say that the position of the art of military medicine and surgery stands upon a sound foundation, and that its future may be regarded with confidence and sanguine expectation.

The views of great authorities who derive their knowledge from extensive first-hand practical experience gained in the field cannot fail to serve as a

most valuable asset to the less experienced, and must do much to enable them to derive the utmost value from the experience which will, in time, be theirs. The series covers the whole field of war surgery and medicine, and its predominating note is the exhaustive, practical and up-to-date manner in which it is handled. It is marked throughout not only by a wealth of detail, but by clearness of view and logical sequence of thought. Its study will convince the reader that, great as have been the advances in all departments in the services during this war, the progress made in the medical branch may fairly challenge comparison with that in any other, and that not the least among the services rendered by our great ally, France, to the common cause is this brilliant contribution to our professional knowledge.

A glance at the list of surgical works in the series will show how completely the ground has been covered. Appropriately enough, the series opens with the volume on *The Treatment of Infected Wounds*, by A. Carrel and G. Dehelly. This is a direct product of the war which, in the opinion of many, bids fair to become epoch-making in the treatment of septic wounds. It is peculiar to the war and derived directly from it, and the work upon which it is based is as fine an example of correlated work on the part of the chemist, the bacteriologist and the clinician as could well be wished for. This volume will show many for the first time what a precise and scientific method the " Carrel treatment " really is.

The two volumes by Professor Leriche on *Fractures* contain the practical application of the views of the great Lyons school of surgeons with regard to the treatment of injuries of bones and joints. Supported as they are by an appeal to an abundant clinical experience, they cannot fail to interest English surgeons, and to prove of the greatest value. It is only necessary to say the *Wounds of the Abdomen* are dealt with by Dr Abadie, *Wounds of the Vessels* by Professor Sencert, *Wounds of the Skull*

*and Brain* by MM. Chatelin and De Martel, and *Localisation and Extraction of Projectiles* by Professor Ombrédanne and R. Ledoux-Lebard, to prove that the subjects have been allotted to very able and experienced exponents.

ALFRED KEOGH.

# EDITOR'S PREFACE

War-wounds of the vessels do not perhaps form a very extensive class of injury compared with certain others, such as fractures, wounds of the joints, or injuries of the head, abdomen, or thorax, but, owing to the urgency of the symptoms they produce, and the serious consequences to which they give rise, their proper treatment when they do occur is a matter of great importance. Up to the present time very little has appeared in the surgical literature of the Allies upon this subject, and a good deal of uncertainty exists as to the best line of treatment to be followed. Therefore a review of the whole subject has become a real need, and this Professor Sencert has endeavoured to supply in the volume before us. In it he addresses himself chiefly to those at the Front, upon whom falls the important duty of dealing at once with these severe cases as they are brought in, and his object is, in his own words, "to convey a clear idea of what should be done in each class of case," and to give "a brief account of the best method of doing it." A study of his book will show that he has succeeded admirably in his aim. The possible methods of dealing with wounds of the blood-vessels and their sequelæ are so numerous, that the average surgeon may well be pardoned for having a somewhat

confused idea as to the exact indications for each of them, and as a result the views upon the treatment of these important injuries in war have been apt to be a little hazy, as a perusal of the literature of the subject will show. Professor Sencert, however, has brought to bear upon the problem a great deal of critical acumen, and has checked his views by an appeal to the wide practical experience of himself and his fellow-workers, and the result is a well-thought-out line of treatment based upon sound anatomical and pathological grounds that all can understand clearly.

In view of the claims made before the war for the various reparative suture methods, and the rather extensive use made of them by the surgeons attached to the armies of the Central Powers, it is interesting to note the frequency with which Professor Sencert advocates the older method of ligature—a view that appears to be in harmony with the practice in our own service.

It is a matter for congratulation that we at last have a work which aims at putting the treatment of this very important group of war-wounds upon a sound and logical basis, and I am sure all its readers will join with me in congratulating Professor Sencert upon the lucidity and thoroughness with which he has accomplished a difficult task.

F. F. BURGHARD.

# INTRODUCTION

THE object of this book is to describe the progress which has been made in the practical surgery of the blood-vessels during these two years of war.

Hospital experience and an excellent literature of the subject had long familiarised us with the vascular wounds incidental to civilian life. The experiments of the Val-de-Grâce School had shown what would be the nature of the wounds inflicted upon the blood-vessels by projectiles employed in the next war. But in 1914 these results were still unconfirmed by practical experience. During the two years which have elapsed since then, however, the number of vascular wounds which have come under observation has been very great. It has been possible to observe the various anatomical types in the living subject; to follow the stages of their anatomical and clinical development; and, on the foundation thus provided, to establish rational and considered methods of treatment.

The first part of the book consists of a study of the wounds of the large blood-vessels in general. In the second part, wounds of particular vessels are described, special attention being given to the operative problems presented by each class of case.

I must, however, emphasise the fact that the main

principle governing the surgery of the blood-vessels does not differ from that governing the surgery of war-wounds in general. The last two years have abundantly shown that in war-surgery there is one ruling principle and one only, namely, that of immediate intervention. With very rare exceptions, all war-wounds should be operated upon at once. Timely exposure of the entire damaged area is alone able to prevent infective complications. Methodical surgical excision of the wound is the sole method of converting a contused and infected wound into one which is clean and healthy, and of assuring its clinical progress under definitely aseptic conditions.

This rule is nowhere more inexorable than in its application to wounds of the vessels. Early operation affords the only means of guarding against reactionary and secondary hæmorrhage, and of preventing those mechanical and septic complications, to the development of which the infiltration of blood in the tissues is so eminently favourable. It is, moreover, the sole measure which guards against the occurrence of later complications, such as aneurism. Here, as elsewhere, the only rational method is the preventive method.

My sincere acknowledgments are due to Professor Jacob, and to my friend Latarjet, who have so kindly placed at my disposal for the purposes of this book the valuable resources of the Val-de-Grâce Museum.

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CONTUSION OF THE VESSELS



## *PART TWO*

## WOUNDS OF INDIVIDUAL VESSELS

# *Part One*

# Wounds of the Vessels in General

# WOUNDS OF THE VESSELS

## CHAPTER I

## ANATOMICAL AND PHYSIOLOGICAL CONSIDERATIONS

### 1. Anatomical Description

WOUNDS produced by rifle-bullets, shrapnel-balls, and shell-splinters vary greatly from one another. In the case of the arteries, the wounds caused by rifle-bullets may be lateral and partial, complete and circumferential, or perforating.

Lateral wounds are caused by projectiles striking the outer third or fourth of the transverse diameter of the vessel (fig. 1). The adventitia, the middle and the internal coats, are lacerated, whilst radiating rents of the intima, of varying extent, prolong the external lacerations along the interior of the vessel. The retractility of the middle coat tends to separate the lips of the vascular wound, and also to cause a slight change in the axis of the vessel, so that the segments above and below are deflected towards each other, thus forming an obtuse angle with the wound at its apex (fig. 1). This double action of the middle coat results in an enlargement of the lateral wound,

which continues to gape, thus encouraging hæmorrhage. These lateral wounds vary in size from a mere slit to complete division of the vessel (fig. 2).

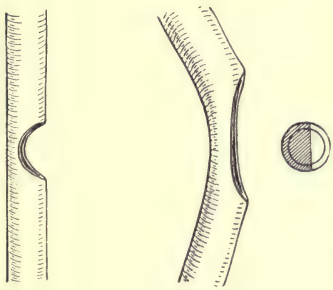


Fig. 1.—Diagram showing lateral wound of an artery.

Complete division, even of the large vessels, is more frequent than one would suppose, and is almost the only kind of wound met with in medium-sized arteries. Its frequency in large arteries is explained by the fact that at short range the explosive effect of the bullet is such, that the artery traversing its track is extensively torn and broken up, sometimes with great loss of substance (fig. 3).

I saw a young soldier who had been wounded by a bullet, which entering the right buttock emerged at the level of Poupart's ligament, encountering the femoral artery on the way. The vessel was broken up; there was a gap of two inches between its upper and lower extremities, and these were very much frayed (fig. 4).

Fig. 2.—Diagram showing two lateral wounds of an artery.

At medium or long range, on the other hand, the bullet is less stable, and is, in consequence, very easily diverted. Hence, instead of being

struck normally by the point, the arterial wall is hit more or less obliquely by the side of the bullet, which tears it in the same way as a large projectile.

For the same reason, few perforations are met with in arteries, and then only in the larger trunks. Figs. 5 and 6 show a perforation of the common iliac artery and one of the common carotid by rifle-bullets. These perforations are smaller when the velocity of the bullet is low. Their diameter always appears less than that of the bullet. This is due to the fact that the artery is forced back and stretched before being pierced, in such a way that, when the bullet has passed and the vessel recovers itself, the edges of the wound come together, and the extent of the lesion is lessened. Sometimes the perforation is situated in the middle of the vessel, and sometimes nearer one margin, when it closely resembles a lateral wound (fig. 7).

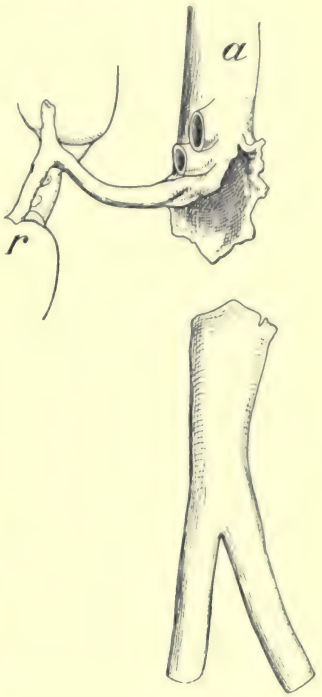


FIG. 3.—Complete division of the abdominal aorta by a rifle-bullet. Lesion of the renal artery. (Latarjet's case. Val-de-Grâce Museum.)

In the veins, also, lateral wounds, complete division or perforation, are produced by rifle-bullets. The

vein is less elastic than the artery, and ruptures

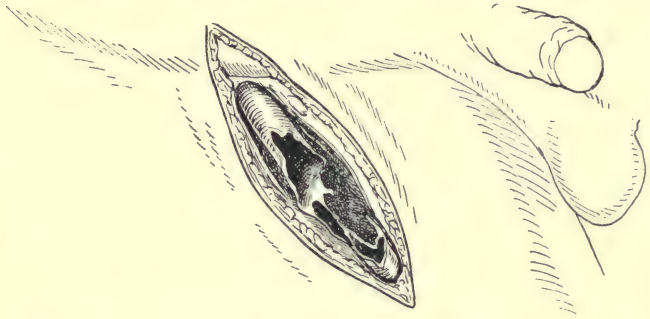

FIG. 4.—Complete section of the femoral artery by a rifle-bullet. (Author's case.)

rather more easily in consequence. Contrary to what might have been expected from previous experience, complete rupture of the companion vein is often seen in conjunction with a lateral wound of the artery. The ends of the divided vein are clean and hardly lacerated at all, and their walls come together without retraction of the internal coat. Lateral wounds and perforations are also met with. When a bullet passes between an artery and a vein, it may leave a lateral wound of both. In such a case the

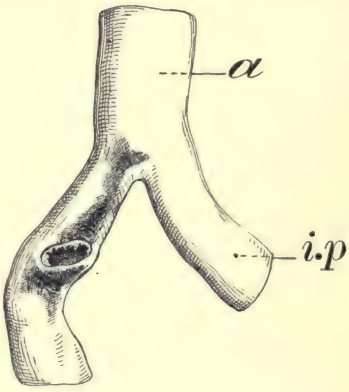


FIG. 5. — Perforation of the right common iliac artery by a rifle-bullet. (Latarjet's case. Val-de-Grâce Museum.)

openings face each other, and adhere by their margins immediately after the passage of the missile.

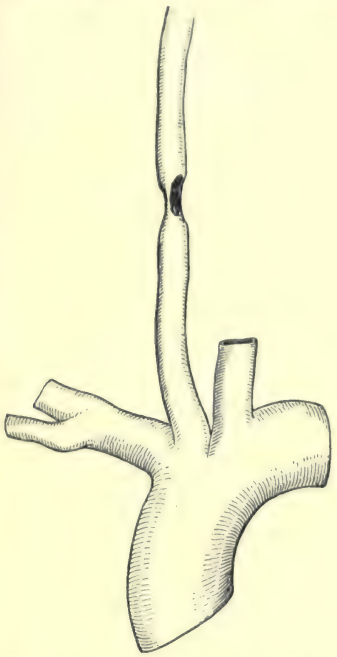


FIG. 6.—Perforation of the left common carotid by a rifle-bullet. Death almost immediate. (Latarjet's case. Val-de-Grâce Museum.)

As a matter of fact, associated wounds of both artery and vein are very frequent. Isolated injury of either vessel may of course occur, but they are more often found together. Any of the varieties of injury may be found in combination.

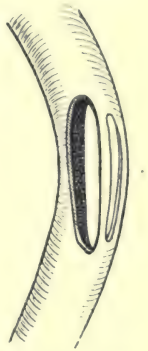

FIG. 7. — Diagram showing lateral perforation of an artery.

There may be a perforation of artery and vein, complete division of both vessels, or a lateral wound of each (figs. 8 and 9).

One very important point, to which I particularly wish to direct attention, is the number of vessels which may be injured by the same projectile. Not only the

artery and its companion vein may be wounded, but also collateral branches arising below the point of injury and situated on a deeper plane, or a bifurcating branch may have been struck behind the chief trunk. I have seen the vertebral artery wounded together with the common carotid, and the

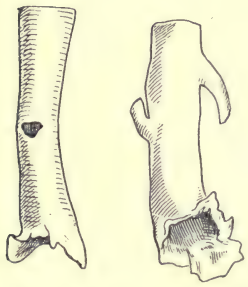

FIG. 8.—Wound of the femoral vessels by a shrapnel-ball at the level of the crural canal.

Artery and vein are both completely divided. The artery shows a lateral wound above the level of complete section. (Latarjet's case. Val-de-Grâce Museum.)

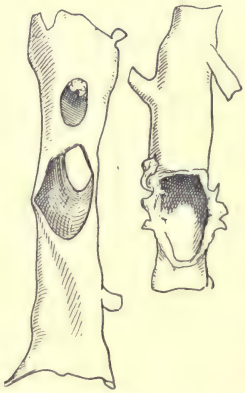

FIG. 9.—Lateral wound of the external iliac artery, with multiple perforations of the vein by shell-fragments. (Latarjet's case. Val-de-Grâce Museum.)

deep with the superficial femoral. Quénu saw the trunk of the interosseous divided at the same time as the brachial in the bend of the elbow. In operating for a hæmatoma in Scarpa's triangle, P. Duval found a rent in the deep femoral vessels, as well as a wound of the superficial femoral artery and vein. This multiplicity of lesions, which is associated with shell-fragments as well as with bullets, has a considerable therapeutic importance. As a matter of fact, it is

one of the chief reasons for preferring ligature in the wound itself to tying the vessels above the injury.

Fragments of shells, grenades, and aerial torpedoes also cause vascular wounds of widely varying types. I have seen actual punctures from minute, sharp fragments of a grenade. Sometimes the fragment

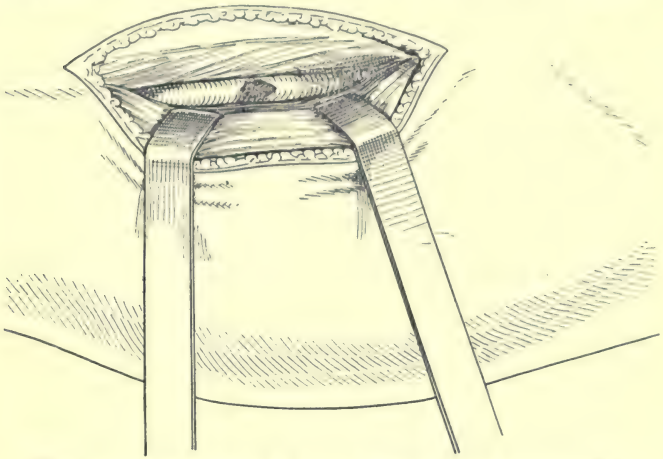

FIG. 10.—Lateral wound of the posterior tibial by a grenade-splinter. The splinter is seen lodged in the wound, which it occludes. (Author's case.)

remains fixed in the wall of the vessel. Fig. 10 shows a small grenade-fragment impacted in the lumen of the posterior tibial artery, the case having shown no symptom of arterial injury. On opening up the wound I came upon the posterior tibial, and found the splinter fixed in its wall. More or less extensive lateral tears, which may even amount to complete rupture, are sometimes observed; or there may be true perforation. This last, however, is obviously a rare lesion, since it implies a very small splinter

and a large vascular trunk. I have seen it (fig. 11) in the carotid trunk, which was perforated through

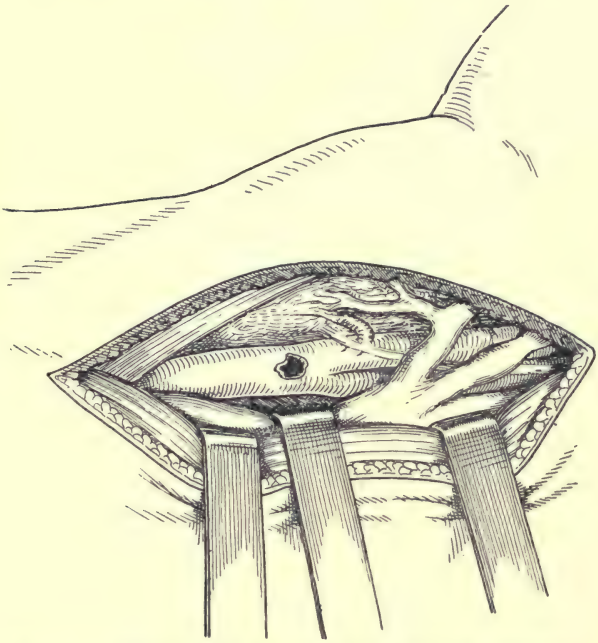

FIG. 11.—Perforation of the carotid bulb by a shell-fragment. (Author's case.)

and through by a sharp fragment the size of a lentil, which fragment I removed from the posterior opening in the vessel, where it had lodged. Lastly, there may be complete division or crushing, as in cases where the limbs are torn off or severely crushed by large fragments of shell or by minor projectiles. On the surface of the stump, or at the bottom of the extensive wound, may be seen the artery and vein,

sometimes gaping, more often lacerated and flattened, but not bleeding.

Such, briefly, are the principal types of war-wound presented by the vessels. It is, however, essential that vascular lesion should not be regarded as constituting in itself a clinical entity. Its course is determined as much by the general characters of the wound as by the specific nature of the vascular injury.

It is hardly necessary to point out that bullet-wounds differ entirely from those caused by shell-fragments. As a general rule, if the range is fairly long, bullets cause simple puncture of the tissues; the orifices of entrance and of exit are punctiform, and the whole track, subcutaneous, aponeurotic, and muscular, is barely visible on operation. The tissues, separated for a moment, close up in normal position and resume their normal relationships directly the bullet has passed. There is no foreign body in the track, because the bullet penetrates the clothing by severing the threads and pushes no débris before it. Such wounds are generally slight, and are not septic.

Shell-wounds, on the contrary, are very different. Anatomically they may be broad or narrow, but they are never punctiform; physiologically they are contused and septic.

The cutaneous opening is irregular, with contused and lacerated edges exuding, often very copiously, a sanguineous fluid. Beneath the skin the cellular tissue is lacerated; the aponeurosis, either torn or simply perforated, covers a deep and tortuous cavity in which the muscle lies contused and crushed. Contusion and sepsis are the leading characteristics of

such wounds. The contusion is so great that the edges of the wound, the cellular tissue, the aponeurosis, and the muscles constituting the walls of the bullet track, are devitalised at once. The degree of contusion may extend even to actual mortification of the tissues. The extent of the contusion is always greater than the apparent limits of the wound; it includes, to a varying depth, the whole length of the track, whether subcutaneous, muscular, or osseous.

Infection is conveyed directly by the agency of the projectile and the débris which it carries with it. As these jagged fragments pass through clothing, leather accoutrements, and even note-books, they drive before them a thousand septic particles which they deposit along the entire length of their track, burying the largest at the very bottom of the wounded area. Thus an admirable incubation chamber for microbes is formed, where in a closed tube, protected from air and light, germs may multiply at their ease.

Thus the course of the vascular lesion is determined by the general characteristics of the wound.

### 2. Anatomical and Physiological Course

The anatomical and physiological development of bullet-wounds differs from that of shell-wounds.

**A. Bullet-wounds.**—As soon as the artery is wounded the blood escapes and is effused round the vessel. The first obstacle which it meets with is the perivascular sheath, supported and kept rigid by the neighbouring tissues. The bullet in its passage does not destroy this barrier; it separates a few muscular fibres, which come together again after it has passed.

There is no bullet track, and no wound cavity. Thus the blood immediately encounters powerful barriers which prevent it from spreading very far. Hemmed in thus, the blood in the immediate neighbourhood of the vessel coagulates rapidly, and the clot thus formed closes the arterial wound like a plug or cork (J.-L. Petit).

The anatomical conditions of the wound are much more favourable to this spontaneous hæmostasis when there is complete division of the artery instead of a lateral wound. In the former case the retraction and curling up of the middle and internal coats within the adventitia obliterates the lumen of the artery, whereas in the case of the lateral wound there is retraction of the internal coat only, which tends to render the wound more gaping.

This preliminary hæmostasis once established, cicatrisation of the vascular wound goes rapidly forward. The small fibrous parietal cicatrix or the two terminal cicatrices, as the case may be, are rapidly lined by proliferation of the endothelial cells. This spontaneous repair has been verified by both clinical and operative observations. Cases of arterial bullet-wound have been observed which for some time presented all the stethoscopic signs of arterial or arterio-venous lesion, and which healed so completely that no trace of murmur was distinguishable. Moreover, the existence of spontaneous arterial cicatrices has been afterwards verified by operation. Le Jemtel has reported a case of cicatrisation of both ends of the axillary artery divided by a ball which also damaged the nerves in the axilla. Lexer, operating upon a man three weeks after he had sustained a paralysis of the ulnar, found a lateral cicatrix in the

brachial artery which had reduced the calibre of the vessel to one-half. In another case the same surgeon found the brachial divided, and each end spontaneously healed.

Most frequently, however, things do not fall out so happily. Under the influence of the repeated pulsations, the blood extravasated outside the vessel tends gradually to infiltrate beyond the sheath into the intercellular spaces and the interstices of neighbouring muscles. Once the cellular tissue has given way, the infiltration continues until the pressure of the extravasated fluid equals the arterial tension. Owing to the fact that the wounds in the different tissue layers do not correspond, the blood does not reach the cutaneous wound and cannot escape externally. Thus a diffuse arterial hæmatoma is formed. If the vessel is subcutaneous or superficial, like the femoral in Scarpa's triangle or the brachial at the bend of the elbow, the hæmatoma is superficial, and forms a tumour visible to the eye. But if the vessel is deep, like the popliteal or the posterior tibial, the hæmatoma is infiltrated into the interstices of the deep muscles, distending and swelling the limb, but not forming a visible tumour. In some cases, by following the adventitia of collateral vessels, it may pass from one muscular layer to another. Thus a diffuse hæmatoma of the superficial femoral may extend into the region of the adductors, and thence, by following the course of the perforating arteries, it may reach the posterior aspect of the thigh. In other cases the hæmatoma may be multilocular in character, presenting an anterior and a posterior sac separated by a muscular wall. Hæmatomata of this kind are seen in the thigh when the deep and

the superficial femoral are both wounded at the same time.

This periarterial effusion of blood is variously termed diffuse aneurism, false aneurism, diffuse aneurismal hæmatoma, or pulsating hæmatoma. These designations all appear to me to be meaningless. I agree with Monod that there are grounds for describing the condition as arterial hæmatoma, the name given it originally by Cruveilhier.

As the result of contact with the limiting tissues the blood gradually coagulates at the periphery of the effusion. The coagulated blood contracts, the irregular prolongations of the effusion are reduced, and, as the hæmatoma becomes established, it takes on a certain regularity. It is like a river in flood which, after spreading far and wide, gradually withdraws, and at a given moment settles down into its permanent bed. The irritation set up by the clot in the neighbouring tissues gives rise to an infiltration of serum and leucocytes, which at first forms a sort of œdematous perihæmatic mass, and later a firm lardaceous wall, which, by a progressive tissue organisation, becomes gradually differentiated in proportion to the age of the hæmatoma. At the same time a white lamination, lining the internal surface of the sac, and giving it the appearance of a vessel wall, is deposited by clots. It is owing to this phenomenon that a hæmatoma is sometimes mistaken for true aneurism. As a matter of fact, there is no true aneurismal wall which may be isolated and removed. Up to at least the fifth week this pseudo-sac may be made to disappear by pressing out the clots from inside it. It is not an aneurism; it is an encysted arterial hæmatoma.

How does this arterial hæmatoma terminate? Most frequently the inflammatory connective-tissue wall becomes defined and hardened, and the peripheral layers of the clot become laminated and adherent to it; the centre of the hæmatoma, on the other hand, which is close to the arterial wound, and is continuously under the influence of the systolic pulsations, becomes softened, and is gradually hollowed out into a regularly shaped cavity, into which the blood-stream enters with each heart-beat. The pressure of the circulating blood against the wall of this cavity causes it to become thinner, and it is more or less completely lined by an endothelial proliferation from the edges of the arterial opening. In this manner a sac with organised walls, lined with endothelium, and bounded by a progressively defined connective-tissue sac, is formed round the vessel. It is in direct communication with the interior of the artery, and pulsates synchronously with it. It is evident from the nature of these characters that the condition is now one of true arterial aneurism.

Unfortunately, however, even in the case of bullet-wounds, this favourable course is only too frequently interrupted by the occurrence of very serious complications. These may arise from two causes, namely, the progressive growth of the hæmatoma, and its infection. The anatomical and clinical significance of these facts will be considered later.

The development of an arterial bullet-wound is not quite the same when accompanied by a wound of its companion vein.

1. The first group of cases comprises those in which the bullet passes between the artery and the vein and inflicts a lateral wound on each. The two orifices

correspond exactly, and, from the beginning, they adhere so accurately and so completely by their margins, that there is no appreciable effusion of blood around the vessels (fig. 12). From the beginning of the war the base hospitals have reported many of these cases of arterio-venous communication. This exact correspondence of arterial and venous perforation cannot, however, be very frequent. The resistance of the walls to the projectile is not the same in the two classes of vessel, and their retractility is also different. Where the two openings do not exactly correspond we have the beginnings of an arterio-venous hæmatoma. But the extravasated blood finds the central end of the vein so easy of access that it is rapidly taken up by it, and nothing remains but a slight effusion in the perivascular sheath.

FIG. 12.—Diagram showing the direct communication of an arterio-venous wound.

Cicatrisation of the two wounds is accomplished by an endothelial proliferation, which quickly unites the edges of the fistula. Between the two vessels, above and below the opening, the blood in the sheath takes part in the organisation of a fibrous tissue which unites the arterial and venous walls for a distance of an inch or more. This adhesion of the two vessels is of great importance. It prevents both the ligaturing of the communication and the reconstitution of the two vessels by a double suture. One invariable and immediate consequence of arterio-venous communication is dilatation of the central

and peripheral ends of the vein in the neighbourhood of the union. The violent projection of blood towards both ends of the vein enormously increases the venous tension. The vein dilates and thickens, thus presenting the characteristic features of aneurismal varix (fig. 13). The dilation may be regular and spindle shaped, or it may become irregular and bulging in

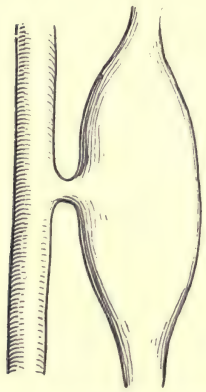

FIG. 13.—Diagram showing aneurismal varix. The vein is evenly dilated.

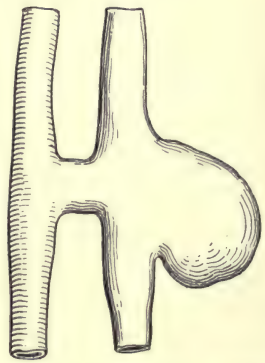

FIG. 14.—Diagram showing arterio-venous aneurism. The sac is entirely venous.

the form of a sac (fig. 14). The central end of the artery, meanwhile, undergoes considerable modification. It becomes thin and atrophied; it loses its tension, and dilates in its turn. This, in its simplest form, is the condition termed arterio-venous aneurism.

2. In the majority of cases the arterial and venous lesions are more complex, but their course is practically the same. Sometimes there is a double perforation of artery and vein; sometimes a lateral wound of the artery with complete division of the vein, or *vice versa*;

sometimes complete division of both artery and vein. In every case we find, immediately after the passage of the bullet, a hæmorrhage both arterial and venous, which spreads around the vessels, inside and outside the adventitia, like a diffuse arterial hæmatoma. Owing to the ease with which the blood passes into the central end of the vein this effusion is never very

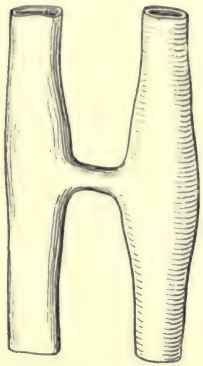

FIG. 15.—Diagram showing arterio-venous aneurism. The two vessels are united by a small fibrous canal.

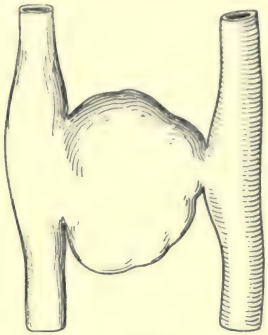

FIG. 16. — Diagram showing arterio-venous aneurism with an intermediate sac.

extensive. Moreover, the hæmatoma is soon bounded by an inflammatory wall, the formation of which is not hindered, as it is in arterial hæmatoma, by the pulsation of the blood. Thus the brief stage of diffuse hæmatoma gives place to that of an encysted hæmatoma, the centre of which is a channel of communication between the artery and vein. In the simplest cases the intermediate hæmatoma undergoes progressive retraction, until operation shows only a small fibrous canal, about half an inch in length, uniting

the two vessels (fig. 15). In other cases the vessels are united by a true sac, the wall of which becomes gradually isolated and differentiated until it can be removed in its entirety (fig. 16). Finally the conditions are very much complicated by dilatation of the central end of the vein. The gravest complications occur, however, where communication takes place in the vicinity of a tributary vein, for here very considerable modifications of form and dimension are effected, which influence the whole of the neighbouring vascular system. Under such circumstances as these the arterio-venous aneurism assumes forms and relationships which it is most difficult to foresee, and it occurs in all possible varieties, from the simplest aneurismal varix to the most complex varicose aneurism.

**B. Wounds from Shell-splinters.**—These are of two kinds :—

1. Those in which the external wound gapes widely.
2. Those in which it is partially or completely obliterated.

1. *Extensive wounds.*—When the wound corresponds to extensive loss of skin and muscle caused by a large splinter it gapes widely ; when due to a comminuted fracture with much cutaneous and muscular laceration, or to the loss of the whole or a portion of a limb, it gapes very widely.

The blood flows out immediately the vessel is opened, and the external hæmorrhage is often sufficient to cause instant death on the field. Sometimes the vascular wound communicates with one of the large cavities, such as the pleura or peritoneum, when death may follow quickly as the result of internal hæmorrhage. We shall return later to a consideration of these points.

There are various factors, however, which tend to check this dangerous hæmorrhage. Diminution of the arterial tension due to acute anæmia, retardation of the blood flow, and syncope are conspicuous, and perhaps secondary, causes. In my opinion, the high degree of contusion of the vessel in the neighbourhood of the actual wound supplies the primary cause. I have had men brought to my ambulance with great ragged wounds at the root of a limb, with the fore-arm, arm, or leg crushed or torn off, and have found no sign of hæmorrhage on removing the dressing. On carefully cleansing the wound and removing the clots from its depths the femoral, popliteal, or axillary artery is found to be wounded laterally, ruptured, torn or lacerated. The wound is closed by a clot, already firm and adherent. Where division is complete, the lumen of the artery is blocked by the external coat stretched in front of the inner coats, which are retracted inside the sheath. On carefully examining lesions of this kind, the middle and internal coats are found mangled and frayed, with hanging shreds which adhere together, favouring the obliteration of the vessel. A protecting clot is thus often formed extending an inch above the wound. On two occasions I saw the axillary artery apparently gaping at the bottom of the axilla without the emission of a single drop of blood. On passing a grooved director into the central end of the vessel I ascertained that it was closed a little distance above. These conditions are readily explained by the high degree of crushing and contusion by which shell-wounds are accompanied. The distant disturbance caused by the striking of the projectile, together with the direct shock and the elongation of the vessel, explains the extent of the

arterial contusion. That the vessel should be affected in the same way as everything else in the track of the missile is not surprising.

This hæmostasis is in its nature very precarious, and the least shock, the slightest movement, sometimes a mere increase in the blood-pressure, may, some hours after, displace the clot and set up a fresh hæmorrhage, called reactionary hæmorrhage.

What happens to this gaping wound, at the bottom of which a large vessel is injured ? Nine times out of ten the vascular wound is recognised and complications are averted by suitable treatment. But it may happen that it is not recognised, and the case may be regarded as one of simple injury to the soft parts. Now it is well known that all such wounds are contused and septic, and that the degree of the infection is determined solely by the local condition of the wound. A surface wound, such as that under consideration, open and gaping and exposed to air and light, however much fouled it may appear to be, will never become the seat of serious and rapid sepsis. It can never, as in the case of the narrow, confined wound, become a closed chamber for the multiplication of germs, and it is only exceptionally that gangrene and diffuse suppuration are found in it. A simple localised infection during the progressive elimination of the contused walls of the injured area is all that is usually presented.

After eight, ten, or twelve days it is not unusual in these conditions for a secondary hæmorrhage to occur. This may be fatal at once, or it may recur in successive bouts, terminating in death. These secondary hæmorrhages depend upon several factors: the vascular wall, severely bruised for some distance

from the wound, may necrose gradually, and, when the slough separates, it may open the vessel above the obliterating clot. On the other hand, the clot itself, soaked in the septic fluids stagnant in the wound, may gradually soften and become less adherent to the edges of the wound; a sudden movement, a change of position on the part of the patient, may serve to detach it, and so open up the vessel either partially or entirely.

The normal course, then, of shell-wounds which are extensive from the beginning leads to hæmorrhage, which may be primary, reactionary, or secondary.

2. *Punctured wounds.*—The conditions are quite different when the wound is narrow and confined. If the course of the projectile is very oblique, if the cutaneous and vascular wounds do not directly correspond, or if foreign bodies, such as clothing or fragments of muscle and aponeurosis carried by the projectile, block the track, the blood flowing from the vessel cannot readily escape externally. There may be some bleeding, but it will not be the external hæmorrhage of extensive wounds. The blood is extravasated round the vessel and its adventitia. Its rapid effusion is favoured by the existence of a true traumatic area, a ready-made cavity hollowed out at the expense of the muscles and the torn aponeuroses. Thence it filters into the muscular sheaths and under the aponeuroses, which it raises and distends, and it fills all the spaces which are free or distensible for some distance above and below the wound. In this way a diffuse arterial hæmatoma is formed, sometimes of enormous size.

It must not be imagined, however, that the arterial hæmatoma always reaches that enormous size at once.

The contusion of the vessel and the extensive laceration of the internal coat for some distance from the wound greatly facilitate arterial thrombosis and spontaneous hæmostasis. The area of the wound is hardly filled with clots before the bleeding stops and the swelling ceases to increase. I have several times been surprised to discover, at the bottom of a wound containing a few clots, in the popliteal space or on the internal surface of the thigh, a wound of the femoral or popliteal artery temporarily obliterated by a thrombus.

Nevertheless the arterial hæmorrhage is generally very large, and coagulation does not take place until the effusion has attained considerable dimensions. The more slowly it forms the further it extends into the central end of the vessel, until it reaches to the nearest collateral branches, which it obstructs, thus adding to the causes of rapid gangrene of the wounded limb. The principal trunk being obliterated, circulation can be carried on only by the collaterals above and below the perforation. But the clot often obstructs the origin of these collateral branches, and the powerful pressure of the effusion obliterates them in their length, so that the conditions for the re-establishment of the circulation are extremely unfavourable.

We have to deal, moreover, with a septic wound. The conditions in this case are the reverse of those accompanying extensive wounds, and are extremely favourable to the rapid development of sepsis. At the bottom of this bruised and ragged cavity, protected from air and light, in the midst of clots which readily become putrescent, the germs conveyed by the projectile and by fragments of clothing multiply with

great rapidity. From the beginning infection is very severe, and is frequently accompanied by the evolution of gas, which is given off into the wound. The increased distension occasioned by the gas completes the blocking of the collateral vessels, and from this moment gangrene becomes inevitable. It is a gangrene due to causes both direct and indirect, mechanical and septic, and its appearance immediately endangers life.

Sometimes, however, the sepsis is not at first so severe. Instead of an anaerobic infection leading to gas gangrene or gaseous cellulitis, a simple, slow phlegmonous inflammation leading to simple suppuration of the hæmatoma may develop. This suppuration occurs chiefly when the hæmatoma is comparatively small. Large hæmatomata place life and limb too speedily in danger to allow of slow complications such as this. Small hæmatomata, on the other hand, which are often unrecognised, give rise to local septic conditions, which range from a simple inflammation to suppuration which is either diffuse from the outset or becomes so. The condition terminates very naturally in secondary hæmorrhage. The extravascular and the arterial clots become softened and separated from one another by the course of the infection; the vascular wound is suddenly left gaping, and external secondary hæmorrhage, which rapidly proves fatal, is the result.

Thus the normal course of shell-wounds, when they are narrow and restricted, leads to septic arterial hæmatoma. When this is considerable, it leads to septic gangrene; when it is small, to local sepsis and secondary hæmorrhage.

## CHAPTER II

## CLINICAL AND THERAPEUTICAL CONSIDERATIONS

### 1. *Extensive Wounds*

THESE include extensive loss of the soft parts, caused by a ricochet bullet, a shell-splinter, or a minor projectile; perforating wounds from short-range bullets with explosive effects; and laceration with or without loss of a portion of a limb. The implication of large vessels in such wounds results in copious external hæmorrhage.

**External Hæmorrhage.** — Hæmorrhage from a wounded artery is very profuse. The blood is bright red in colour, and spurts from the wound in jets, sometimes even bubbling. The hæmorrhage is controllable by compression of the limb above the wound. Sometimes, however, as in certain wounds of the hand, forearm, or face, compression between the wound and the heart fails to arrest the bleeding, the blood escaping equally from the central and peripheral ends of the divided artery.

In the case of a large vein the blood is dark red, almost black, in colour, and flows either in a steady stream, or in a large continuous jet, which may be projected for several inches. Muscular contractions,

straining, or the effects of expiration may give the jet a misleading appearance of pulsation. The bleeding in this case may be lessened or arrested by compression below the wound. Sometimes, however, as in the case of a large vein at the root of the neck, compression between the periphery and the wound does not arrest the hæmorrhage, as the blood continues to escape from the central end of the vein.

Finally, where both an artery and its companion vein are involved, as they frequently are, the pulsating arterial jet predominates, while the venous blood flows in a sheet over the whole surface of the wound.

Death may ensue rapidly, sometimes in a few seconds, as the result of abundant hæmorrhage, and it is only those in the immediate neighbourhood of the patient who can do anything to arrest it.

Sometimes, however, in spite of the absence of immediate treatment, a large vascular wound does not prove fatal. Emotion, fright, pain, and the rapid fall of blood-pressure may cause syncope. The patient becomes very pale, the eyes turn up, and he loses consciousness. The flow of blood is retarded, a clot forms in the hole in the vessel, and the hæmorrhage ceases.

This spontaneous hæmostasis is favoured by certain contributory circumstances. It is more frequent in complete division than in lateral wounds. The degree of contusion of the vascular walls is an important factor; the more the artery is bruised and lacerated, the further do the lesions of the internal coats extend into the lumen of the proximal segment, and the sooner, in consequence, does thrombosis occur.

Thus it happens that many cases of serious lesion of main vessels are brought alive to the dressing

station. Indeed, one might be almost tempted to believe that spontaneous hæmostasis is very frequent, if one did not remember how many there must be in whom it has not taken place, and who have died on the field.

I myself have seen a score of cases in which the axillary, femoral, or popliteal vessels lay extensively injured at the bottom of a gaping wound, and yet, in spite of the absence of ligature or other preventive treatment, there was no hæmorrhage.

**Acute Traumatic Anæmia.**—When a patient is brought to the dressing station some hours after injury with an extensive wound, accompanied by serious vascular injuries which are no longer bleeding, the general symptoms are unmistakable. The face is pale and bathed in sweat; the lips and conjunctivæ are colourless; the look is vacant; the voice feeble; the body and limbs are completely motionless; consciousness is dulled, and the patient makes no complaint; the pulse is small and rapid, 120 to 130; the respiration is short and shallow; the nose and extremities are cold. Sometimes the patient shows slight agitation, and complains of being unable to see, of buzzing in the ears, of suffocation, vertigo and dizziness. All these symptoms are those of acute anæmia. The mere sight of such a completely exsanguine patient makes the diagnosis obvious. It is not necessary to remove the dressings to know that there is injury of one of the great vessels.

Exposure of the wound confirms the diagnosis. Excluding the cases in which a limb has been torn off or crushed, exposure will reveal an extensive wound of the axilla, of Scarpa's triangle, or of the popliteal space filled to overflowing with red clots,

with a small thread of venous blood trickling from the inferior angle. It is important that the dressing should not be removed nor the patient disturbed until everything is in readiness for operation, the early steps of which will serve to confirm the diagnosis.

If left to themselves these cases are doomed to almost certain and speedy death, which may supervene without fresh hæmorrhage, from increasing weakness passing into fatal syncope. The patient continues pale and colourless, the sight becomes more and more dim, the buzzing in the ears louder; the respiration becomes more and more superficial, the pupils dilate, and the pulse becomes too rapid to count and almost imperceptible. Gradually consciousness fails, leaving only the reflex action of respiration, which becomes progressively weaker, irregular and unequal. It stops altogether, is resumed once or twice, and finally ceases entirely.

The extreme gravity of these anæmic conditions, even when they do not seem to threaten immediate death, cannot be overestimated. A patient who had bled a great deal, but was bleeding no longer, was brought to my ambulance with an extensive wound below the clavicle and division of the axillary vessels. The wound was cleansed, both ends of the artery were tied without the loss of a drop of blood, and a dressing was applied. The patient did not rally; he became gradually weaker, and died three hours later. A vigorous soldier had the head and the upper part of his humerus shattered and his axillary vessels torn. There was no hæmorrhage, and the degree of anæmia apparent was not sufficient to contra-indicate the operation. The shoulder was disarticulated without perceptible loss of blood, yet he died two hours

later. I could give many examples of the great importance attaching to these anæmic conditions in the immediate prognosis of wounds. One is too apt to say that the patient is safe because he is not losing blood, that the artery is tied and will bleed no more. But death will often follow in a few hours without further hæmorrhage. There is a certain degree of anæmia from which the organism cannot rally. By means of the treatment which we shall consider presently the general condition may be improved and the symptoms relieved, but all the ground gained in half an hour may be lost again in a few minutes. One of my assistants, Dr Joussemet, has studied the arterial tension with Vaquès' apparatus in a large number of cases. It is his opinion, and one which I heartily endorse, that there is a minimum below which arterial tension cannot fall without a fatal result ensuing.

**Reactionary Hæmorrhage.**—In contrast to the cases where death occurs from primary hæmorrhage without further loss of blood, there are others who succumb to reactionary hæmorrhage after some hours of temporary arrest of the bleeding. It is obvious that spontaneous hæmostasis is a very precarious affair. The clot by which the hæmorrhage is arrested is very easily displaced by a sudden movement, a blow, a strain, a rise in the blood-pressure, or recovery from syncope. How many deaths from delayed hæmorrhage must have taken place between the field of action and the dressing station, or between that and the casualty clearing station! In September 1914 a strong young soldier was struck by a shell-splinter which divided the femoral artery; he fell and lost consciousness. He was picked up with no sign of

hæmorrhage, and brought to my ambulance. On the way he gradually recovered consciousness, and on arrival thought himself strong enough to walk alone. But at the first step a violent hæmorrhage through the dressing took place, and before he reached the operating theatre he was dead. I could give many similar examples of the precarious nature of spontaneous hæmostasis. In nearly every case it leads to delayed hæmorrhage.

Thus the majority of those who sustain a wound of one of the larger arteries succumb to external hæmorrhage on the field. Those who escape immediate or rapid death are liable to die during their transit from the trench to the dressing station, or even after reaching it, from reactionary hæmorrhage or acute anæmia.

### Indications for Treatment

The treatment of large wounds consists in the immediate arrest of the external hæmorrhage, the prevention of reactionary hæmorrhage, and the management of the profound anæmia. By what practical measures are these results achieved?

**A. In the Trench and at the Aid-post.**—The only medical persons who have the opportunity of seeing and treating urgent external hæmorrhage are the regimental hospital orderlies always present with the infantry in the trenches, the divisional and regimental stretcher-bearers who carry away the wounded when they fall, and the medical officers attached to the infantry units. The method of procedure is as follows:—

If the wound is situated below the root of a limb,

the first idea of the wounded man, his comrade, or anyone else who witnesses a severe and threatening hæmorrhage, is to apply a constricting band between the wound and the heart. The elastic bandage found in the stretcher-bearer's bag, a napkin, a handkerchief, the wounded man's necktie, or a bootlace, are usually employed for this purpose, a piece of wood, a stone, or a lump of turf being slipped between the

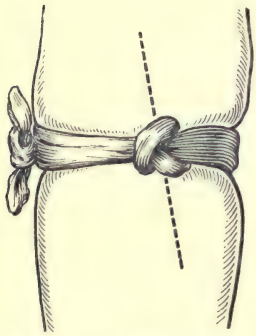

FIG. 17.—Mayor's tourniquet. (After Toubert.)

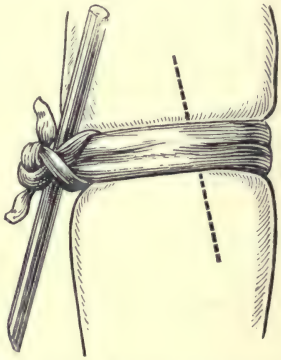

FIG. 18.—Morel's emergency tourniquet. (After Toubert.)

band and the skin to convert the former into a tourniquet. One cannot but admire the ingenuity which can create a pressure pad and the tourniquet of Mayor or Morel (figs. 17 and 18) out of nothing, and thus in many cases avert a serious external hæmorrhage.

It is obvious that in the trenches, on the field, and even at the aid-post, temporary arrest of hæmorrhage is the most that can be accomplished. The best method of effecting this is by compressing the limb above the wound. But it must be borne in mind that a tourniquet should never be applied unless it

is either certain or very probable that there is a wound of a large artery. Too many people—hospital orderlies, stretcher-bearers, and even medical officers—mistake the bleeding which occurs in all wounds for arterial hæmorrhage, and apply the tourniquet to all indiscriminately. Now the application of a tourniquet may constitute a grave danger to both life and limb. The danger is relatively insignificant if the constriction is soon removed, but constriction is serious if it becomes prolonged. The cessation of both arterial and venous circulation, the sudden interruption of all trophic stimuli through compression of the nerves, and the starving of the tissues by the pressure of an overtight band are all conducive to gangrene of the portion of the limb thus isolated. Moreover, the missile deposits on the surface of the wound numerous germs, the propagation of which is favoured by the devitalised and anæmic condition of the tissues. Under these circumstances the frequency with which gangrene, both mechanical and septic, follows the application of the tourniquet is not to be wondered at. The method is in fact justly regarded as one of the chief contributory causes of gas gangrene. It should be employed only with the greatest discrimination, and should be confined to large wounds from which the blood escapes in forcible jets, the unmistakable sign that an important artery has been injured. When a tourniquet has been applied, a special label should be attached, in order that those at the dressing station may at once recognise that the case is not suitable for evacuation. These cases should be conveyed as soon as possible to the surgeon, who will effect the permanent arrest of the hæmorrhage by the measures to be described later.

If the wound is at the root of a limb, in Scarpa's triangle, the axilla or the neck, proximal compression is impossible. Temporary arrest of hæmorrhage under emergency conditions may be effected in two ways: by direct pressure upon the bleeding point, and by the temporary closure of the wound.

Direct compression is effected by thrusting one or more fingers into the wound and closing the vessel. Serious hæmorrhage may easily be arrested in this manner. The drawback to the method is that it practically prevents the transport of the patient. For this reason its chief field of usefulness is at the dressing station while the surgeon is preparing to tie the vessels in the wound. I remember the case of a man, however, who was wounded in the neck by a knife in a public square and fell to the ground bleeding profusely from the internal jugular vein. A doctor who was passing placed his finger on the wound and kept it there until the patient reached the hospital, where I, being on duty at the time, ligatured both ends of the vein. Such a case as this is exceptional, however, and direct compression is more often carried out by means of a compress, a field dressing, or anything at hand that can be pressed into the wound as a dressing. The extemporised pad is secured by a turn of bandage or other means, and then the patient is taken to the surgeon as soon as possible. This method of procedure is, however, attended by certain disadvantages. It is not always efficacious, it may increase the risk of sepsis, and it is not universally applicable. It is particularly inapplicable to certain wounds at the root of the neck, where it is impossible to apply sufficient pressure to arrest the hæmorrhage without

compressing the air-passages. It is in such cases that temporary closure of the wound is indicated.

It will be shown later that in many cases of punctured wounds of large vessels transport for a short distance, say to a dressing station, is perfectly well tolerated. The blood spreads round the vessel and raises and distends the skin ; spontaneous hæmostasis takes place, and the patient is able to reach the surgeon. Such being the case, is there no way of transforming an extensive wound from which the blood flows freely into a limited one favourable to spontaneous hæmostasis ? I once saw a man brought into the hospital who had been struck in a factory 25 miles away by a splinter of iron which divided the common carotid after making an opening in the skin 2 inches long. A doctor who was on the spot a moment after the accident occurred closed the skin wound with a Kocher's forceps, and the patient was brought to the surgeon without the loss of a drop of blood.

The proper treatment, then, is compression above the wound, compression in the wound, or temporary closure of the wound, and then conveyance to a dressing station without loss of time.

**B. At the Ambulance.**—The surgeon has two objects in view : first, to secure permanant hæmostasis, and second, to overcome the profound anæmia.

I. PERMANENT HÆMOSTASIS OF A WOUND OF A MAIN VESSEL may be secured by ligature of the vessel, prolonged forci-pressure, or vascular suture.

*Ligature.*—This operation consists in the application of a firm ligature to both ends of the divided artery. In spite of all that has been said to the contrary, No. 2 catgut is, in my opinion, strong enough for the largest arteries.

The mechanism of permanent hæmostasis is as follows : On tying the ligature tightly, the middle and internal coats are ruptured and retract within the adventitia, their extremities coming together in the form of an actual dome, to adopt Forgue's expression. It is a mistake to tie the ligature loosely. The coats unite by first intention, and there is no need for coagulation (fig. 19).

Fig. 19.—Diagram showing effect of a tightly tied ligature upon an artery.

Union by first intention in this fashion may, however, be interfered with by either sepsis or vascular contusion. However slight may be the sepsis in the region of the vascular wound, and however inconsiderable the lesion extending up the internal coat, the blood coagulates in the ends of the vessel. The clot in the central end projects for a varying distance into the lumen, and may extend up and block an important collateral branch. This is a factor which considerably affects the results of ligature.

To obtain arterial cicatrisation without or with a minimum of thrombosis two conditions are essential : first, that the ligature is and remains aseptic ; second, that it is applied to a healthy portion of the vessel.

For the ligature to be and to remain aseptic it must be used in tissues which have been surgically prepared. It is common knowledge that the walls of all war-wounds are contused and devitalised from the beginning. They are infected from the very outset, the germs multiplying not only on the surface of the tissues, but in the depths of the devitalised zone.

Under the influence of the defensive reactions of the body all the dead skin, cellular tissue, muscle and bone forming the walls of the wound become liquefied, detached from the surrounding healthy tissues, and gradually eliminated. The process of elimination is naturally accompanied by an inflammation of varying intensity, ranging from a simple and transient serous discharge to profuse and persistent suppuration. It is not difficult to foresee the result of ligature of an artery at the bottom of a wound such as this.

It is believed by many that suppuration of this kind may be met by opening up the wound and irrigating with bactericidal solutions, such as solutions of hydrogen peroxide, chlorinated soda, carbolic acid, or the hypochlorites. But no one has ever seen a contused wound treated by antiseptic irrigation which granulated and healed up without first passing through the stage of elimination of the dead parts. Irrigation, by its mechanical action, may perhaps hasten the separation of sloughs, but that is all. I am convinced that the sole method of preventing suppuration in war-wounds is immediate surgical intervention. The operation consists in the immediate excision of the contused tissues, swarming as they are with germs and irrevocably condemned to suppuration and eventual death. The cutaneous edges of the wound, the cellular tissue, the débris of muscle and aponeuroses should all be excised ; free and adherent splinters of bone should be removed by means of a rugine, leaving a large, clean wound with fresh and bleeding walls, at the bottom of which lies the injured artery. By this means a contused and infected wound is converted into one which is clean and aseptic, and the first condition of successful arterial ligature is assured.

The second condition is to apply the ligature to a healthy part of the vessel. It is only by cleaning the contused wound and careful excision of its walls that the whole extent of the injury to the artery becomes visible. By irrigating the wound in the vessel with saline solution the extent of the laceration of the middle coat and of the ruptures of the inner coat within the lumen of the vessel may be plainly seen. If thrombosis is to be avoided, the ligature must be tied well above these injuries, hence the vessel should be treated in a similar manner to the wound ; it should be freed from its sheath, and the ligature applied to a sound portion, the subjacent contused portion being cut away. Owing to its elasticity the tied artery retracts up its sheath, and is thus protected from external injury.

By this method an aseptic ligature is effected, which will progress under aseptic conditions, and terminate in cicatrisation of the artery without thrombosis. The conditions are essential to safe and certain ligature, and the case in point is but an illustration of the technique applicable to all war-wounds.

*Forci-pressure.*—The employment of forci-pressure to obtain permanent arrest of hæmorrhage is in the nature of a makeshift, and is rarely indicated in a recent vascular injury. As we shall have occasion to show later, this does not altogether apply to old and infected wounds, nor to secondary hæmorrhage. In the case of recent injuries, forci-pressure is employed only where ligature is impossible, as, for instance, when an artery is badly torn and very much retracted at the bottom of a wound, the walls of which are inelastic and in which inspection is impossible. I employed it in one case of complete division of the

gluteal where the artery had retracted so far beneath the pelvic arch that isolation was impossible. I also saw it employed in one case of rupture of the popliteal artery with its companion vein, both vessels being clamped together transversely. In both cases permanent arrest of hæmorrhage was obtained.

*Suture.*—The suture of a vessel is not a difficult matter provided that the vessel has been surgically prepared, that is to say, isolated, dissected out, and, of course, rendered exsanguine by one of the numerous methods of securing temporary arrest of hæmorrhage. Both straight and round needles, according to requirement, are employed. These should be round in section, without cutting edges, and very fine (Kirby's Nos. 15 and 16 are the best). Very fine silk sterilised in vaseline is used for the stitches.

Lateral suture is performed in the following manner. The needle is preferably a straight one, especially when the wound is sufficiently large and gaping to permit of its manipulation. It is held in the right hand, and the first stitch is placed in the angle of the wound nearest the operator. The left index finger supports the vessel close to the wound and holds it well up to the needle (fig. 20). The third or fourth finger of the left hand is employed to tauten the thread after the first stitch has been inserted. The stitches perforate all the coats, and are placed $\frac{1}{12}$ inch apart along the entire length of the wound as a continuous suture. To ascertain whether there is leakage from the line of suture the blood is allowed to flow into the vessel. If a minute drop of blood appears between two stitches, an additional stitch should be added at that point.

Theoretically, the method is applicable to incomplete rupture and to a perforation of the artery.

In making a circular suture the first step is to put two or three guiding threads (Carrel) at equal distances apart around the circumference of the central end;

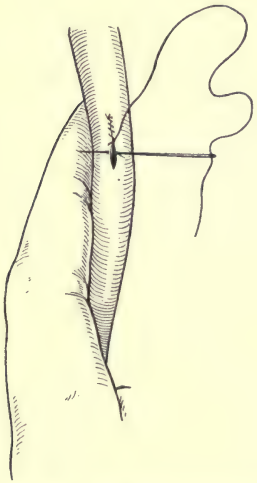

Fig. 20.—Diagram showing lateral suture of an artery.

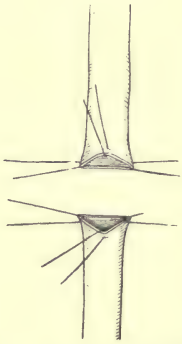

Fig. 21.—Diagram showing circular suture of an artery. First stage: application of the guiding threads.

these are then passed through the corresponding points in the peripheral end (fig. 21). When drawn tight these threads bring the two ends of the vessel together, giving the section a triangular form. By pulling lightly upon two of these threads the assistant presents a transverse wound to the surgeon, who unites the edges with a continuous suture with the stitches close together. The same is done upon the remaining sides of the triangle (figs. 22, 23). The

impermeability of the suture is tested by restoring the circulation in the vessel; where necessary, supplementary stitches are inserted.

Theoretically, the method is applicable to complete section and to complete rupture of the vessel.

Associated with circular suture is the *vascular*

FIG. 22.—Diagram showing circular suture of an artery. Second stage: commencement of the running suture.

FIG. 23.—Diagram showing circular suture of an artery. The circular running suture is nearly finished.

*graft.* Although arterio-arterial and peritoneal grafts have been proposed and even performed, it is an undoubted fact that the arterio-venous graft is the sole grafting method which is really practicable in human surgery.

The graft may be obtained from the accompanying vein or from one in the opposite limb. The great advantage of the former method lies in the fact that a segment which preserves connection with its sheath, its branches, and the tissues surrounding it, presents

all the requisite conditions of viability. I believe that this is far the better method, for the risk attaching to ligature of the vein is infinitely less than the disadvantages inevitable to the transport from a distance of a complete graft from the opposite limb.

Theoretically, vascular transplantation is applicable to cases where the loss of vascular substance is too extensive to be amenable to circular suture.

Thus, apart from forci-pressure, which must be regarded as a method of necessity, there are two principal methods of obtaining permanent hæmostasis. How is the choice between these methods to be made ?

*Choice of a method of effecting permanent hæmostasis.*—Ligature of a wounded vessel has long been regarded as a simple, easy, and efficacious operation. Its fundamental advantages lie in its simplicity and its security. It is not necessary to enlarge here upon the simplicity of the operation, and its security is equally well established. Former experience in this direction is abundantly confirmed by results obtained in war-wounds. The danger of the method lies, however, in the risk of abrupt suppression of the circulation in the area supplied by the vessel, with consequent gangrene of the limb.

Is this danger as great as it was commonly believed to be before the war ? Statistics published before 1914 show that the average incidence of gangrene was as follows :—

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| After ligature of the | | | subclavian, | in | 5 | per cent. | of cases. |
| ,, | ,, | ,, | axillary, | ,, | 15 | ,, | ,, |
| ,, | ,, | ,, | brachial, | ,, | 5 | ,, | ,, |
| ,, | ,, | ,, | common iliac, | ,, | 50 | ,, | ,, |
| ,, | ,, | ,, | common femoral, | ,, | 25 | ,, | ,, |
| ,, | ,, | ,, | popliteal, | ,, | 15 | ,, | ,, |

Thus, although comparatively rare in the case of the upper limbs, its incidence was extremely frequent in the lower ones. These figures must not, however, be taken as representative of ligature in recent vascular wounds, for they include also the figures for ligature in diffuse arterial hæmatoma and in aneurism. On the other hand, it may be urged that gunshot-wounds are more liable to gangrene than those of any other class. Such wounds are almost invariably contused, and they are associated with extensive laceration, and with contusion of the collaterals and of neighbouring veins and nerves. The ischæmia provoked by the application of a tourniquet, the vasomotor disturbances due to irritation of the collateral vessels, and the contusion of the periarterial sympathetic nerve-plexuses are all factors that inevitably predispose to ischæmic gangrene of the limb. Yet, in spite of all this, gangrene after ligature of a recently wounded artery is exceptional.

Out of a large number of cases in which the axillary, femoral, or popliteal vessels were ligatured within a few hours of injury I have seen only two instances of gangrene—one after ligature of the common femoral, and one of the popliteal. As a matter of actual fact, the circulation after ligature is rapidly re-established by way of the collateral vessels, and, at the end of three or four days, the pulse (radial or pedal) reappears. This shows very clearly that, in the vast majority of cases, simple ligature of a large artery is not in itself sufficient to provoke gangrene.

The true causes of gangrene after ligature are those that impede the establishment of the collateral circulation. Such are vascular thrombosis, reaching from the ligature to the collaterals above, and

peri-arterial hæmatoma, which compresses the collaterals above and below the wound. Now in the class of large wound at present under consideration arterial hæmatoma does not occur. And if the wound in general, and the vascular wound in particular, be treated surgically in the manner described above, thrombosis, which is the outcome of arterial contusion and infection, will also not occur. As I shall show later, this does not altogether apply to ligature for arterial hæmatoma, where the collateral vessels, owing to compression by the effused blood, are definitely paralysed and, even after evacuation of the hæmatoma, are unable to assure the circulation of the limb. I have notes of seventy cases of ligature of main arteries where the vessels were tied within a few hours of the injury and no hæmatoma of any size was present. The position of the ligatures was as follows :—

| | | | |
|---|---|---|---|
| Common carotid | 1 | External iliac | 1 |
| External carotid | 1 | Femoral | 11 |
| Internal jugular vein | 2 | Gluteal | 2 |
| Axillary | 10 | Popliteal | 6 |
| Brachial | 5 | Popliteal vein | 2 |
| Ulnar | 7 | Anterior tibial | 4 |
| Radial | 10 | Posterior tibial | 8 |

Ischæmic gangrene occurred only twice, once after ligature of the femoral and once after ligature of the popliteal.

A contrast is provided by the histories of forty-two cases of diffuse arterial hæmatoma in which a main artery was ligatured. Including those cases only in which the ligature was applied to the dangerous arteries, namely, the axillary, femoral, and popliteal, gangrene occurred in the following proportion : axil-

lary, two in five; femoral, two in ten; popliteal, two in five.

It is evident, then, that ligature of a sound portion of an arterial trunk in a large wound which has been surgically prepared is accompanied by only slight risk of ischæmic gangrene. Ligature is a simple operation which does not endanger the life of the patient, and it appears to be almost equally free from danger to the limb.

Vascular suture is in theory the ideal method, for it assures arrest of hæmorrhage, while preserving the lumen of the vessel intact.

*Restitutio ad integrum* after suture of a vascular wound depends on two conditions: the aseptic course of the suture, and the absence in the neighbourhood of the suture of lesions likely to provoke thrombosis.

Asepsis is as essential to the success of arterial suture as it is to ligature. The method of surgical disinfection of the wound by early and careful excision was described in a previous paragraph, and there is no reason why the site should not be prepared for suture in the same way as for ligature. It is incomprehensible that so many surgeons should condemn vascular suture in wounds of war simply because these wounds are septic wounds. When a suture is efficiently performed, and there is no leakage from the suture line, there is no reason why it should be more exposed to infection than a ligature or, for that matter, a normal artery which has been isolated and denuded in the wound. The disinfection of the wound lies entirely in the hands of the surgeon, and it is invariably obtained by efficient excision.

Contusions of the intima offer a serious obstacle to

the normal progress of arterial suture. To suture a lateral wound, or to unite the two ends of a divided artery without taking such lesions into account, is to court disaster. A thrombus forms, the artery is obliterated, and the entire *raison d'être* of the suture is lost. Or, worse still, gangrene may be provoked by emboli from the thrombus, when the suture becomes a positive source of danger.

In the case of a lateral wound the edges should be cut away until all trace of the laceration of the internal coat is lost. It follows that, in many cases, the wound exceeds one-half of the diameter of the vessel and is no longer amenable to lateral suture, but must be treated by resection and circular suture. Under these circumstances the indications for lateral suture become very much reduced.

Where rupture is complete, the two ends of the vessel must also be cut away until the external and internal lacerations disappear and the two surfaces are absolutely clean-cut. Here, again, the limits within which a loss of arterial substance is reparable by circular suture are very soon passed. It is generally conceded that a loss of an inch and a half is the extreme limit within which circular suture is permissible. By keeping the limb in a special position it is undoubtedly possible to facilitate the coaptation of the ends of the vessel, and the vessel may be mobilised by liberation at a distance after ligature and section of the first collaterals, but these are merely expedients. When the loss of the wall reaches the limit above mentioned, circular suture becomes impossible.

In such a case, is vascular transplantation indicated? This operation is successful only where the graft is

protected from external injury from the very outset, and where its walls are enabled rapidly to form adhesions with the tissues which surround and preserve it. Thus the method is not applicable to wounds which must be kept open.

It is evident from the details contained in the preceding paragraphs that, owing to the specific anatomical conditions incidental to war-wounds, arterial suture is in general a long and complex operation, which is assured of success only when preceded by extensive excision of the wound. This explains why the number of arterial sutures done since the beginning of the war is very limited. On the one hand, we have in ligature a simple, easy, and certain method which is almost entirely free from danger; on the other, in arterial suture a long and tedious operation, leading at great cost to precisely similar results. No wonder the decision is in favour of ligature?

Should suture then be absolutely excluded? As a matter of fact, it should not. The indications are best arrived at in the following manner:—

The wound is well opened up, excised and cleansed. Hæmorrhage is arrested by pressure above, and the condition of the arterial wound is carefully examined. Where laceration is extensive, or where there is complete rupture, with or without loss of substance, each end of the artery should be ligatured in the wound. Where there is a slight lateral wound, such as may be caused by a small fragment of shell or grenade, the choice lies between section of the vessel with ligature of both ends, and lateral suture. Is it expedient to sacrifice an artery, especially a dangerous artery which is only slightly wounded,

by cutting and tying it? In such a case the edges of the wound should be caught with fine forceps and everted, the artery emptied by washing it out with a little saline solution, and the damage then examined at leisure. If the lesions are very limited, and there is no laceration of the intima, lateral suture may be safely undertaken. Where the conditions are the reverse of these, the vessel should be divided and each end tied. The conclusions to be drawn then are: that ligature of the vessel is the method *par excellence* for the arrest of hæmorrhage from recent vascular wounds, and that indications for suture are exceptional.

II. Treatment of Acute Anæmia.—The surgical measures for assuring permanent arrest of hæmorrhage are reinforced by measures intended to overcome the profound anæmia arising from loss of blood.

In addition to the minor measures enumerated below, there are two principal methods of treating the condition, namely, by injection of artificial (physiological) serum, and by transfusion of blood.

The minor measures, all of which are valuable aids to treatment, include warmth; bandaging the limbs over a wool compress; inclination of the body with the head low; oxygen inhalations; hypodermic injections of ether, camphorated oil, or strychnine. It is most essential that the patient should be kept warm, even in summer, especially towards night or daybreak, and after lying on the ground during the early part of the night. The constant, warm temperature of the operating theatres in the motor-ambulances marked a great advance in this direction. The individual heating of the patient by one of the numerous

devices introduced during the last two years is a valuable auxiliary measure. The simplest method is to enclose the patient, exclusive of the head, in a kind of cage, under which a portable heater is introduced (fig. 24).

*Injection of physiological serum.*—Of all the methods employed to reduce the profound anæmia which accompanies large wounds of war, this is the simplest,

Fig. 24.—J. Poucel's hot-air stretcher apparatus.

the most widespread, and, after transfusion of blood, the most efficacious. The serum most commonly employed is Hayem's serum, a solution of 7 per 1000 of common salt. J. Gautrelet, however, whose experience is based on numerous physiological experiments, has replaced it with a formula of Locke's. Locke's preparation represents the only true physiological serum in the sense, that it is the only fluid which is " entirely able to fulfil the functions of the circulating blood, and, unaided, to assure and to re-establish normal organic function, notably that of the heart."

Its composition is as follows :—

| | |
|---|---|
| Sodium chloride | 8 gm. |
| Calcium chloride | 0 gm. 20 |
| Potassium chloride | 0 gm. 20 |
| Bicarbonate of soda | 0 gm. 20 |
| Glucose | 1 gm. |
| Distilled water | 1000 c.cm. |

It is prepared by simple solution of the ingredients and filtration. It is sterilised by boiling or in an autoclave, and is readily prepared at any dressing station. It is not proposed to enter here into the purely physiological advantages which render this preparation superior to Hayem's serum. These have been categorically defined by Gautrelet. For my own part, I have used at least 20 litres (704 oz.) of Locke's serum at the front, and, although I have no sphygmographic records of the intensity and rapidity of its action in comparison with that of Hayem's serum, I am firmly convinced that it is a most efficacious and reliable medium. I have no hesitation in recommending its employment.

Injection is performed either hypodermically or intravenously. In grave hæmorrhage, such as that now under consideration, it should be performed intravenously whenever possible.

The most suitable site is either one of the superficial veins at the bend of the elbow, or the internal saphena immediately in front of the internal malleolus. When transfusion is carried out during operation the latter site is preferable, as the manipulation is less hampering to the surgeon.

The classical technique of intravenous injection consists in pricking the skin immediately over a vein

and at once puncturing the vein. The method is, however, not applicable here. Owing to the extreme hæmorrhage the veins are empty and relaxed, and are barely visible. To attempt the puncture of such a vein is usually to miss it, and to succeed in pricking it is, more often than not, to traverse it. It is very rare indeed for the needle to be correctly placed at the first attempt. It has been affirmed that to puncture a vein accurately it is sufficient to prick the skin on one side of the vein and to force the point of the needle sideways until it penetrates the vessel wall. The method is undoubtedly a good one.

Fig. 25.—Canula for intravenous transfusion of serum. (Willems.)

Nevertheless, to puncture a vein quickly, unhesitatingly, and successfully, by far the best method is to make an incision half an inch long in the skin over the vein, isolate the vessel by a stroke of a director, and to insert the needle when one can see clearly what one is doing. Some surgeons prefer a needle with a short bevel, some a needle with a long one. It is very difficult to obtain good needles of a large size which are well adapted to the injection. According to Willems, English surgeons employ a curved canula (fig. 25) 2 mm. in diameter, with a blunt, bevelled point, which is introduced into the vein after it has been exposed and incised. The calibre of the canula permits of the injection of 1–1½ litres (35–52 oz.) of the solution in a few minutes. There is no doubt that the instrument is an excellent one.

The immediate result of transfusion is to diminish or to abolish the most marked of the anæmic symptoms. The lips and conjunctivæ recover their colour, the general pallor decreases, the pupils contract, and there is a subjective sensation of well-being. If the blood-pressure is taken on the patient's arrival, and again after the transfusion of 1000–1500 gm. (35–52 oz.) of serum, a considerable rise will be observed. I have at this moment before me the tracings obtained at my ambulance by my colleague, Joussemet. The maximal pressure, by Vaquès' instrument, rose from 8 to 12, 10 to 15, 9 to 15, 0 to 8, etc. The minimal pressure rose from 6 to 8, 6 to 10, 0 to 10, 6 to 9, etc. The significance of these figures lies in the fact that where the blood-pressure rises steadily and the rise is maintained hæmorrhage is the main factor, if not the only one, in the production of the hypotension, and the prognosis is in consequence favourable. But where, in spite of transfusion, the pressure either does not rise, rises very little, or rises only to fall again immediately, the inference is certain that the hæmorrhage is not the fundamental cause of the hypotension and of the clinical signs which accompany it. In cases such as these the result is referable to the sympathetic reaction so characteristic of traumatic shock. This aspect of the matter will be more fully dealt with in a later chapter. For the moment it is sufficient to emphasise the fact that if after transfusion of serum the blood-pressure rises steadily and rapidly the prognosis is favourable, and the patient will recover.

*Transfusion of blood* consists in passing into the circulation of the exsanguine patient a more or less considerable quantity of blood taken from a healthy

subject. I shall not enumerate all the ways in which this may be done, but shall confine myself to two methods of which I have had personal experience—direct transfusion by means of Elsberg's canula, and indirect by means of sterile paraffined tubes.

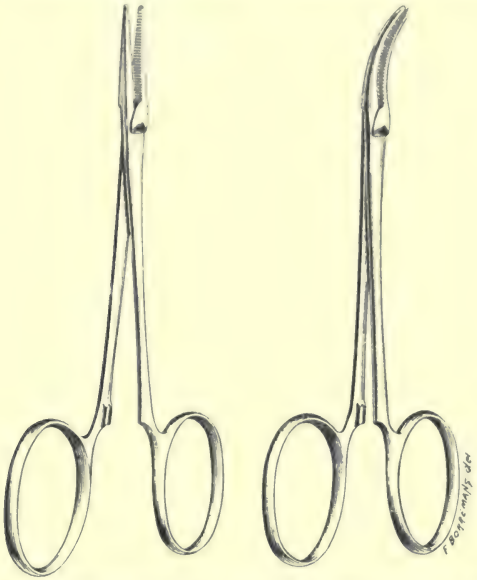

Fig. 26.—Halsted's forceps for delicate dissection work and ligature of small vessels.

*Direct transfusion by means of Elsberg's canula.*—The patient, the recipient, is laid horizontally on the operating table, and the healthy subject, the donor, lies on another table of the same height parallel to the first. These two tables are arranged so that the right arm of the donor and the left arm of the recipient lie alongside each other and perfectly parallel on a small table placed between the two operating tables.

The operation consists in anastomosing the radial artery of the donor with the basilic or cephalic vein of the recipient by the intervention of Elsberg's canula. Both limbs are stretched at full length, painted with tincture of iodine, and enclosed in sterilised towels. Novocaine is used as a local anæsthetic for both donor and recipient, the artery being first injected with 10 c.cm. of a 1 per cent. solution of novocaine. The same solution is injected in the

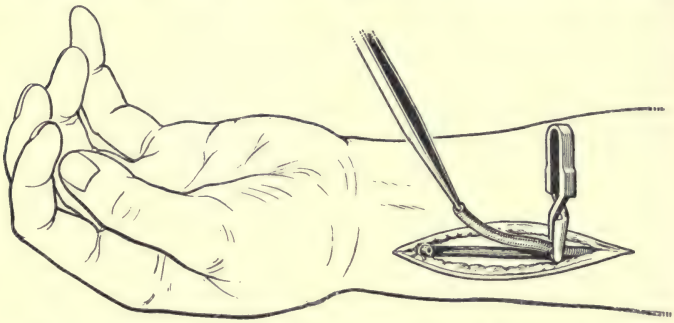

FIG. 27.—Transfusion of blood. Preparation of the radial artery of the donor.

neighbourhood of the vein of the recipient after a bandage has been placed round the limb higher up, to be tightened when the vein has to be exposed.

An incision 2 inches long is made along the line of the pulse, exposing the radial. This is separated from its sheath by means of a director, which involves the ligature of three or four very small collateral branches which the artery gives off at this level. To secure these arterioles Halsted's slender forceps (fig. 26) are employed, and the vessels are tied with very fine catgut. Near the upper end of the incision the artery is clamped with a special artery-clamp

with parallel blades, ligatured as near the lower end as possible, and divided immediately above the ligature. This gives a free segment of the artery about 2 inches long (fig. 27).

Elsberg's canula (fig. 28) is then placed on the radial. This instrument is in the form of two metal half-cylinders, the concavities of which face each other, and which may be separated or approximated by a screw on the handle. On the external surface of each half-cylinder are two little curved hooks pointing away from the tip of the cylinder. The

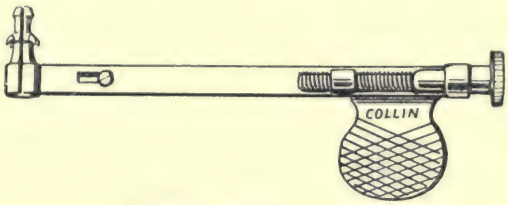


FIG. 28.—Elsberg's canula.

freed artery is placed between the two halves of the cylinder in such a way that its cut end protrudes a third of an inch beyond the tip of the canula. The two parts are then screwed together until they exactly touch the vessel walls. The free end of the vessel is then seized with fine forceps and split with a fine bistoury introduced into the lumen along $\frac{1}{6}$ inch of its length (fig. 29). Then, while the canula is steadied by an assistant, the edges of the split portion are seized with two pairs of fine forceps, such as are used in ophthalmic work, and the segment turned back until it can be caught by the little hooks (fig. 30). Dehelly points out, with justice, that this manœuvre is difficult if the split portion is too far from the end

of the canula ; $\frac{1}{8}$ inch, no more and no less, of the artery is left intact beyond the tip of the canula.

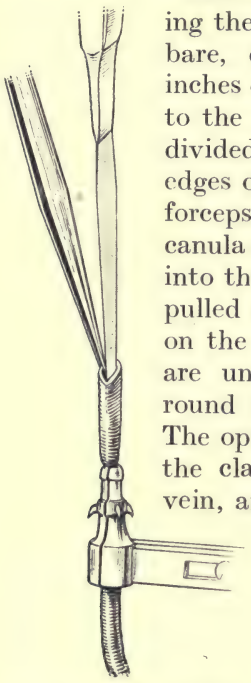

Fig. 29. — The segment of the artery which protrudes beyond the canula is split with the bistoury. (Guillot and Dehelly.)

The vein, rendered visible by tightening the constricting bandage, is now laid bare, dissected out, and freed for 3 inches of its length ; a ligature is applied to the peripheral point, and it is there divided. The assistant then grasps the edges of the divided vein with two fine forceps, and the operator coaxes the canula covered with the inverted artery into the lumen of the vein. The vein is pulled down over the artery and caught on the little hooks, and the two vessels are united more firmly by a ligature round the base of the hooks (fig. 31). The operation is completed by removing the clamp forceps from the artery and vein, and by slightly separating the two sides of the cylinder by means of the screw so that the lumen of the artery is quite free. The blood passes directly from the artery into the vein, which is seen to pulsate, while the assistant keeps the two limbs in contact, and the operator keeps the vessels moist by sprinkling them with warm artificial serum.

*Indirect transfusion by means of tubes sterilised in paraffin* (*Carrel's method modified by Bérard*).—When the artery has been completely isolated in the radial groove a lateral incision, not exceeding half the circum-

ference of the vessel, is made with very fine scissors, and into this a Carrel's tube is introduced. Carrel's tubes are slender tubes of silver $\frac{1}{5}$ mm. in thickness, bent in the form of an elongated S, and ending in small bulbous enlargements meant to retain ligatures. These canulæ are sterilised in a paraffin mixture, and are kept in glass tubes like those for catgut (Daufresne). The tube is grasped by special forceps and inserted into the opening in the artery, a ligature below the bulbous enlargement fixing it in place. The artery is now ready (fig. 32).

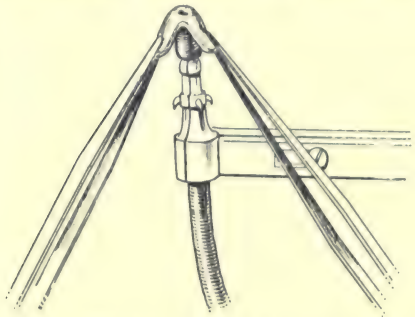

FIG. 30.—The split artery is turned back on the canula. (Guillot and Dehelly.)

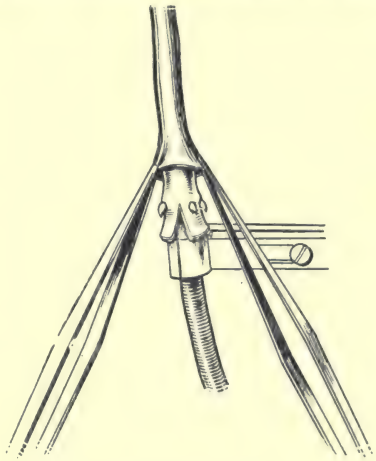

FIG. 31.—The canula, capped with the artery, is introduced into the vein. (Guillot and Dehelly.)

The vein of the recipient is next prepared, the arm of the donor is then placed in such a way that the end of the canula is touching the segment of vein

prepared for it, and a snip is made in the vein similar to that in the artery. Before inserting the canula into the vein the arterial clamp is loosened in order to expel any air that may be present, and the canula is then slipped quickly into the vein and secured by a ligature. Both artery-clamps are now removed, and transfusion is established.

Whichever mode is employed, transfusion is

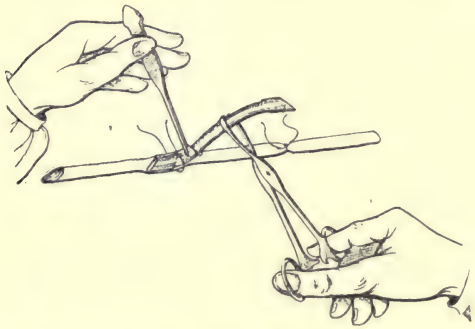

FIG. 32.—Introduction of the transfusion canula into the artery. (Bérard and Lumière.)

arrested either when the donor shows the first signs of anæmia, such as vertigo, thirst, sweating, etc., or when the main anæmic symptoms disappear in the recipient, when the mucous membranes resume their colour, the limbs become warm, and the pulse perceptible.

Transfusion of blood is an operation of unquestioned efficacy. All who have employed it have had unhoped-for success with it, and I have myself, thanks to it, seen a surprising case which might be called a resurrection. Nevertheless, there are those who object to it, some declaring it to be useless if not dangerous.

I do not propose to enter upon such a discussion, or to inquire into the respective merits of intravenous injection of serum and transfusion of blood. The intravenous injection of physiological serum which fills up the vascular system and raises the blood pressure is an excellent method of treating anæmia. Its simplicity, rapidity, and efficacy make it the best method for everyday use. Transfusion of blood is, in theory, the ideal method of treating profound anæmia. Not only does it fill the vascular system and raise the blood-pressure, but it introduces the corpuscular elements into the body and causes a living fluid, containing all the indispensable internal secretions, to circulate through it. The length of time required for the execution of the method renders it, however, unsuitable for general employment, especially under war conditions.

## 2. *Punctured Wounds*

### SYMPTOMS, DIAGNOSIS, AND CLINICAL COURSE

This group includes penetrating bullet-wounds with punctiform skin wounds, and penetrating or perforating wounds produced either by a shrapnel-ball, or a fragment of shell, grenade, or torpedo. In the first case, the orifices of entrance and exit are punctiform ; in the second, the orifices are not punctiform, but the wound is characteristically narrow, and is almost entirely closed, either by the missile itself, by débris of all kinds, or by the absence of parallelism between the lesions of subjacent anatomical planes.

If, in such a wound, a large vessel is ruptured the results may be as follows :—

1. The situation of the damaged area may be such that the vascular wound is in open communication with a cavity, either splanchnic, pleural, or peritoneal. From the moment of injury the blood is effused into the serous cavity, and internal hæmorrhage results.

2. The situation of the damaged area may be such that the gaping vascular wound is not in communication either with a serous cavity or with the exterior. The blood is effused into the damaged area and the tissues surrounding it, and a diffuse hæmatoma results.

3. The situation of the vascular wound and its relationship with the surrounding tissues may be such that only slight interstitial hæmorrhage takes place. Here we have a vascular wound without hæmorrhage.

### 1. Internal Hæmorrhage

Internal hæmorrhage occurs in association with penetrating wounds of the thorax and abdomen. A large parietal or splanchnic vessel in the pleura or peritoneum has been opened and the blood escapes freely into the serous cavity.

In the majority of cases death follows with extreme rapidity. In the case of rupture of a large mediastinal vessel (aorta, vena cava, pulmonary vein) or of a large abdominal vessel (abdominal aorta or vena cava, renal vessels, cœlic axis), death is inevitable. The wounded man dies on the spot a few moments after the injury has been received, before a doctor can be summoned to his aid.

I have, however, observed one exceptional case. I operated two hours after the injury upon a man who had been wounded in the precordial region by a shot

from a revolver. He presented all the signs of a cardiac wound, and, as a matter of fact, I found the orifice of entry in the anterior wall of the left ventricle. Having sutured the wound, I found the orifice of exit in the posterior wall of the same ventricle, in the auriculo-ventricular furrow. I sutured it, and closed the pericardium without having discovered the missile. The patient lived from eight in the morning until five in the evening. The autopsy showed that the ball had passed through the descending portion of the aortic arch, around which an enormous mediastinal hæmatoma had formed.

In other cases death is delayed for several hours, or even for several days. It is not inevitable, and may be averted by appropriate treatment. This applies particularly to penetrating wounds of the thorax, with lesion of the parietal vessels or of the pulmonary vessels of the second order. More frequently the conditions arise in association with penetrating wounds of the abdomen, with lesion of the parietal or splanchnic vessels (gastric, gastro-duodenal, splenic, mesenteric, colic).

In these cases, as sometimes happens in external hæmorrhage, emotion, such as pain or fear, combines with the rapid lowering of the blood-pressure to produce syncope. The patient loses consciousness, the flow of blood diminishes, and finally ceases. I have shown in an earlier chapter that complete rupture is more favourable to spontaneous arrest of hæmorrhage than is partial division, and that it is more frequent in association with contused and lacerated wounds than with a clean-cut section. But in the cases under consideration, especially those of pleural hæmorrhage, spontaneous arrest is facilitated

by certain contributory causes. The first of these is intra-pleural pressure, which tends to increase until it equals that within the vessel. The second is the retraction of the pulmonary parenchyma, the tissue contracting upon itself until it finally obliterates the lumen of the injured vessel.

A patient who is brought to the ambulance a few hours after injury with a thoracic or abdominal wound accompanied by internal hæmorrhage presents a complex of general and local symptoms the diagnostic significance of which is unmistakable.

The general signs are those of profound anæmia. The patient is extremely pale ; the face is waxen, and covered with sweat ; the mucosa are blanched ; the voice is weak and broken ; the pulse is small, almost imperceptible, and very rapid. While he is being warmed the patient presents signs of extreme anguish ; he is restless, sighs deeply, repeatedly sits up in bed only to fall back exhausted on the pillows. Do these striking general symptoms point to grave internal hæmorrhage ?

This clinical picture, which is portrayed only in broad outline, is observed in a large number of cases, but it is not always referable to the same causes.

It sometimes happens that the patient is wounded in many places ; a first glance shows that the arms, legs, trunk are riddled with wounds. Closer examination reveals the fact that a leg, a forearm, perhaps several segments of a limb, are fractured, yet moving them does not provoke either pain or protest.

In other cases two or three very extensive wounds of the trunk or limbs are discovered, vast lacerated areas situated in the back, the buttocks, the roots of the thighs, produced by violent explosion or by

secondary missiles, such as pieces of wood or iron blown off from objects in the neighbourhood of the wounded man. The rents in the skin reveal the torn and broken muscles beneath covered with dirt, portions of clothing and mud, and closer inspection of this formidable traumatic area shows that the tissues are dead.

In both cases no important viscera have been injured, and there is in fact no great amount of hæmorrhage, either external or internal, no *a priori* cause for the gravity of the symptoms. This is the condition commonly known as *traumatic shock*.

Generally speaking, traumatic shock is characterised by an abnormal and profound lowering of the blood-pressure. Extensive hæmorrhage, whether external or internal, inevitably produces rapid and extreme hypotension. It is certain, however, that there must be other determining causes, for the condition is observed, as in the cases under discussion, where hæmorrhage is comparatively slight.

There is no doubt that traumatic shock arises from a complexity of causes. Among the etiological factors we must include general nervous exhaustion, due to multiple stimulation of peripheral nerves; sympathetic vasomotor reaction, produced by multiple wounds; and general toxæmia, due to rapid death of bruised and lacerated tissues and the absorption from large surfaces of the products of tissue destruction caused by wounds.

However that may be, is traumatic shock distinguishable from acute anæmia? Or rather, when faced with the serious symptoms which I have described is it possible to define how far they are due to hæmorrhage or to other causative factors, namely, toxæmia

and nervous shock ? It has certainly been said that in anæmia the pallor is greater, the colour more waxen, and the nails whiter ; in shock, on the other hand, the fulness of the veins causes cyanosis of the face, the hands, and the nails. In anæmia, too, the " air hunger " and restlessness are said to be more marked ; and in shock, general insensibility and anæsthesia are more profound. But these are really only shades of difference, and it is often very difficult to say *a priori* whether a patient is suffering from anæmia or from shock. More often than not, if the wound is thoracic or abdominal he may be suffering from both.

The condition of arterial tension provides valuable information on this point. A patient is brought to the dressing station pale and pulseless with one or more abdominal wounds. The maximum arterial tension, measured by Vacquès' instrument, is eight, the minimum four. Immediately, and before doing anything else, whilst a laparotomy is being prepared for, he should be given an intravenous injection of 1500 c.cm. of adrenalinated physiological serum. If the arterial tension, taken a few minutes later, has risen quickly and well, and the mucosa and the face show a little more colour, the condition is largely due to acute anæmia. If, however, the tension remains low, or rises very little and falls quickly to its former level, the symptoms are attributable to a cause or causes other than anæmia. The prognosis is favourable in the first case, unfavourable in the second.

The local signs of internal hæmorrhage are those of intra-thoracic or intra-abdominal fluid. Thoracic dulness with disappearance of the vesicular murmur occurring immediately after a chest wound can be due only to hæmothorax ; and abnormal dulness in

the flanks, shortly after an abdominal wound, must be due to internal hæmorrhage. Gastro-intestinal bleeding occurs more slowly and is less profuse.

If left alone, these patients almost certainly die rapidly from continued or recurring hæmorrhage. Undoubtedly wounds of the thorax with pleural hæmorrhage which go on to recovery are frequently seen. Immediately after the wound has been received a very abundant hæmothorax occurs, sometimes so great as to displace the heart and depress the liver; then the hæmorrhage may be arrested, the effusion may cease to increase, and the patient picks up and begins to recover. This is due to the fact that the vessels involved in the pulmonary wound are the arterioles and the small veins, not one of the large mediastinal vessels, for in the latter case hæmostasis would not be likely to occur. It is even more improbable in the case of injury to a large vessel near the thorax, such as the subclavian artery or vein. I operated once on a young soldier who had a shell-splinter-wound in the clavicular region, involving the subclavian vein and the dome of the pleura. Although the pleura was full of blood, the vein continued to bleed, and blood escaped from the external wound with each respiration.

In intra-peritoneal hæmorrhage the likelihood of spontaneous arrest is very much less than in a pleural hæmorrhage; the bleeding continues, and without operation death is inevitable.

### 2. Diffuse Hæmatoma

Diffuse hæmatoma is associated with perforating or penetrating wounds by bullets or splinters. When

the artery is wounded the blood escapes into and around the vascular sheath, into the cellular tissue and between the muscles, and, being unable to escape externally, forms what I have already called a diffuse arterial hæmatoma.

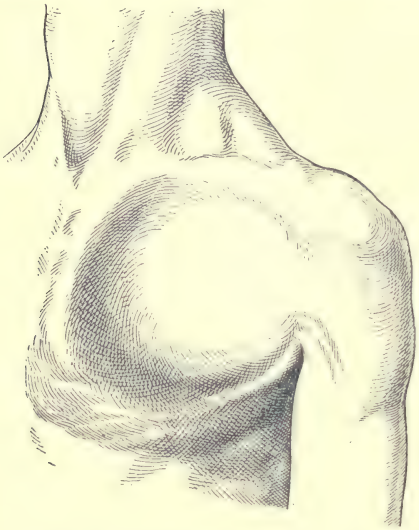

Fig. 33.—Arterial hæmatoma of the axilla. (Author's case.)

I have already shown that, in the case of a bullet-wound with punctiform orifices and an insignificant track, the hæmatoma will form slowly and progressively, rarely attaining any great size; whereas a shell-splinter, which produces a non-punctiform orifice and has a well-marked track, gives rise to a rapidly increasing hæmatoma, which may attain enormous dimensions. These forms of hæmatoma may be regarded as typical, and will be described in turn. Between them lies a range of intermediate forms.

*Extensive hæmatoma, developing rapidly.*—When a man is brought to the dressing station some hours after being wounded with a very large diffuse hæmatoma, he presents a combination of local symptoms which allows the diagnosis to be made at a glance.

The most noticeable symptom is marked swelling of the wounded limb, which differs in character according to whether the hæmatoma is superficial or deep. *A superficial hæmatoma*, such as that accompanying a wound of the axillary or superficial femoral vessels, presents considerable swelling, which raises the skin of the injured area and forms a tumour of varying

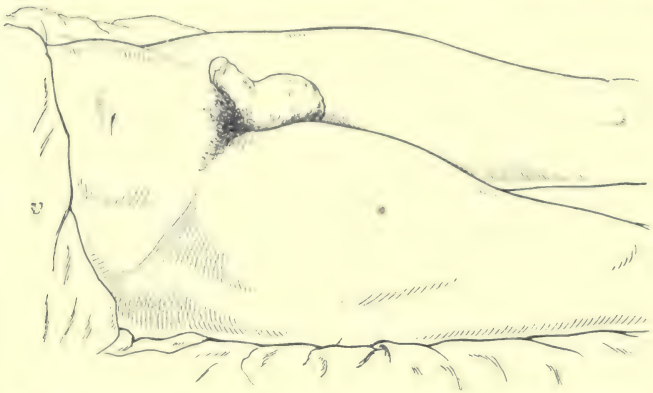


Fig. 34.—Diffuse hæmatoma of Scarpa's triangle. (Author's case.)

dimensions and vague outline. It is, however, a true definable tumour, distinct to both sight and touch. An axillary hæmatoma which elevates the anterior wall of the axilla is shown in fig. 33. Fig. 34 shows a hæmatoma of the common femoral filling up Scarpa's triangle.

Sometimes the swelling appears to be bi-lobed. In the thigh, for instance, the principal mass may be situated in front of the adductors, while a second mass appears behind them.

In the case of *a deep hæmatoma*, such as may follow a wound of the popliteal or the posterior tibial,

the swelling of the limb is general. There is no local tumefaction ; there is a general increase in the size of the limb, which looks as if its cutaneous envelope were too tight for the tissues which it contains. In a superficial hæmatoma there is rapid occurrence of an extensive ecchymosis. In an axillary hæmatoma, for instance, this may extend over the lateral surface of the thorax, the back, and the lumbar region as far as the iliac crest. In a deep hæmatoma there is no ecchymosis.

Whether the hæmatoma be superficial or deep, the whole limb is altered in shape, in general appearance, and in colour. It is more or less swelled and œdematous, the skin is pale, yellowish, distended, and cold, and the peripheral pulse is imperceptible. In the region of the superficial swelling or of the most distended part of the limb palpation reveals a diffused puffiness, suggestive of fluid infiltration, but not true fluctuation. On applying the flat of the hand to the swelling, expansile movements may be felt synchronous with the cardiac pulsations, and this movement of expansion is absolutely pathognomonic. Unfortunately it is not a constant sign, or at least it is often very difficult to detect.

Upon auscultation an intermittent murmur is generally apparent, which is synchronous with the pulse, and is due to the passage of the blood impelled by the systolic wave through the arterial wound, the edges of which vibrate as it passes. This murmur is never present except in lateral wounds and incomplete sections of vessels. We know, however, that it is in association with such wounds as these, in which spontaneous hæmostasis is rare, that a large diffuse hæmatoma is observed. For the first few

days the murmur is loud, harsh and shrill, becoming softer and deeper as the lips of the arterial wound become gradually thickened. The murmur is continued along the proximal portion of the vessel, but not for any great distance. In certain circumstances these stethoscopic signs are of considerable diagnostic value. In the case of a wound of the posterior tibial, for example, an intermittent murmur may be the sole sign of the actual cause of a diffuse swelling of the calf.

The symptoms, then, of a diffuse arterial hæmatoma are: localised swelling or diffuse distension of the entire limb, with expansile movements and an intermittent murmur; pallor and coldness of the limb, with suppression of the peripheral pulse.

*Small or medium-sized hæmatoma, developing slowly.*—The characteristics of a peri-arterial hæmatoma are usually less clearly defined. In the type which has been described, the invasion of the cellular tissues is sudden and rapid, producing in a few minutes, or at most a few hours, either an enormous swelling by which the skin is raised and distended, or a very considerable distension of the entire limb. In the case of the peri-arterial hæmatoma, on the other hand, the effusion of blood may encounter certain obstacles by which its course, and the consequent growth of the hæmatoma, is checked. Bullet-wounds with a narrow track favour this early limitation of hæmorrhage. Certain shell-splinter injuries with severe contusion involve early arterial thrombosis, by which the hæmorrhage is arrested. Consequently, instead of a large, rapidly-forming hæmatoma, such as I have described, we have a smaller and more insidious hæmatoma, the *a priori* diagnosis of which is not

evident. Some localised swelling and a certain amount of distension are present, but then how frequently these symptoms are observed apart from arterial injury!

*A venous hæmatoma*, or the simple effusion of blood which follows any wound, may cause swelling of the injured part if the escape of blood externally be even slightly hindered. Even where there is no vascular lesion this hæmatoma may be copious, especially if the tourniquet applied at the first dressing station has been applied too loosely, and thus has favoured slight venous hæmorrhage. Below the swelling the limb is pale; it is often cold, and the peripheral pulse is imperceptible. I would draw attention to the fact that patients reach the dressing station seriously chilled, with both lower limbs absolutely "icy," the wounded limb being colder even than the other. Before ascribing this coldness to arrested circulation, the patient should be slowly and gradually warmed by local and general measures. Abolition of the peripheral pulse is also not a pathognomonic sign, because in a patient whose arterial tension is low a venous hæmatoma may compress the main artery sufficiently to obliterate an already feeble pulse. Purely nervous lesions, too, may retard, or even abolish, the pulse.

Pulsations synchronous with the pulse immediately suggest arterial hæmatoma. It must not be forgotten, however, that a venous hæmatoma may transmit the pulsations of a neighbouring artery, sometimes with great distinctness. On the other hand, the absence of pulsation and of expansile movements does not necessarily exclude arterial hæmatoma. In the voluminous and rapidly forming hæmatomata, such as

I have described, the expansile movements of the tumour at once strike the eye. In medium and small hæmatomata, on the other hand, they are extremely difficult to detect.

A systolic murmur, however, is pathognomonic, and the use of the stethoscope in doubtful cases cannot be too strongly insisted upon. At the same time, it will not determine the diagnosis in every case. If a murmur can be detected, arterial injury is certain, but from the absence of a murmur no positive conclusion can be drawn.

*Inflammatory distension*, corresponding to a commencing local infection, may also cause localised or diffuse distension of the limb in the early days after the wound. Localised or diffuse inflammatory swelling, due to commencing local infection, is sometimes observed in the days immediately following injury. A wound in the neighbourhood of a large trunk suggests a vascular lesion, although the symptoms all point to a circumscribed suppuration in process of development. The skin is hot, red, distended, and glossy, and there is a rise in the axillary temperature. Although these signs are those of a circumscribed suppuration, they may all be present in arterial hæmatoma. Also diffuse distension of a limb, the calf, for example, is equally suggestive of diffuse arterial hæmatoma or of deep-seated gaseous cellulitis. The differential symptoms are pulsation and a murmur, but they are not invariably present. In such cases the diagnosis must remain doubtful.

Thus, in spite of a searching examination, the surgeon may at first fail to recognise an arterial hæmatoma. The condition may be mistaken for a simple venous effusion of little clinical importance,

for a circumscribed suppuration, an abscess, or a deep-seated sepsis. Such an error in diagnosis may be attended by serious consequences. Are there no other diagnostic factors which may be relied on in doubtful cases? There are two symptoms which are practically never absent in these arterial lesions; they are loss of power in the limb, and pain.

When there is no serious vascular or nervous lesion, even quite large wounds of the soft parts are accompanied by nothing more serious than some discomfort and a comparatively slight loss of power. Hence if the wound is a small one unaccompanied by fracture, the patient is usually able to move the limb without much difficulty. But when a large vascular trunk is injured, the case is very different. Let us suppose a wound of the popliteal space. The leg is immovable; it is flexed on the thigh, which is in a position of abduction and external rotation. By pressing his hand on the outer side of the injured knee the patient endeavours to prevent any movement of the limb. The attempt to extend the leg in order to examine the wound provokes a reflex contraction and very severe pain. I have often been impressed by this powerlessness, which does not seem in accordance with an apparently harmless wound without fracture. In such a case a vascular or nervous lesion should be suspected. The presence of swelling or hæmatoma settles all doubt; there is a lesion of the main artery.

A patient with a wound of the calf or thigh is sometimes brought to the dressing station complaining of intense, deep-seated, and persistent pain, in spite of the fact that his wound presents only a diffuse swelling, ill-defined in character and difficult of

detection. This pain is a cardinal symptom. Deep-seated pain which is not increased by pressure can only be due to deep-seated distension of the tissues, and during the first hours after injury such distension can only be caused by deep-seated effusion of blood, that is to say, by a diffuse hæmatoma.

Lastly, vascular injuries frequently lead to the speedy appearance of serious general symptoms. A wound of a main artery may not only at once react on the heart, producing tachycardia with dilatation, but it frequently affects the general condition of the patient to a very marked extent. I have described above the combination of symptoms characteristic of traumatic shock. Nowhere is its onset more rapid than in the case of wounds of the large vessels. Is this due to the fact that these vessels are surrounded by a peculiarly sensitive sympathetic plexus? I do not know. But in the case of apparently quite simple wounds, I have often been able to conjecture, if not actually to diagnose with certainty, from the nature of the general symptoms, the existence of a deep-seated vascular injury.

In doubtful cases, then, in the absence of local pathognomonic symptoms, an arterial hæmatoma may be distinguished from a venous hæmatoma, from a circumscribed suppuration, or from the beginning of deep-seated sepsis, by a combination of local and general symptoms sufficiently definite to point the way to a correct diagnosis.

Having diagnosed a case as one of arterial hæmatoma, what will be its clinical course?

### Clinical Course of Diffuse Hæmatoma

**1. A LARGE AND RAPIDLY-FORMING HÆMATOMA** is inevitably associated with serious complications.

A. *Ischæmic gangrene.*—In a large group of cases, gangrene of the wounded limb, or of the portion of the limb below the wound, takes place either at once or very rapidly. This is due not only to division of the main artery of the limb, but more particularly to increasing compression exerted by the effused blood upon the collateral circulation. I have already shown that it is only exceptionally that ligature of a main artery causes gangrene of the parts supplied by it ; this only takes place when the collateral circulation is arrested. An extensive hæmatoma constitutes an almost insurmountable obstacle to the development of the collateral blood-supply.

In spite of everything that can be done, the limb remains cold, pale, and insensitive ; the skin is icy-cold to the touch ; the extremities become livid ; the fingers and the hand or the dorsum of the foot, as the case may be, are covered by more or less confluent red blotches ; and the skin dries up, shrivels, and turns black. This is the dry form of gangrene, and it is very rare. Fig. 35 shows a case of dry gangrene of the fingers and part of the left hand of a patient with hæmatoma of the axilla. But more commonly the epidermis is detached, and blisters filled with a reddish serous fluid are formed. Later the skin turns black or greenish in colour, and becomes deliquescent. This is the moist form of gangrene, and in actual practice it is almost the only form encountered. We shall see the reason for this directly.

The first appearance of gangrene is accompanied

by very strongly marked general symptoms. These symptoms are associated with an intense toxæmia originating at the seat of the disease, the onset of which is dramatic in its suddenness. In the course of a few hours the system is invaded by toxins in enormous quantity, and the patient succumbs rapidly, even amputation of the limb being unavailing.

B. *Ischæmic and septic gangrene.*—This class of case is characterised by the sudden development of very serious infection. I need not repeat that shell-

Fig. 35.—Dry gangrene of the hand following a wound of the axillary artery. (Lefort.)

splinter-wounds, owing to the septic condition of the torn and lacerated tissues, specially predispose to the occurrence of serious sepsis. Bullet-wounds, however, must not be regarded as immune. Here the track is distended by the effusion of blood, which forces it apart and, as in the case of shell-wounds, forms a kind of deep-seated incubation chamber, where the colonies of microbes carried in by the bullet may multiply at their ease.

The bruised and ragged track of a shell-wound, excluded as it is from light and air, is a singularly favourable *milieu* for the development of the germs

conveyed by the missile and the débris which it carries with it. They develop with incredible rapidity, and in a few hours induce very serious local sepsis, generally with the formation of gas in the wound. Thus arises the most serious form of gas gangrene, which originates and develops beneath the aponeuroses and muscles in the deep-lying tissues apparently out of reach. The traumatised area is predisposed to gangrene by reason of the extreme local anæmia, the immediate appearance of trophic lesions due to arrest of the blood-supply, and the continued pressure of the effused blood on the devitalised tissues. Thus, when it is exposed to invasion by microbes whose virulence has become intensified by the favourable conditions of their *milieu*, it is not surprising that the most serious septic complications at once appear. Moreover, these gas-forming microbes evolve it in the devitalised area, whence the gas invades the neighbouring tissue spaces and insinuates itself for some distance between the muscles, which it compresses. The collateral circulation is thus finally blocked by the added external pressure. A few hours later gangrene appears, a gangrene at once ischæmic and septic, which speedily poisons the patient and kills him. It is impossible to lay too much stress on the enormous importance of arterial lesions, especially of diffuse hæmatoma, in the etiology of gas gangrene, the most formidable complication to which wounds are subject.

**2. A SMALL AND SLOWLY-FORMING HÆMATOMA.**—The development of medium-sized or small hæmatomata varies considerably according to the case. It may be generally accepted that, with a few exceptions, the progress of the wound is determined by the nature

of the missile. In the case of a shell-splinter, the wound should be regarded as infected from the first. In the case of a bullet, it may be regarded as primarily aseptic; infection determines the progress of the hæmatoma.

**A. In association with Shell-wounds.**—Every shell-wound is contused and infected, the degree of infection ranging from the most diffuse gaseous sepsis to the smallest circumscribed suppuration.

(*a*) *Gas gangrene.*—In some cases the original infection takes the form of gas gangrene from the beginning. It has been shown that the traumatised area presents remarkably favourable conditions for its development. Hæmatomata of moderate size are singularly predisposed to it. Among other cases I remember an infantry captain, exceptionally tall and strong, who was brought to me in May 1915 with a perforating shell-wound of the thigh. The thigh was much swollen and distended, but the tumefaction was most marked on the posterior and external parts. Suspecting a deep-seated hæmatoma consequent on a wound of the deep femoral, I opened the hæmatoma and evacuated it. It was due to a wound of the second or third perforating artery, and this I ligatured. Although I left the wound open, freed the surrounding muscles, and incised the tissues on all sides, I could not overcome the septicæmia which had originated in the area of the hæmatoma, and four days later the patient died. It cannot be too often repeated that hæmatomata, even the smaller ones, have a dangerous predisposition to gaseous cellulitis.

(*b*) *Diffuse cellulitis and circumscribed abscess.*—The earlier stages of the primary infection are not always of this extreme virulence. Some hours after

the injury, usually not later than the next day, the skin in the region of the wound and all over the swollen limb becomes red and œdematous. From the wound itself a sero-sanguineous fluid, which may be either purulent or sanious, exudes. The skin around the wound is hot, distended, and tender on pressure. Pain, which has been constant since the injury, increases, and becomes more intense; it is aggravated by the least movement or the slightest pressure. At the same time the temperature rises, reaching 101° or 102° Fahr.; the pulse is rapid, the tongue dry, and the urinary secretion diminished. In short, all the symptoms of commencing suppuration are seen.

In certain cases this suppuration may lead to local complications, which rapidly become dangerous. The tumefaction spreads, extending above the wound as far as the root of the limb. The condition is that of true diffuse cellulitis, imperilling life and limb. In other cases, whether because the wound being larger it allows the septic fluid to escape freely from the first, or whether because it has been surgically enlarged, the complications are less serious. The sepsis is localised, and the condition corresponds to circumscribed suppuration.

The most serious and most frequent complication, however, is secondary hæmorrhage.

*Secondary hæmorrhage.*—This is justly regarded as the most dangerous complication of wounds. It may proceed from newly-formed capillary vessels, arterioles, or large arteries. Hæmorrhage from newly-formed capillary vessels occurs in septicæmic and debilitated patients during the course of septic wounds, in compound fractures, and in open stumps after amputation. The wound is pale and atonic, the granulations are

sparse and pale, and fill the drainage tubes with little fungating plugs. A day comes when, without any apparent cause, a sanguinous oozing takes place in the wound, which without being copious is yet sufficient to place the enfeebled patient in immediate danger. Hæmorrhage of this type is late, scanty, and recurrent.

Hæmorrhage from the arterioles occurs in the course of contused and septic wounds of the forearm, hand, buttocks, calf or foot, which, having been very freely opened up, have escaped early complications. As the wound clears up, however, its walls gradually necrose and come away as sloughing shreds. Small vessels included in the contused and gangrenous area also undergo mortification, and about the sixth, eighth, or tenth day the walls of these may suddenly give way. Sometimes the bleeding occurs during the dressing of the wound, but sometimes it takes place in the night, without apparent cause. The patient, feeling the moisture, calls out; by that time the dressing is completely soaked, and the bed is stained with blood. The dressing is rapidly removed, the wound packed, and the result watched, though generally not for long. Next day, or very soon after, a fresh hæmorrhage takes place. The wound is again packed, and the hæmorrhage arrested a second time. But the patient, who was left by the first hæmorrhage in a very enfeebled condition, is now very seriously affected, and if a third attack cannot be warded off by means of antipyrin, adrenalin, or gelatine serum, he will certainly die. Hæmorrhages from arterioles or from small arteries, such as the radial, the gluteal, the peroneal, etc., are early, copious, and repeated.

During the early days secondary hæmorrhage from

a large artery follows very rapidly on the opening, whether spontaneous or surgical, of a circumscribed cellulitis. This class of hæmorrhage is the most grave. In the case of a penetrating wound of the axilla or upper part of the limb with some swelling, the patient may have been under observation in hospital, he may even have been discharged without his arterial hæmatoma having been discovered. Symptoms of purulent inflammation then appear, and, either spontaneously or after incision, putrid clots escape from the wound, followed by bright red blood in a quantity which from the first may be alarming. In the vast majority of cases the accident occurs in the absence of the surgeon; the patient, who up to then has been feverish, and from whose ill-drained wound a copious sanious fluid has exuded, suddenly finds his dressing saturated. Terrified by the sight of blood, he calls out and faints. He is found bathed in blood and pallid, with colourless mucosa and dilated pupils. Death often supervenes in a few minutes without any chance of surgical intervention. In other cases the occurrence takes place under the eyes of the surgeon, who opens what he supposes to be a cellulitis and finds putrid clots. The cleansing of the wound is followed by dangerous hæmorrhage. As a general rule, this circumstance is favourable, for it enables the operator to secure permanent hæmostasis on the spot. Nevertheless death is sometimes almost instantaneous, as in a case where a tonsillar swelling, which had been regarded as an abscess but proved to be a septic hæmatoma of the carotid, was opened by way of the mouth. Secondary hæmorrhages from main arteries, such as the carotid, subclavian, or common femoral, are early, single, and very copious.

Thus arterial hæmatoma consequent upon shell-wounds of the vessels may lead either to primary complications of extreme gravity, such as gas gangrene or diffuse suppuration, or it may give rise to secondary complications which are equally serious, namely, cellulitis either circumscribed or diffuse, sepsis either rapid or tardy, but always involving the risk of serious secondary hæmorrhage.

**B. In association with Bullet-wounds.**—As a general rule, the chief characteristics of bullet-wounds are their comparative insignificance and their freedom from sepsis.

I have already shown that in the absence of sepsis, by reason of its comparatively small size, the arterial hæmatoma undergoes anatomical changes which lead gradually to the formation of an arterial or arterio-venous aneurism. I have described the manner in which a sac wall, circumscribed and amenable to extirpation, is gradually formed around a cavity of varying size, which is in direct communication with the lumen of the artery. The clinical picture is that of a traumatic arterial aneurism, which differs considerably from arterial hæmatoma. When a hæmatoma is opened it empties itself at once ; the tightly packed clots escape, and the surrounding tissues, in which the distension had created a cavity, return at once to their normal position, thus obliterating the space occupied by the clots. The results of opening an old traumatic aneurism are very different ; fluid blood escapes freely, the incision gapes, but the wall of the sac does not collapse. We have here two widely divergent anatomical conditions, the second of which is, however, the outcome of the first. Is it possible to determine the length of time required

for an encysted hæmatoma to become an arterial aneurism? This varies naturally with the vessel, its calibre, and the size of the primary hæmatoma. Experience, however, shows that the encysted hæmatoma does not acquire a distinct aneurismal sac until five or six weeks after the injury. As a general rule, the anatomical stage may be determined by well-marked clinical signs.

The tumefaction, at first diffuse, becomes gradually more circumscribed, while at the same time the œdema and distension diminish, and the rest of the limb assumes an appearance more nearly approaching the normal. The early symptoms of pain and powerlessness gradually decrease, the condition becomes stationary for a time, and the stage of traumatic aneurism is reached.

*Arterial aneurism.*—Traumatic arterial aneurism presents the following features: along the course of an artery, and at a point corresponding to an old bullet-wound, a tumour appears, usually regular in form, smooth and ovoid in shape, and varying in size from a pigeon's egg to a closed fist (fig. 36). The surface is smooth and regular, and the consistence varies with the age of the tumour. The more recent the tumour, the softer, more compressible, and fluctuating it is, becoming harder and more resistant as it gets older. It is generally fixed, and cannot be moved either transversely or in the long axis of the limb.

On inspection of the tumour, pulsation and regular movements of expansion are distinctly perceived. These coincide with the pulse. On auscultation a murmur, more or less harsh in character and synchronous with the cardiac systole, can be made out. It is due not to vibration of the orifice between the

artery and the aneurism, the edges of which are curled up and well coated with endothelium, but to the vibration of the successive waves of blood which meet and form an eddy in the interior of the sac. The murmur is loudest at the centre of the tumour, and becomes less distinct as the stethoscope is moved towards the periphery.

Investigation of the pulse below the aneurism gives important information. It is less strong than that of

FIG. 36.—Arterial aneurism of the left ulnar artery, following a gunshot-wound. (Tanton.)

the opposite side, and is also delayed in time, this retardation being pathognomonic of arterial aneurism.

Compression of the peripheral end of the artery increases the intensity of the pulsations, the expansion and the murmur, while compression of the central end diminishes the tumour and abolishes the pulsations and the murmur.

Besides these physical signs there are subjective symptoms, the intensity of which vary with the case. Occasionally there is practically no pain or discomfort, but it is more usual to find subjective symptoms

corresponding to lesions of the neighbouring structures. It has been shown that peri-arterial hæmatoma is accompanied by pain due to tension of the deep tissues, and by loss of function consequent upon muscular contraction due to the effusion of blood. The retraction and limitation of the hæmatoma usually modify these troubles, but seldom abolish them altogether. On the contrary, owing to the contraction of the peripheral connective tissue at the circumference of the sac, all the peri-arterial structures included in this sclerosed tissue are drawn down into it and become incorporated with it. This results in œdema of the limb from venous compression, neuralgia, paralysis and atrophy from compression of the nerves, and ischæmic paralysis due to sclerosis of the muscles. These functional disturbances, the intensity of which varies according to the case, have a large share in determining the details of surgical treatment.

*Arterio-venous aneurism.*—An arterio-venous aneurism does not, as a rule, attain the dimensions of an arterial aneurism.

I have already described the derivative action which, in simultaneous arterial and venous injury, is exercised upon the arterial hæmatoma by the central end of the vein. I have also pointed out that the circumscription of the arterio-venous hæmatoma is very rapid, and that it tends to become transformed into a sacculated arterio-venous aneurism.

When it has reached a sufficient size, the arterio-venous aneurism shows itself as a limited and more or less reducible swelling of soft consistence. It pulsates synchronously with the pulse, and also shows movements of expansion. Its dominant feature is

the thrill, which is best described as a kind of vibration similar to that caused by the vibration of a metal disc. Once experienced, it can never be forgotten.

On auscultation a continuous murmur is heard, which grows louder at each systole. The systolic beat is sometimes soft and musical, at others louder, resembling the clapping of the valves in aortic disease. These sounds are most distinct at the point corresponding to the site of arterio-venous communication. Slight compression at this point causes the thrill, pulsation, and bruit to disappear. The thrill is transmitted above and below the aneurism. In a case involving the hypogastric (internal iliac) vessels, upon which I operated with Cotte, a very strong thrill extended from the internal malleolus to the apex of the heart. The systolic murmur is also transmitted towards the periphery. The continuous murmur diminishes in intensity with the distance from the aneurism, until the systolic sound alone is audible.

Above and below the tumour the injured vessels present the following characteristics: towards the heart the pulse is full and strong, more so than on the sound side; towards the periphery it is weaker, and is sometimes imperceptible. As in the case of arterial aneurism, compression above increases the symptoms, compression below diminishes them.

In addition to these physical signs there are also functional symptoms of varying intensity, corresponding to diminution of pressure in the peripheral arteries, and to increase of pressure in the peripheral and central veins. On the peripheral side there is functional derangement by œdema and cyanosis of the limb, tingling, cramp, neuralgic pains, and sometimes

a sensation of cold in the extremities; and on the central side by palpitation, breathlessness, and dilatation of the right side of the heart.

It is in this manner that, in a large proportion of cases, arterial hæmatoma following a bullet-wound leads to the formation of an arterial or an arterio-venous aneurism.

**Complications.**—In a small number of cases the course is disturbed by complications, which may be grouped under two heads :—

1. Sudden and rapid enlargement of the hæmatoma.
2. Infection of the hæmatoma.

1. *Sudden and rapid enlargement of the hæmatoma.* —This enlargement generally takes place in the first days after injury. The clot which had temporarily obstructed the arterial wound becomes softened or displaced. The patient having somewhat recovered from the shock of the initial injury, the systolic beat is stronger, and, under its influence, an infiltration of blood takes place which may acquire enormous proportions. In certain cases of arterio-venous hæmatoma the sudden enlargement is due to the obstruction by a clot of the venous orifice, which until then had sucked in the arterial blood, thus preventing increased hæmorrhage. Morestin reports an interesting case of this kind. It was a case of arterio-venous hæmatoma of the axillary vessels, with thrill and continuous murmur, but with no great swelling, and without much functional disturbance. One day the swelling suddenly increased, the ecchymosis spread, and very severe pain was complained of, whilst the thrill and the continuous murmur disappeared. A clot had closed the vein and blocked up the derivative channel.

Whatever may be the cause, sudden enlargement

of the hæmatoma leads to complications of extreme gravity, to gangrene of the limb, or sloughing of the skin over the surface of the tumour.

Gangrene from ischæmia of the limb is due to centrifugal pressure, to the obliteration of the collateral arterial channels by the effused blood; and sloughing of the skin by centrifugal pressure occurs when the effusion, restrained by resistant anatomical planes from passing into the deeper tissues, extends towards the surface of the body. The skin gets pale and becomes gradually thinner, and a sloughing patch appears on the top of the tumour. The speedy separation of the slough causes not only the discharge of the contents of the hæmatoma, but its certain infection.

In cases where the enlargement of the hæmatoma does not lead to gangrene or rupture, it may result in serious complications due to compression.

Compression of the veins is followed by rapid and considerable œdema of the limb, which may be mistaken for suppuration. Persistence of the œdema is accompanied by loss of power, and finally by complete functional muscular and nervous disorganisation which renders the limb useless. Compression of the nerves produces paralysis, anæsthesia, trophic and vasomotor disturbances, and pain which is sometimes intolerable. Paralysis of the median, ulnar, or external popliteal nerve may be produced or be increased in this manner, or paralysis of all the nerves at the root of a limb may occur. Finally, compression of the muscles is accompanied by a varying degree of ischæmia, which may sooner or later result in muscular degeneration and ischæmic paralysis.

2. *Infection of the hæmatoma* is not as uncommon as the insignificant characteristics of the external wound

would suggest. The effusion of blood turns the potential track of the bullet into an actual track. It fills this track with clots, which are highly susceptible to infection. These clots insinuate themselves by degrees across the aponeuroses and the muscles, finally reaching the near neighbourhood of the cutaneous wound by an irregular and tortuous track. Thus although there may be no primary infection from the passage of the bullet, a secondary infection proceeding from the small cutaneous wound may in this way reach the deep parts. This may give rise to a deep infection, either circumscribed or rapidly diffuse, and in either case a suppuration may occur, leading to secondary hæmorrhage.

A comprehensive review of the anatomical and clinical development of arterial hæmatomata shows that large and rapidly formed hæmatomata very soon lead either to ischæmic gangrene or to ischæmic and septic gangrene of the wounded limb ; that medium-sized, slow-forming hæmatomata if primarily infected, as in shell-splinter-wounds, lead to rapid sepsis and secondary hæmorrhage. When, however, such hæmatomata are aseptic, as is usually the case with punctiform bullet-wounds, they lead to the regular and slow formation of arterial or arterio-venous aneurisms. This favourable development may, however, be disturbed by complications, such as rapid enlargement, rupture, or infection, which introduce the grave symptoms incidental to large septic hæmatomata.

### 3. Wounds of Vessels without Hæmorrhage

Not the least of the clinical surprises of this great war has been the discovery of the dry arterial wound

(Fiolle). It has been observed by all surgeons in the neighbourhood of the firing line, and the rationale of its method of production is now known.

A dry arterial wound may occur in association with bullet-wounds. The artery is completely severed; spontaneous hæmostasis is effected by the curling up of the tunica intima; there is no bleeding.

Or the bullet may injure an artery and a vein simultaneously and, passing between them, cause two lateral wounds facing each other and uniting by suction at their cut edges. A few drops of blood in the sheath constitute the only hæmorrhage, the arterial blood being rapidly drawn into the path of least resistance by reason of the venous aspiration. No hæmatoma is formed.

Sometimes the same is observed in connection with shell-wounds. A deep-lying artery is struck by a projectile, which tears it but remains fixed in the arterial wound. Fig. 10 represents a wound of the posterior tibial by a splinter which has stuck in the arterial wall, the wound being absolutely bloodless. Sometimes it is a scrap of clothing, a fragment of accoutrement, or a shred of leather which stops the vascular orifice and temporarily prevents hæmorrhage.

Lastly, in many cases the contusion of the vessel, extending well beyond the wound, induces rapid arterial thrombosis. The floating shreds of the internal and middle coats block the vessel for half an inch or more above the wound, and furthers the rapid formation of a clot. Here again we have a dry arterial wound. This form, like the others, was discovered fortuitously in the course of an incision to relieve tension.

Clinically, these arterial wounds without hæmato-

mata are often unrecognised. There is nothing to suggest an arterial wound : no hæmorrhage, external or internal ; no hæmatoma. The sole factor liable to excite remark is, that the cutaneous injury is situated in the course of a large vessel. But even with this guide the most searching clinical examination fails to reveal the vascular lesion. Dry arterial wounds are accordingly rarely recognised in the first instance, but are revealed only by the complications to which they give rise.

When a shell-wound is properly treated by free incision exposing the site of injury and excising the track of the missile, the vascular injury cannot be overlooked. The situation of the cutaneous wound and the direction of the track in the neighbourhood of important vessels necessitates a minute and careful operation. Before making the first incision, an assistant should be ready to compress the main artery at the root of the limb, after which the edges of the wound and the walls of the track are carefully dissected out by cautious incisions. In such circumstances an arterial wound cannot escape notice.

If the incisions have been superficial and the depths of the wound have not been explored, the arterial injury will be overlooked, with the result that the contused and infected wound becomes purulent, and a circumscribed suppuration, if no more serious complication, results. External secondary hæmorrhage or diffuse secondary hæmorrhage speedily follows, according to whether or no the damaged area has free communication with the exterior. It is generally at the base hospitals that this grave complication is observed. The patient is brought in with a suppurating wound which has not been thoroughly opened

up; when this is done, the interior is found to be completely lined with granulations. Sometimes it is merely drained. The suppuration appears to be diminishing, when a secondary hæmorrhage, either single or repeated, supervenes, and may lead to death.

In the case of a bullet-wound the vascular injury is almost sure to be overlooked. At first no reason for operation is apparent; the patient is discharged, and the vascular wound is not diagnosed until later, often by a mere chance. As I have shown, it is sometimes discovered during an operation. But it is more often recognised clinically, generally by chance, although it is sometimes suggested by the appearance of slight functional symptoms corresponding to a small arterial aneurism or an aneurismal varix.

Aneurismal varix is the simplest form of arterio-venous aneurism. It is characterised by the anastomosis of an artery and a vein, with more or less dilatation of the central end of the vein. Clinically speaking, it is generally discovered by chance, as when on passing the hand over the neck of a patient an unexpected thrill is felt. This thrill, together with the continuous murmur augmented at each systole, which is so frequent in arterio-venous aneurism, is the essential and characteristic symptom of an aneurismal varix. Except for the tumour, this condition is an arterio-venous aneurism, and I need not repeat what I have already said upon the subject.

To sum up. In shell-wounds, dry wounds of the arteries lead sooner or later to secondary hæmorrhage. In bullet-wounds, they may terminate in spontaneous recovery, though more frequently they lead to the formation of a small arterial aneurism or an aneurismal varix.

## INDICATIONS FOR AND METHODS OF TREATMENT

### I. Internal Hæmorrhage

The object of treatment is to arrest persistent internal hæmorrhage, to prevent the recurrence of hæmorrhage which has been temporarily arrested, and to combat the anæmia.

I do not propose to enter here into the details of such treatment. The management of thoracic and abdominal hæmorrhage is one of the most interesting details of the treatment of thoracic and abdominal wounds, but this is not the place to enlarge upon it. It is sufficient to say that intra-peritoneal hæmorrhage constitutes one of the most imperative indications for immediate laparotomy. Pleural hæmorrhage, on the contrary, seldom calls for exploratory thoracic operation unless the precise vessel which has been wounded has been ascertained. When the pleural hæmorrhage is of parietal origin, it is clearly amenable to direct surgical hæmostasis. When, however, it is derived from the root of the lung, although in theory it should benefit from surgical intervention, in practice it is almost invariably beyond the resources of surgery.

### II. Arterial Hæmatoma

#### 1. Extensive and Rapidly-forming Hæmatoma

In this class of case the therapeutic aims are largely preventive. Ischæmic gangrene is a very probable complication ; a gangrene which is both ischæmic and septic is an almost certain one.

To prevent ischæmic gangrene it is necessary to evacuate the hæmatoma, the centrifugal pressure of which obliterates the collateral circulation, and to guard against its recurrence by permanent hæmostasis of the arterial wound. To prevent a gangrene which is both ischæmic and septic the wound should be freely opened, and all its ramifications laid bare. Both objects are obtainable by a single operation. The following are the different steps: All clots, which are very susceptible to infection, all infective portions of clothing, as well as the missile itself, should be removed; the blind contused wound should, in short, be transformed into an open and clean one.

1. *Preventive hæmostasis.*—Experience shows that the opening of a large hæmatoma should never be undertaken without first securing as complete a provisional hæmostasis as possible. It has been said that preventive hæmostasis may be dispensed with; as a matter of fact it is possible to open a large hæmatoma, rapidly to evacuate the clots which it contains, and, after having discovered the wound, to seize the artery and tie it. The manœuvre is one, however, which should never be attempted. The hæmorrhage may from the very outset be overwhelming. It is impossible to distinguish anything, and the sole resource is to apply a forceps at random. This may easily tear the vessel and increase the hæmorrhage. Or, with the wounded vessel an important nerve may be seized, the ligaturing of which may involve the worst complications. The results of opening a large carotid, subclavian, or axillary hæmatoma without preventive hæmostasis are beyond description. I well remember a case of a large

arterial hæmatoma at the base of the neck which was operated upon by one of my chiefs without this precaution. The sac was hardly opened when a fearful hæmorrhage bathed us from head to foot. Putting my hand into the wound I gripped the carotid with the forceps, but was unable to arrest the hæmorrhage, and the patient died on the table in less than two minutes. The vertebral had been divided behind the common carotid. I am firmly convinced that preventive hæmostasis is an indispensable condition of operation.

The simplest means of securing hæmostasis is to apply an elastic band, such as an Esmarch's tubing, round the limb above the wound. This procedure is not applicable to hæmatoma in the neck or at the root of limbs, and in any case I believe it to be dangerous. Short as is the time of its application, Esmarch's tubing induces a vasomotor paralysis of the arterioles and small veins on which the collateral circulation depends, and this must constitute a serious obstacle to the re-establishment of the circulation. Momburg's method has even less to recommend it. It is a barbarous proceeding, which consists in applying a very tight elastic band round the body between the floating ribs and the pelvis in order to suspend the circulation in the lower half of the body.

Digital compression of the vessel above the tumour is much simpler, much less dangerous, and equally efficacious. Unfortunately it can be applied only to hæmatomata situated in the limbs, and is not applicable to those at the base of the neck or at the root of the limbs.

In this latter case the vessel is laid bare by a suitable incision, and direct temporary hæmostasis

is effected. In the case of a carotid hæmatoma the artery is exposed at the base of the neck ; in the case of the axillary, the third portion of the subclavian ; and if the hæmatoma is at the root of the thigh, the external iliac. It is unadvisable to tie the exposed vessel with catgut, as the risk of dividing the internal or even the middle coat is considerable. In such a case, removal of the ligature after operation leaves an arterial thrombus, which is extremely prejudicial to the re-establishment of the circulation. As a rule it is sufficient to raise the artery and kink it over a piece of coarse catgut, thus obliterating the lumen. This method has another advantage besides its harmlessness. If, after opening the hæmatoma, there is any difficulty in detecting the arterial wound, it is easily found by relaxing the traction upon the vessel for a moment. I have operated successfully in this way on the common carotid, the subclavian, and the external iliac.

2. *Exposure of the wound in the vessel.*—After preventive hæmostasis has been secured, the hæmatoma is laid open. Before doing this it is most essential to expose the hæmatoma very extensively. Where the vessel is in the continuity of a limb a free incision from one end of the swelling to the other should be made ; where, however, the vessel is situated at the root of a limb or in the neck, a longitudinal incision is not sufficient ; a musculo-cutaneous or an osteo-musculo-cutaneous flap should be raised. It may even be, as I shall show later in the case of the axilla, that exposure can only be effected by division of the pectoral muscles, or that the inner two-thirds of the clavicle must be temporarily resected before easy access to the subclavian or first part of

the axillary vessels can be obtained. I repeat emphatically that a very wide means of access is essential to the success of the operation.

When the hæmatoma has been exposed, it should be well opened by one free incision. The edges of the wound are held well apart by an assistant by means of two strong retractors, while the clots are rapidly cleared out and one or two swabs thrust into the wound. Risk of serious hæmorrhage is obviated by the preliminary hæmostatic measures, and the bleeding is frequently insufficient to soak through the swabs, which are removed one after the other and the vascular wound examined at leisure. This state of things is not invariable, however. In spite of the preliminary precautions, the blood may continue to well up from the depths of the wound, soaking the swabs and flooding the wound. This hæmorrhage may proceed from a wound of the accompanying vein, or from a collateral branch opening from the artery itself below the ligature; or it may proceed from another artery, or from a deep-seated collateral branch. I have seen many examples of such multiple arterial wounds.

It is essential that the source of the persistent hæmorrhage should be ascertained. The upper end of the vessel is compressed at the upper angle of the wound by means of a gauze pad held in the hand, and the pad is moved slowly down the entire length of the wound, so as gradually to expose the artery and its branches and lay bare the whole field of the hæmatoma. If there is bleeding from the wound in the main artery, the hæmorrhage is derived from a branch in the neighbourhood of the wound. If the continuity of the artery is unbroken, the latter

may be raised, when the branch will be seen as a taut cord, which may be seized with forceps. If the hæmorrhage is from the lower end, nothing is easier than to apply the forceps to the artery. If the wound in the artery remains dry, the blood may come from a neighbouring vein, and its origin will be revealed by its colour and manner of flow. The hæmorrhage may come from a deeper artery or one of its branches, which it is not always easy to find. I have already mentioned those bi-sacculate hæmatomata caused by simultaneous injury of the superficial and deep femoral arteries, examples of which have been reported by P. Duval and Mauclaire. It is sometimes very difficult to find the deep vessel by way of the narrow track which separates the two sacs. In such a case the track should be enlarged, both sacs emptied, and the vessel again sought for. The operation is always a delicate one, and it is frequently extremely difficult.

3. *Permanent hæmostasis.*—When the wound in the vessel has been fully exposed, it may be secured by ligature, forci-pressure, or suture.

*Forci-pressure* is an exceptional method, which should never be employed except in a case of absolute necessity, when it is quite impossible to do anything else. It will seldom be required when operation is performed early. It may be necessary in the case of a deep-seated artery such as the gluteal, where the injury is close to its exit from the pelvis, and ligature is practically impossible. Its application for forty-eight hours will secure permanent hæmostasis.

*Ligature* is employed after both ends of the vessel have been secured by forceps in a case of complete division; when the vessel is only partially divided it

is compressed by forceps above and below the wound, the vessel between is severed, and its ends are tied.

Ligature in a wound is a simple, easy, and effectual operation. Can it be said to be free from danger ?

When considering extensive wounds, I stated that the ligature of a main artery does not in itself endanger the vitality of the limb to any great extent. The same cannot be said, however, of ligature in hæmatoma.

According to statistics taken before the war, gangrene after incision of a hæmatoma and double ligature in the wound was not common. Among 157 cases collected in 1911, Monod and Vanverts found only ten cases of gangrene, or 6·3 per cent. Individual consultation with each surgeon who has had occasion to treat such cases at the front during this war gives a different impression of the serious nature of these lesions. I refer, of course, to extensive hæmatomata of important arteries, such as the lower part of the axillary, the external iliac or common femoral, or the lower end of the popliteal. I myself saw two cases of gangrene of the hand and forearm after incision of an axillary hæmatoma out of the five cases on which I operated, two cases out of nine after incision of large hæmatomata at the top of the thigh, and two cases out of five after incision of popliteal hæmatomata.

The great gravity of the operation is not surprising when we consider the intensity and the extent of the contusion caused by shell-splinters, the multiplicity of the vascular branches, arterial and venous, which are injured, the variety of the accompanying nervous lesions, and, lastly, the frequently enormous size of the hæmatoma which finds in the wounded

area a ready-made field for its rapid extension. The collateral branches which have escaped being wounded have been so compressed by the tense effusion, that it is only too probable that the resulting vasomotor paralysis will prevent the re-establishment of the circulation even after evacuation of the hæmatoma. These large, rapidly-forming hæmatomata are hardly ever seen at the base hospitals, such patients being cured before their arrival, or never getting there at all.

We see, then, that double ligature of the wound after evacuation of a large diffuse hæmatoma is an operation which, in the case of certain large arteries, is followed, in nearly one-third of the cases, by partial or total necrobiosis of the distal part of the limb.

In these circumstances it is of great importance to know beforehand whether the re-establishment of the collateral circulation is probable or not. The surgeon who is about to open a hæmatoma of the axilla will require a more specific guide than mere statistics if he is to make a wise choice between double ligature, simple, easy, and efficacious, and an attempt at vascular suture, which is complex, difficult, and perhaps less certain. Is it possible to foresee in each case the condition of the circulation of the limb after ligature ? The attempt should at least be made.

If, after having provisionally checked the flow of blood in the artery for a few seconds, no signs of arrested circulation, such as coldness and lividity of the digits, are evident, we may hope that the circulation will be re-established. This rather vague indication may be confirmed by means of a small incision at the extremity of a toe or a finger, or even, as Quénu has suggested, by the exposure of a small

terminal arteriole, or an artery such as the dorsalis pedis. If the accompanying vein is compressed, and its distal end swells up rapidly in spite of occlusion of both ends of the wounded artery, the conclusion is obvious that the blood continues to flow into the limb and to return by the veins. Lastly, in cases when blood escapes from the lower end of the wounded vessel at the moment when the forceps are applied to it, as is well seen in the case of the external carotid, for example, there is no cause for anxiety, the collateral circulation is present, and is sufficient. If this triple test is negative, it is impossible to foresee the result of ligature.

*Vascular suture* (*arteriorraphy*) is an invaluable resource. When speaking of the treatment of extensive arterial wounds I compared the ligature, which is simple, certain, and without danger, with suture, which is equally certain, and equally free from danger, but more complex and of uncertain efficacy. In cases of that type, ligature was preferred on account of its harmlessness.

The greater risk of the ligature in large recent hæmatoma certainly increases the indications in favour of arterial suture. If suture is to be attended by complete success, by which I mean the maintenance of arterial permeability, the edges of the vascular wounds must, unfortunately, be freely revivified by paring them. This complicates the execution of the suture ; it may convert a lateral wound, if not into a complete division, at least into one so extensive that lateral suture cannot be applied to it ; and in the same way it may turn a complete division, with more or less ragged edges, into a loss of substance of an inch or more. Circular suture is, therefore,

most frequently indicated. In these circumstances it is not to be wondered at that the number of primary vascular sutures performed before the war was extremely small. Monod and Vanverts, in 1911, were able to describe only nine cases of diffuse arterial hæmatoma resulting from gunshot-wounds, and treated by incision and arterial suture. Of these nine cases, only three correspond to the large primary hæmatomata which are here under consideration. Since the war, Sébileau has reported a case of suture of the popliteal which did not avert amputation of the limb, and Couteaud described the suture of a lateral arterial wound which was unsuccessful. On the other hand, Pauchet and also Lemaitre have twice successfully sutured the femoral. Out of thirteen sutures performed by Soubbotitch, eight were lateral and five circular. The circular sutures were in all cases successful; of the lateral sutures, three failed and five were successful. For my own part, before the war I had on four occasions sutured the femoral artery in diffuse hæmatoma, resulting in two cases from knife-wounds, in one from a revolver-bullet, and in one from a petard-wound. I was, therefore, prepared for vascular suture in injuries of war, and have several times attempted it. But the extent of the vascular lesion and the intensity of the contusion of the walls have always obliged me to abandon it. Nevertheless I am convinced that the method should be persevered with. Great success has attended its employment in the treatment of aneurisms, and success should be equally possible, though perhaps less easy, in the case of diffuse hæmatomata. Before deciding on permanent ligature, it is advisable in cases where gangrene is feared first to attempt lateral

arterial suture where possible, and circular suture where necessary. Should suture prove impracticable, it is not too late to resort to ligature.

Venous suture is a perfectly useless proceeding. Suture of the femoral, axillary, or even the jugular vein is never indicated, ligature in these cases being entirely free from risk.

4. *General treatment of the wound.*—When hæmorrhage has been finally arrested, the next endeavour is to convert the contused and lacerated wound into a clean one, which shall be dry and ready to heal. The method has been described above, and I need not repeat it here.

### 2. Medium-sized or Small Hæmatoma of slow growth

**A. FOLLOWING A SHELL-WOUND.**—The danger of immediate serious infective conditions, such as gangrene and diffuse cellulitis, as well as of infective conditions, the appearance of which, though less prompt, leads almost inevitably to secondary hæmorrhage, is an indication for immediate surgical intervention. The treatment of the vascular wound is here again only a special item in the treatment of this class of wounds in general. Every shell-wound should be promptly operated upon, especially when it is complicated by a wound of a vessel. It may happen that on the admission of the patient to hospital an arterial hæmatoma is not recognised. This may be due either to its small size and tardy development, or to a hasty and incomplete examination. Consequently the wound is insufficiently cleansed and dressed, and the patient discharged without further

attention. The vascular wound does not show itself until some days later, when sudden increase of the swelling or, more frequently, a secondary hæmorrhage takes place. The question of treatment resolves itself into the management of either of two very different conditions:—

1. A hæmatoma of medium size, recently formed and easily diagnosed.

2. A suppurating wound with either diffuse secondary hæmatoma or secondary hæmorrhage.

In the first case, the method is that which has just been described. The size of the swelling has no clinical significance. The same precautions and the same technique must be employed in the management of a small or medium hæmatoma as in that of a large one. These measures are provisional hæmostasis, free exposure and incision of the hæmatoma, and treatment of the vascular wound according to the instructions given above. I would remark that the smaller the hæmatoma and the less threatening the symptoms of compression, the less is the consequent menace to the collateral circulation and the less the risk of the double ligature.

In the second case, the work of the surgeon is often difficult. The most difficult problem is that of secondary hæmorrhage.

**Treatment of Secondary Hæmorrhage.**—It was not my original intention to enter here into the details of the treatment of secondary hæmorrhage. As a matter of fact, it does not occur if prophylactic treatment against infection is methodically and carefully carried out. Secondary hæmorrhage is no longer observed at front-line stations, where all wounds from large missiles are at once subjected to

the extensive surgical measures to which I have so frequently referred. Neither is it observed at base hospitals, where any imperfection or insufficiency of the surgical treatment at the front is immediately supplemented. Secondary hæmorrhage was much talked of at the beginning of the war, but no one mentions it to-day. Everybody knows that it is a sign of inefficient treatment; it is a living reproach to the operating surgeon.

Nevertheless secondary hæmorrhage does occur in rare instances, and such cases must receive appropriate treatment. They comprise those exceptional cases of hæmorrhage into the dressings in the atonic wounds of septicæmia, the more numerous cases in which hæmorrhage from an infected wound takes place as the result of an undetected wound in an artery of small or medium calibre, and the cases in which secondary hæmorrhage occurs as the result of the infection of an arterial hæmatoma which has either passed unnoticed or has not received early treatment. To these I would add secondary hæmorrhage as the result of secondary ulceration of large arteries, the ulceration being due to friction of the vessel against a foreign body, such as a missile or a bony splinter. Grégoire has recorded a case of this kind. It may also result from prolonged contact with a rigid indiarubber drainage tube. Finally, secondary hæmorrhage may take place after extensive denudation of a vessel, especially if the latter is in contact with extremely septic material, as in wounds of the neck or at the angle of the jaw, which communicate with the bucco-pharyngeal cavity.

The capillary hæmorrhage of atonic and septic wounds is treated by complete removal of the granu-

lations, and the minute and careful curetting of the wound. This is the ideal mode of disinfection. Hæmorrhage of this sort cannot be arrested by sprinkling the granulations with local medicaments, or by exhausting the entire series of hæmostatic remedies. The whole area of the wound must be curetted, incisions being made where necessary, until the underlying healthy tissues, aponeurosis, muscle or bones, are plainly seen. When all the septic granulations are removed, the hæmorrhage will cease of itself. The post-operative measures include the employment of heliotherapy and hot air—not chemical antiseptics, but the physical agents, light and heat.

Secondary hæmorrhage of arterial origin is by far the most frequent. The sole method of treatment is by immediate operation. Owing to the nature of their origin there is great risk in attempting to arrest these hæmorrhages by timid and imperfect methods, such as compression in the wound, which is both ineffectual and dangerous. It is ineffectual, because the hæmorrhage recurs with each change of tampon, and frequently reappears in spite of plugging. It is dangerous, because the close plugging of a septic wound increases the infection, endangers the vitality of the walls, and leads, in the end, to a serious and rapid extension of the sepsis. The only rational method is by immediate operation.

The first operative measure is the free exposure of the traumatised area ; the second, the isolation of the bleeding vessel, and its ligature above and below the opening.

In infected tissues such an operation presents considerable difficulty. In the first place, it is not

always possible to open up the traumatised area. As the result of œdema and infiltration, the walls are rigid and fail to collapse; the wound remains deep and rugged, especially if it be in the neighbourhood of a bony surface, as around the trochanter, in the popliteal space, or in the gluteal region. Thus operation is performed at the bottom of a rigid cavity into which it is difficult to see. That cavity is, moreover, carpeted with granulations, covering a layer of hard tissue, in the very midst of which the wounded artery is concealed. The spot from which the bleeding takes place is seen at the bottom of the wound, and an attempt is made to catch the artery with the forceps, but the points tear the tissues and do not hold. It is only after considerable trouble, and not always even then, that the forceps are at last fixed and the hæmorrhage arrested. The replacing of the forceps by a ligature is also very difficult. Either the extremity of the forceps cannot be disentangled, or the ligature breaks, and the manipulation has to be repeated. One or more forceps must sometimes, therefore, be left in place. In such a case as this forci-pressure fulfils one of its most valuable indications.

In the face of these difficulties, it has been suggested that ligature in the wound should be replaced by ligature at a distance. The finding and controlling of the actual source of hæmorrhage being a matter of difficulty, would it not be well to tie the artery above the wound in sound tissues where the anatomical landmarks would enable it to be easily found? Theoretically, ligature at a distance is very inferior to ligature in the wound. It may be useless, it may be ineffectual, and it may be dangerous; useless, if

it is applied, for example, to the axillary below the clavicle for a hæmorrhage in the axilla, the source of which is a wound of the subscapular, which continues to bleed; ineffectual, if between it and the opening in the vessel there is a collateral branch conveying blood into the wound; and dangerous, if it can only arrest the hæmorrhage by interfering with the collaterals on which the restoration of circulation in the limb depends. But in spite of these undoubted drawbacks, ligature at a distance remains the last resource in difficult cases.

Where and how should it be performed? Must a fresh incision be made away from the wound, the artery found, and a provisional ligature applied to it? Or may the wound be merely enlarged in an upward direction until the vessel is found in healthy tissues? This depends, I think, upon the nature of the case.

In cases where it is easy to enlarge the wound in an upward direction until the artery is found, this should be done directly and without a fresh incision. As soon as the artery is found it should be tied as near to the bleeding point as possible. This is generally the best method in wounds of the calf, the forearm, or the arm. But if the wound is difficult of access, if its walls are rigid, or if, above all, the vessel changes its direction above the wound, as happens in the case of the popliteal and the gluteal, it is better at once to apply a temporary ligature in healthy tissues away from the wound. Thus ligature of the external carotid is very successful in hæmorrhage from some wounds of the neck, the face, or the bucco-pharyngeal cavities; ligature of the femoral at the adductor opening in wounds of

the popliteal space ; and ligature of the hypogastric (internal iliac) in some deep wounds of the buttock. But ligature is only the first step in the operation. The second is equally indispensable. It consists in thorough opening up of the wound, which is now protected from all risk of hæmorrhage, curetting of its walls, and as complete an exposure of the vascular wound as the conditions permit, followed by isolation of the vessel and double ligature in the wound.

**B. FOLLOWING A BULLET-WOUND.**—The track is insignificant and practically aseptic. Should operation take place at once, as soon as the wound is seen and a hæmatoma diagnosed ? Or should the patient be kept under observation to allow an aneurism to form ?

Many surgeons are in favour of the later operation, and affirm that it has many advantages. In proportion as the hæmatoma grows older and retracts, it diminishes in volume. The arterial or arterio-venous aneurism in which it ends is much smaller than the original hæmatoma, and is therefore more easily accessible. As cicatrisation proceeds the wound becomes healthier, and, most important of all, the collateral circulation is gradually established, until finally it constitutes a blood-supply which renders obliteration of the main artery of no importance.

Other authors, on the contrary, are in favour of early operation, the advantages of which are as follows : It is the sole safeguard against complications which may arise during the progress of the wound, such as sudden enlargement or septic infection of the hæmatoma. Contrary to expectation, it

is much less difficult than a delayed operation. The danger to the circulation of the limb is also less, for the wounded vessel is tied immediately above and below the wound, and no collateral branch is damaged. Delayed operation, on the other hand, involves the extirpation with the aneurism of a vascular segment, which may include one or more important collaterals. Lastly, by evacuating the hæmatoma and preventing the formation of fibrous tissue round the bleeding point, which leads ultimately to the development of an aneurismal sac, early operation constitutes the best prophylactic measure against venous compression, and especially against secondary nerve lesions, which, as we know, so frequently darken the prognosis in operation for aneurism.

For my own part, I am convinced that it is best to operate immediately on small hæmatomata as on large ones. The object here is not, as in the case of large or septic hæmatomata, to prevent ischæmic or septic gangrene, infection or secondary hæmorrhage ; it is to anticipate from the first all possible complications. Moreover, and this is a very important point, early operation upon a small arterial hæmatoma is easier, more certain, and less dangerous than the later operation upon an arterial or arterio-venous aneurism.

The practical problems of treatment are as follows:—

1. *Primary operation.*—A patient is brought to a front-line station with a perforating bullet-wound of a limb. The orifices of entrance and exit are so situated that it is almost certain that the track of the bullet crosses the line of one of the main vessels, and examination reveals the existence of a medium-sized or small hæmatoma. In spite of the insignificant and

aseptic nature of the wounds, and in spite of the absence of risk of gangrene, is it necessary to expose the vessels at once by means of a special incision and treat the vascular wound directly? Yes, without a doubt.

The operation is identical with that described above. The first steps are to secure preliminary hæmostasis by digital compression above the wound, or by exposing the artery and passing a temporary ligature; then to expose the hæmatoma by a suitable incision, opening it freely and laying bare the wounded vessels. The operation is completed by the careful exposure of the vascular lesion and the establishment of permanent hæmostasis. In wounds of this class the risks of ligature are reduced to a minimum. The arterial lesion is generally clean, and only slightly contused. The thrombus in the proximal part of the vessel is small, consequently there is little risk of intravascular obliteration of the collateral branches. Further, as the hæmatoma is not large, and the collaterals are scarcely compressed at all, there is every chance of complete restoration of the circulation. Finally, the wound is aseptic and may be closed safely, the risk of secondary inflammatory swelling, which might interfere with the resumption of the circulation, being negligible.

It is, however, essential that the result of ligature should be ascertained beforehand by means of the tests given above. Should there be any suspicion of the possibility of gangrene, lateral or circular suture should be performed.

The suture of the skin and the insertion of a small drainage tube at the most dependent part completes the operation.

2. *Secondary operation.*—The case here is no longer that of a fresh wound or an injury a few hours or a few days old. These are subjects in whom the vascular wound has been overlooked, or in whom the hæmatoma has formed slowly and gradually, and who are brought to a base hospital two or three weeks or more after the wound has been received. The openings have cicatrised, but the course of the bullet is marked by a more or less extensive swelling, presenting all the symptoms of an arterial hæmatoma. The phrase arterial hæmatoma is deliberately employed, for the word " aneurism " is at this stage most misleading. The sac has no distinct wall, this so-called tumour is not extirpable, and it is not amenable to the treatment of true aneurism. In its present stage the hæmatoma is best treated by the operation which we have just described, namely, incision of the sac followed by direct hæmostasis in the wound.

Here again the first step, after securing temporary hæmostasis, consists in the thorough opening-up of the sac by suitable incision and exposure of the wounded vessel. I would draw attention to some important particulars. The sac contains very little fluid blood ; it is filled with black clots like grapes, which are carefully removed by means of a swab, and sometimes with the curette. When the clots are removed there is no longer any sac ; there is only a cavity between the muscles, the walls of which fall together, and at the bottom of which the wounded vessel is found. It is sometimes difficult to distinguish it among the blackened tissues stained with the colouring matter of the blood. At last a small bluish-white patch is seen, limited in extent, showing

up distinctly against the black colour of the surrounding tissues. That is the arterial endothelium, and the wound of the vessel is now easily recognised. The artery is isolated, tied or sutured, and the operation is finished. The wound in the artery is generally detected easily, because the lower end, which brings the blood from the collaterals, continues to bleed. When there is doubt, this sign may be accentuated by momentarily relaxing the compression above the wound.

Thus the treatment of arterial hæmatoma following on a bullet-wound is by incision of the hæmatoma and direct hæmostasis of the vascular wound. This operation should be performed as soon as the hæmatoma is diagnosed, whether at the field ambulance the next day, or at the base hospital two, three, four, or five weeks later if it has only then been recognised.

For how long may the arterial hæmatoma be treated by direct incision? In other words, for how long does it remain without a rigid, detachable wall of its own, which, when it is removed, leaves a gaping cavity, into which the neighbouring collaterals continue to bleed? As previously stated, this varies with the vessel, with its calibre, and with the extent of the original effusion. As a general rule it may be admitted that for the first six weeks the hæmatoma has no wall of its own, and may be treated by direct incision. From that time onwards the possibility of finding a well-formed aneurismal sac, which cannot be treated by simple incision, progressively increases.

It must not be imagined, however, that time, although important, is the only guide to treatment.

Arterial hæmatoma and traumatic aneurism are distinguished by their clinical features. Hæmatoma is diffuse, without exact limitation, and is not a separate entity; a traumatic aneurism, arterial or arterio-venous, is an isolated tumour, well defined, and with remarkably distinctive clinical features. I shall shortly describe the therapeutic indications of these unrecognised or unoperated-upon sequelæ of vascular lesion, arterial and arterio-venous aneurism.

### III. Wounds of Arteries without Hæmorrhage

There is little further to be said in regard to the treatment of wounds of arteries that do not bleed. When the injury is due to a fragment from a large projectile, the arterial wound will be a chance discovery during operation by the surgeon of the ambulance who first sees the patient. Recent experience has removed all doubt as to the necessity of immediate operative treatment for all shell-splinter-wounds; preventive incision has become the rule in all surgical units at the front. Where the femoral, the posterior tibial, or the brachial has been injured by a splinter which remains impacted in the arterial wound, the splinter will be detected in the course of the prophylactic incision. Properly performed, this operation should expose the whole of the traumatised area; it should include the discovery of the missile and lay bare all the ramifications of the wound, no part of which should remain unexplored. Under these conditions it is impossible for the wound of the vessel to be overlooked. As soon as the clot, the shreds of clothing, and the missile are removed, a jet of blood spouts suddenly from the bottom of

the wound and reveals the position of the arterial injury. Its diagnosis constitutes the first stage of the treatment. While an assistant ensures hæmostasis by pressure above, the surgeon wipes out the wound; he then explores it, exposing the vascular lesion, which he treats by one of the methods already described. When compression above the wound is impossible, the artery is exposed above the wound and its lumen obliterated by raising it on a thread, an assistant tightly plugging the wound meanwhile. Not until hæmostasis has thus been secured should the tampon be removed and the wound in the vessel sought for. The directions given for the treatment of hæmatomata are applicable to these cases.

When, on the other hand, the wound is caused by a bullet, or by a minute shell-splinter, the orifice of entrance is punctiform, the track insignificant, and no hæmatoma is present. In such a case the wound in the vessel is almost certain to be overlooked at the first examination. That the flesh-wound is situated near the course of a large vessel is obvious, but in the absence of any hæmorrhage, external, internal, or interstitial, how is a vascular wound to be suspected?

Early diagnosis is, however, possible when the companion vein is wounded simultaneously with the artery, the edges of the venous wound becoming adherent to those of the arterial opening, a primary aneurismal varix being thus formed. The characteristic thrill may be discovered by chance when the hand is laid on the wounded region, and the diagnosis of vascular lesion is then plain. This is, however, quite exceptional, and at a first examination the thrill

may be easily overlooked. An experience such as Broca's may fall to the lot of even the most careful surgeon. While examining a patient he drew the attention of his assistants to the fact that, by some happy chance, the vessels in the track of the bullet had remained uninjured. A few days later the thrill characteristic of a double vascular lesion made its appearance. Thus, in the vast majority of cases, dry arterial wounds, whether by bullet or by minute shell-fragments, escape detection both at front-line stations and at base hospitals. It is not until later that certain minor functional troubles, in association with a small aneurism or an aneurismal varix, make their appearance. The patient, who has been returned to his regiment, finds himself eventually, with a history of vague functional trouble, in the hands of the regimental doctor. It frequently happens that the discovery of an aneurismal varix is entirely fortuitous, made during examination upon quite another count in a patient entirely unconscious of his vascular lesion. It is chiefly their remoter consequences which render these wounds interesting to the surgeon.

The treatment at the ambulances of hæmatomata, whether large, medium, or small, has now been described, together with the various problems of treatment which present themselves in the course of unrecognised or untreated vascular wounds, as well as the treatment of secondary hæmorrhage. We have still to consider the management of the remoter consequence of untreated vascular lesion, namely, traumatic aneurism.

Traumatic aneurism is either arterial or arterio-venous.

## I. Arterial Aneurisms

1. Therapeutics.—The usual course of arterial aneurisms is regularly progressive. The circulatory and nervous disturbances which they cause become gradually more accentuated, and in the course of this slow evolution various complications may suddenly occur which endanger life and limb.

Some cases of spontaneous cure have, however, been recorded. In these the circulation in the sac gradually becomes slower, the fibrinous clots being deposited in concentric layers on the wall, leaving only a narrow channel in the centre, which in its turn is finally obliterated, so that nothing is left of the aneurism but a small fibrous tumour without expansion, pulsation, or bruit. Since the commencement of the war cases of arterial aneurism presenting signs of spontaneous recovery have been shown at the Société de Chirurgie by Pozzi, Routier, and Walther. Such a favourable termination must, however, be regarded as a fortunate exception.

As a general rule the symptoms become gradually more pronounced, the nervous troubles in particular becoming very much intensified. The increasing and repeated compression of the nerves adjacent to the sac or enclosed within its walls induces neuritis, accompanied by the appearance or the exacerbation of very acute pain, with signs of paralysis and anæsthesia and with trophic disturbances. The limb tends to become more and more powerless and painful.

The slow development of the symptoms is, unfortunately, only too frequently hastened by the occurrence of serious complications. These are rupture and inflammation of the sac.

*Rupture of the sac* is due to the progressive attenuation of its walls consequent upon its steady enlargement. Rupture may occur under the influence of the slightest shock or effort, sometimes without apparent cause. It may take place externally, into a neighbouring serous cavity, such as the pleura or the peritoneum, or into the cellular tissue, causing either serious external hæmorrhage, internal hæmorrhage, or diffuse secondary hæmatoma. In the two first cases death ensues rapidly. In the third, all the complications associated with a large diffuse hæmatoma immediately appear, the most rapid of which is ischæmic gangrene of the limb, due to sudden compression of all its blood-vessels.

*Inflammation of the sac* is favoured by the compression of the external tissues. Owing to compression, the vitality of the skin and cellular tissue becomes impaired, with the result that these tissues are susceptible to the slightest infection induced by cutaneous excoriation, however minute. The subcutaneous infection is conveyed to the aneurism, the clots putrefy, and the aneurismal wall softens. A suppuration, either circumscribed or diffuse, now develops, the sudden opening of which results in copious external hæmorrhage.

Finally, apart from rupture or inflammation of the sac, serious complications may occur as the result of *embolism.* Particles from the interior of the aneurismal sac are projected into the efferent artery, which they block, with the result that a gangrene, generally dry, is set up, the extent of which corresponds with the calibre of the obliterated artery.

The gravity of the prognosis in arterial aneurism demands active methods of treatment. We shall

now consider the measures to be employed and the indications for each.

2. Methods of Treatment.—According to Quénu and Muret, there are to-day three principal methods of treating arterial aneurism:—

1. Promotion of the spontaneous obliteration of the sac by coagulation of its contents.

2. Complete extirpation of the aneurism.

3. Cure of the aneurism without removal of its wall.

**FIRST METHOD.**—This includes all the methods of procedure, from acupuncture and ignipuncture to indirect compression and ligature of the artery in continuity above and below the sac, which act directly or indirectly upon the aneurism, and are designed to bring about coagulation of the blood.

A. *Compression.*—I shall do no more than merely mention *indirect compression* of the artery above the aneurism. It is carried out by means of a tourniquet, a leaden pad, or preferably the fingers. During the last twenty years its employment has become gradually less frequent. Out of 410 cases examined by Monod and Vanverts in 1911, compression was employed in only 19, that is, in 4·6 per cent. Of course, excluding the risk of complications, such as embolism and gangrene, the method is seldom efficacious. According to Monod and Vanverts, in more than half their cases it had no influence on the progress of the aneurism.

B. *Ligature.—Proximal ligature of the artery* has for its object the reduction of the circulation in the aneurism. This facilitates the formation of clots, thus favouring spontaneous recovery. Whether carried out immediately proximal to the aneurism

or farther away, at the most favourable portion of the artery (Hunter), the operation is simple and easy. Its simplicity is its only recommendation, while its disadvantages are many. It may be completely useless, as in cases where the aneurism has developed on a secondary branch in the neighbourhood of the main trunk and has been mistaken for an aneurism of the trunk. It is often inefficient, because the circulation is so well maintained by the collateral branches between the ligature and the upper pole of the aneurism that the desired object is not attained. It is obvious that this will happen more frequently after the Hunterian ligature than after Anel's. Even where the method is successful, where circulation is retarded, coagulation takes place, and the growth of the tumour is arrested, the effect upon the functional derangement is very slight. This applies especially to the nervous disturbances, the pain, paralysis, anæsthesia, and trophic derangements, which disappear only with the fibrous sac which compresses and alters the nerve-trunks. It is not surprising, therefore, that the number of failures is great. According to statistics based on 138 cases treated by this method Monod and Vanverts gave 12 per cent. of failures, but this is probably less than the real percentage.

Ligature above the aneurism, however, is not only ineffectual, it is often dangerous. I do not allude to the operative mortality, which ought to be very small if the operation is performed carefully and aseptically. The 7 per cent. of deaths mentioned by Monod and Vanverts is a very large proportion, and is dependent upon the fact that many of the cases quoted were old aneurisms. I refer only to gangrene

of the limb, which is comparatively frequent after ligature, more so than after extirpation. This is due to the fact that the ligature suppresses not only the circulation in the aneurism, but also that in certain of the collaterals, between the ligature and the sac. These are more numerous the higher the ligature is applied. Other factors are supplied by the presence of the tumour, which, after ligature, may compress the collateral vessels, and by the frequency of embolism. In the latter case, particles of the clots in the sac are driven into the distal part of the artery by the blood coming from a collateral. These causes of gangrene occur independently of surgical asepsis and of operative efficiency. It is not to be wondered at that the proportion of cases of gangrene after ligature has only very slightly diminished in the last twenty years. In 1895 Delbet quoted it at 8·25 per cent. In 1910 Monod and Vanverts found the percentage to be 6·5.

I shall say nothing about *ligature in continuity distal to the aneurism*, either quite close to the lower pole of the sac (Brasdor) or at a distance (Wardrop). These are makeshift methods dictated by necessity, and employed only in certain aneurisms at the root of the neck, in which proximal ligature is extremely difficult and hazardous.

**SECOND METHOD.**—The second method, which consists in *extirpation of the aneurism*, is the one most generally employed in France and in Europe generally.

As the first step in the operation consists in exposing the artery immediately above the tumour, preliminary hæmostasis is not necessary. A longitudinal incision is made over the surface of the tumour,

supplemented, where necessary, by one or more transverse incisions, or a flap, which may be cutaneous, musculo-cutaneous, or osteo-cutaneous. When the tumour is exposed, its proximal pole is dissected out and freed as much as possible from the surrounding parts until the afferent vessel comes into view. If the artery is on the anterior wall of the aneurism, it will be found easily, and quickly exposed; when it is on the posterior or lateral wall of the sac, exposure is a longer and more difficult matter. As soon as the artery has been exposed, it should be caught in an artery-clamp. At the distal end of the tumour the same process of dissection and separation is then carried out, the efferent artery being exposed and clamped.

The next step is to dissect out the proximal half of the sac by separating it from the arterial trunk from above downwards. In the course of this manipulation the branches given off from the principal trunk are encountered. These are applied closely to the sac, and often open into it. They should be tied at their origin. The proximal half of the aneurism being now freed, the distal half is dissected in a similar manner, working from below upwards. Its outer surface is very carefully separated from the nerve-trunks which lie along it, and which are adherent to it or closely embedded in it. Sometimes they have to be actually carved out of the fibrous sheath surrounding them. The tumour is now completely isolated, and is retained only by a slender pedicle, where the main artery opens into the aneurism. This pedicle may be extremely slender, or it may be more than an inch in width. Occasionally the isolation of the aneurism is extremely difficult; in

such a case the sac should be opened and dissected out like an adherent hernial sac, one or more fingers being introduced into its interior. When the tumour is completely freed, it is excised close to its attachment to the artery; this may involve the resection of half an inch or more of the vessel.

We are now faced with a loss of the arterial wall, which may be either lateral or circular. It is only necessary to apply a permanent ligature to each end of the artery, and the extirpation of the aneurism is completed (figs. 37 and 38).

FIG. 37.—Extirpated aneurism of the brachial artery. (Professor Jacob's case. Val-de-Grâce Museum.)

The repair of the vessel may also be attempted by lateral or circular suture or by venous transplantation. A fine continuous suture, supplemented, where necessary, by a few interrupted ones, will close a lateral opening in a few minutes. The entire circumference of the vessel may be repaired in ten or twelve minutes by a triple row of continuous suture after Carrel's three supporting threads have been applied. Finally, if the two ends of the artery are not sufficiently close together to permit of a circular suture, a segment from the trunk of a neighbouring vein may be grafted into the gap.

Which is the preferable method of these two?

Extirpation followed by double ligature is a method which may be regarded as innocuous. Apart from

avoidable septic complications, the mortality is almost nil. According to Delbet, 86 cases were published between 1887 and 1895, and these did not include a single death. Between 1895 and 1911 205 cases were published, and of these only 7 terminated fatally—a mortality of rather more than 3 per cent.

The method is also very efficient. To borrow Delbet's phrase, extirpation of an aneurism effects a radical cure, for the patient is permanently relieved of his aneurism and of all the disturbances resulting from it.

FIG. 38.—Arterial aneurism of the ulnar, extirpated at the moment of rupture. (Professor Jacob's case. Val-de-Grâce Museum.)

Extirpation, unfortunately, presents one weak point, and that is the possibility of gangrene. Among the 205 cases collected by Monod and Vanverts, there were 9 cases of gangrene, or 4 per cent. Out of 93 cases which I have found in French and foreign publications since the war begun, there were 9 cases of gangrene, or about 10 per cent. Of these 9 cases, 2 were of gangrene after extirpation of an axillary aneurism, 4 after extirpation of a femoral, and 3 after extirpation of a popliteal aneurism. From these observations, which were confined to aneurisms from war-wounds, gangrene followed extirpation of an

axillary aneurism in 11 per cent. of cases, of popliteal aneurism in 13 per cent., and of femoral aneurism in nearly 30 per cent. of cases.

What is the practical conclusion to be drawn from these facts? That, in the case of all the larger arteries, the axillary, femoral, popliteal, etc., the permeability of the vessel must at any cost be re-established? Where there is no risk of gangrene, such a procedure provides only an unnecessary complication. The essential point is to ascertain beforehand whether, in the particular case under consideration, gangrene is to be anticipated or not. Is this possible?

Valuable information is yielded by pre-operative examination. The presence of rigid, non-elastic arteries in an elderly soldier is an unfavourable prognostic sign. If the circulation in the aneurism is strong, the expansile pulsation very marked, and the bruit loud and harsh, it is certain that the principal artery is still the chief source of the blood-supply, and that the collateral circulation is consequently only slightly established. If the peripheral pulse-beat is as strong as that of the opposite side, the inference is the same. All these signs are, however, vague and uncertain, and more definite data are required. Korotkoff has suggested compression of the vessel above and below the tumour, thus realising the conditions obtained by ligature, and observation by means of the manometer of the variations of blood-pressure in the extremity of the limb. If the peripheral pressure falls roughly to zero, gangrene is probable; if there is no change, gangrene will not occur. The theory is sound, but experience has shown that the method is not reliable in practice.

It is often extremely difficult to produce a degree of compression above the tumour equal to that of ligature.

It is expedient in this connection to recall certain clinical features of arterial hæmatoma. In a former chapter it was shown that when the collateral circulation is sufficient, the extremity of the limb is only slightly affected by a temporary ligature above the tumour. When, however, the collateral circulation is insufficient, the limb turns pale and cold. If the blood is circulating in the limb, compression of the accompanying vein induces a swelling of its peripheral end. Finally, an oozing of blood or a hæmorrhage on the temporary removal of the clamp from the lower end of the divided artery shows that the collateral circulation is established. In specially doubtful cases a small incision, in the tip of one of the digits, for instance, will show whether the circulation is maintained. This combination of methods will furnish sufficiently reliable evidence of the presence or absence of the collateral circulation and the consequent chances of gangrene.

I must not, however, omit to state that the presence of a collateral circulation which is sufficient to prevent gangrene may not be enough to ensure the proper working of the limb. It is well known that the amount of blood required for the preservation of life in the tissues and organs is much less than the amount necessary for the active function of these organs, especially of the muscles. This applies equally in the case of the collateral circulation. That is no doubt the reason for the permanent powerlessness, sometimes complete, which follows the extirpation of some aneurisms. It is undoubtedly an

additional reason for caution in the employment of the double ligature after extirpation of the sac, even in cases where gangrene is not probable.

Thus in a certain number of cases it is unfortunately impossible to determine beforehand whether ligature of both ends of the artery after extirpation of the aneurism will be followed by gangrene of the limb, or at the least by such an impairment of its circulation that function is permanently reduced. On principle, therefore, wherever possible, an attempt should be made to prevent these complications by restoring the permeability of the vessel by lateral suture, circular suture, or even venous transplantation.

In 1911 Monod and Vanverts knew of only two cases of circular suture and two of venous grafting after extirpation of an arterial aneurism. The number of such operations has, however, greatly increased since the war. Soubbotitch has described thirteen cases of arteriorraphy performed by him in arterial aneurism. In eight cases he employed lateral suture. Of these, four were successful; three were unsuccessful, one ending in death; in one case the result was unknown. In five cases he employed circular suture with success. He also reports eighteen further cases of traumatic aneurism due to projectiles, ten of which were treated by lateral and eight by circular suture. Gangrene followed in four cases. Bonin has recently described twelve cases of arterial and arterio-venous aneurism, in eleven of which operation was successful, and in one, a circular suture of the internal carotid, the termination was fatal. The eleven successful operations comprise one lateral and ten circular sutures, six of which were accompanied by venous

transplantation. All these results are interesting. Although owing to certain technical difficulties vascular suture does not absolutely ensure the permeability of the vessel, it must be regarded as the ideal method in doubtful cases, which should always be attempted before recourse is had to permanent double ligature.

**THIRD METHOD.**—The third or American method of *aneurismorraphy* (Matas) consists in opening the sac, examining its internal surface, and adopting procedures which vary in accordance with the conditions present.

When incision of the sac reveals only one arterial orifice which communicates with both the central and the peripheral ends of the artery—in other words, when the aneurism is saccular, arising, so to speak, from a lateral orifice, this orifice should be closed by bringing the endothelial surface of the walls together and uniting them by one or more rows of sutures. The artery is thus shut off from the sac, and the continuity of the vessel is preserved. The sac is coapted by a few mattress sutures. This is the operation known as *reparative aneurismorraphy*, the ideal method in sacculated aneurism.

A sac may be found to contain several openings, or it may have two long orifices corresponding to the afferent and efferent ends of the artery. In the latter case the aneurism is fusiform in shape, and corresponds to a kind of dilated tube which replaces a segment of the artery. There are two possible methods of treatment. Both openings may be closed by suture, in the manner adopted for the single opening in the operation described in the preceding paragraph. This results naturally in the

complete obliteration of the vessel; hence the operation is termed by Matas *obliterative aneurismorraphy.* Or the internal wall of the sac may be sutured round two sounds, which are introduced respectively into the central and peripheral ends of the vessel and are removed as the last stitches are being put in. This operation results in the formation of a narrow channel joining the two ends of the artery, and is known as *reconstructive aneurismorraphy.*

The advantages of the American method are its simplicity and the facility of its execution. As a general rule the free incision of the aneurism is better than a long and difficult external dissection, for it allows the relations of the aneurism with the vessel to be at once perceived.

After the aneurism has been opened, it has been the custom until recently to perform obliterative aneurismorraphy. The method is not obviously superior to extirpation followed by double ligature. On the contrary, it possesses certain distinct disadvantages, due to persistence of the aneursimal sac, and the clinical results are less satisfactory than those of extirpation.

The only really valuable method of treating traumatic aneurism is that of reparative aneurismorraphy. This is a conservative measure, which possesses the advantages of repair of the vessel without the difficulties inseparable from vascular suture after extirpation of the sac. I have performed the operation on one occasion only, and must in fairness admit that it is not always easy. The tissues are hard and friable, and the accurate insertion of the sutures may be extremely difficult. In spite of its difficulty, however, the operation is a very attractive one. In

1911 it was employed nine times in popliteal aneurism with complete success (Quénu and Muret).

*Summary.*—Of the three principal methods of treatment of traumatic aneurism, the classic operation is still extirpation of the sac, with ligature above and below. The ideal method, however, is the re-establishment of arterial continuity by lateral or circular suture, with or without venous transplantation. The method can no longer be regarded as exceptional; on the contrary, it represents a perfectly—one might almost say easily—attainable ideal. The method should always be employed in the case of a dangerous artery and in cases where there is the slightest reason to anticipate gangrene. In spite of its attractiveness, Matas' operation is not of capital value. It is perhaps preferable to extirpation with double ligature, but in view of the fact that it leaves embedded in the tissues a fibrous sac which is occasionally inflamed, it is certainly less advantageous than extirpation followed by immediate repair of the vessel.

## II. Arterio-venous Aneurism.

1. Therapeutic Indications. — Arterio-venous aneurism is far slower and more insidious in its development than arterial aneurism. Months, even years, may pass without an appreciable change in the size of the tumour. Occasionally, though this is exceptional, it diminishes in size; the thrill, expansion, and murmur disappear, and spontaneous recovery takes place. Since the outbreak of war both Pozzi and Routier have shown patients before the Société de Chirurgie who, six months previously, had presented all the signs of arterio-venous aneurism in

the neck. The sole treatment was by rest, yet the tumour, with all its manifestations, thrill, expansion, and murmur, had completely disappeared.

Such instances are, however, rare. As a general rule the tumour persists and, in the long run, produces a varying degree of derangement of the circulation of the limb as well as of that of the heart. The circulatory disturbances are manifested by more or less marked dilatation of the veins below, by œdema, cyanosis, and pain. The pain and œdema are occasionally so intense as to suggest phlebitis. These signs are frequently accompanied by nervous symptoms of varying intensity, such as hypoæsthesia with numbness and paresis of the limb. In exceptional cases the nervous symptoms are sufficiently intense to interfere with the functional activity of the limb. It is very important that the cardiac symptoms should not escape detection, and that their real origin should be recognised. The sudden and rapid return to the right heart of blood projected by the axillary or femoral artery into the central end of the companion vein is accompanied by considerable disturbance of right cardiac function. This is a point which has never been sufficiently emphasised. I consider it one of the chief indications for surgical treatment of the aneurism. I recently operated with Cotte upon a case of arterio-venous aneurism of the hypogastric (internal iliac) vessels, in which the cardiac symptoms, namely, palpitation, dyspnœa, and painful tachycardia, were extremely marked.

Complications are rarely associated with the development of arterio-venous aneurism. Rupture and infection of the sac are quite exceptional; they never occur except in cases where, as the result of fortuitous

obliteration of the venous orifice, the arterio-venous aneurism becomes converted into an arterial aneurism.

The freedom of certain cases of arterio-venous aneurism from grave complications and threatening symptoms furnishes a contra-indication to surgical intervention. These are cases in which an aneurism, which provokes only minor circulatory and cardiac disturbances, is situated in a region which is difficult of access; in these the risks of operation are not counterbalanced by the clinical results. Aneurism at the base of the neck and abdominal and pelvic aneurisms are examples of this. Where, however, the cardiac and circulatory disturbances are very marked, immediate surgical treatment is unconditionally indicated.

2. Treatment.—Having established the fact that the grave symptoms, namely, those of the heart and circulation, are due to the direct passage of the arterial blood into the central and peripheral ends of the vein, the object of all methods of treatment of arterio-venous aneurism is the complete and permanent separation of the two currents of blood and the obliteration of the vascular anastomosis.

Anastomosis is sometimes direct (aneurismal varix), sometimes indirect (varicose aneurism). In reality this distinction is more apparent than real. It is true that a simple aneurismal varix has not, in the true sense, a sac; but the central and peripheral ends of the vein are sometimes so distended that they form an actual pocket at the site of anastomosis. Moreover, the slow inflammation of the neighbouring tissues produced by the repeated impulses from the blood-stream causes them, as in varicose aneurism, to become adherent to the external walls of the

dilated vessels. The two vessels, anastomosis of which is sometimes minimal, and does not exceed 2–3 mm. in diameter, are externally adherent well beyond the limits of anastomosis. Consequently, from the point of view of the operative separation of the two vessels, aneurismal varix presents very similar conditions to those of varicose aneurism. In both classes of case, separation is obtainable only by ablation of the anastomosed arterio-venous segment.

In aneurismal varix the ideal operation is the separation of the artery and vein by ligature of the little canal which unites them; or, where the canal is very short, by separate lateral suture of both artery and vein.

In varicose aneurism the ideal operation is extirpation of the intermediate aneurismal sac, and repair by appropriate suture of the two vessels.

Since the outbreak of war the number of arterio-venous aneurisms treated by ideal methods has rapidly increased. In 1911 Monod and Vanverts knew of only ten cases in which the ideal method was attempted, and in three of these the reparative measure was confined to the vein. Since the war, Soubbotitch has reported nineteen cases of angiorraphy for arterio-venous aneurism to the Société de Chirurgie, of which fourteen were successful, one partially successful, in two suture was unsuccessful, one result was unknown, and one ended in death. Bonin has published nine cases, seven by Hotz and two by Geiger. Makins has described an angiorraphy performed by him in arterio-venous aneurism of the femoral. Individual cases multiply on every side. The cure of arterio-venous aneurism is no longer the

exceptional outcome of unusual technical skill. It is attainable by ideal methods, which are accessible to everyone familiar with the surgery of the vessels. These methods should always receive consideration when operation upon arterio-venous aneurism is undertaken.

Unfortunately the operation is not invariably applicable. In the case of varicose aneurism, the close adhesion of artery to vein, and of both to the surrounding tissues, renders the isolation and separation of the vessels frequently impossible. In the case of aneurismal varix, the fusion of the sac with the tissues and organs which surround it frequently renders total extirpation impossible ; or it necessitates the resection of so considerable a vascular segment, that the vessel is no longer amenable to repair. In such cases recourse is had either to quadruple ligature, obliterating both artery and vein above and below the anastomosis, or to extirpation of the sac with ligature of all the vessels involved.

Quadruple ligature is a comparatively simple and easy operation. It may, however, present considerable difficulty when the arterio-venous lesion is situated in the neighbourhood of a tributary vein, the jugulo-subclavian junction, for instance. In order completely to separate the two vessels it is sometimes necessary in such a case to ligature the innominate artery and the subclavian and jugular veins as well as the carotid.

The method, moreover, presents certain grave drawbacks. It may under certain conditions prove both dangerous and ineffectual. It is ineffectual where the arterial and venous branches open into the sac or into the vascular segment between the ligatures.

The venous collaterals continue to drain the collateral arteries, and the very conditions which operation was intended to relieve continue to exist. Thus all the local signs of aneurism either persist or rapidly reappear. The method is dangerous where the collateral veins leading away from the sac or isolated vascular segment carry off the entire quantity of the arterial blood supplied to it by the collateral arteries, thus preventing their participation in the peripheral irrigation of the limb. Such conditions are eminently favourable to the development of gangrene. A case of von Oppel's, which has frequently been quoted, is very instructive in this connection. The case was one of arterio-venous aneurism in the axilla. Von Oppel ligatured the artery above the aneurism, and then measured the peripheral blood-pressure by Korotkoff's method. The pressure before ligature was 40 mm.; after ligature it fell to zero, proof positive that the whole of the blood supplied by the collateral circulation was conveyed back towards the heart by way of the vein. Two hours later he ligatured the vein above the sac. The peripheral pressure remained at zero, proving incontestably that the sac was still in communication with a large venous channel. Examination revealed a large vein at the back of the sac. This was tied, when the blood pressure again rose to 40 mm.

The extirpation of the sac with ligature of all the vessels which open into it is a longer and more difficult operation than that of quadruple ligature. It is, however, far more effectual, and, judging by accounts published before the war, it is considerably less dangerous. Out of 167 cases of partial or total extirpation, Monod and Vanverts found 110

successful, or 95 per cent. Gangrene occurred in two cases, or 1·7 per cent. It will be shown later, when considering arterio-venous aneurism of individual vessels, that these results are confirmed by those obtained since the outbreak of war.

It is unnecessary, after what has been said concerning quadruple ligature, to enter into the details of the old methods, namely, compression and ligature of the artery proximal to the lesion. These methods are not only effete, they are ineffectual and dangerous.

Thus, apart from the ideal reparative operation, the most suitable method of treatment of arterio-venous aneurism is undoubtedly that of extirpation of the anastomotic segment, with ligature above and below of all the afferent and efferent vessels involved. The technique of the operation is as follows :—

The first part of the operation consists in the complete exposure of the aneurism and of all the vessels involved. It is hardly necessary to repeat that the area must be very thoroughly opened up. In the case of hypogastric aneurism referred to in a previous paragraph, Cotte and I did not hesitate to perform an extensive laparotomy. Having exposed the site, the next step is to ascertain the nature of the lesion, whether aneurismal varix or varicose aneurism, and if the latter, to discover the size of the sac.

In the case of aneurismal varix, the best method is to arrest the circulation by means of clamps applied to both vessels above and below the affected area. It is best to begin with the artery, applying a clamp to it first above and then below. The vein should not be clamped above until the last moment, for the sudden occlusion of the central end prevents the

discharge of the blood brought to the intermediate segment by the collaterals, with the result that the segment becomes enormously distended. The anastomotic segment is now dissected out, and the vein is separated from the artery as far as the point of communication. Where possible the communicating channel between the two vessels is ligatured. Where ligature is impossible, the channel is cut and the

FIG. 39.—Arterio-venous aneurism of the subscapular vessels. (Tixier's case. Val-de-Grâce Museum.)

resulting arterial wound closed by lateral suture. Suture of the venous wound is superfluous, as ligature above and below meets all requirements. Where this, the ideal, operation is not feasible, quadruple ligature must be employed, and the arterio-venous segment between the ligatures extirpated. Ligature above and below the anastomosis may require the application of five ligatures, as in the case of aneurismal varix affecting the venous tributaries or an

arterial bifurcation. Under such conditions, extirpation of the vascular segment may be impracticable.

In the case of varicose aneurism the tumour is first extensively exposed. Artery-clamps are affixed first to the afferent and efferent arteries, and afterwards to the veins. The tumour is then minutely dissected out and extirpated, together with the segments of both artery and vein involved (fig. 39). In view of the loss of vascular supply, the state of the collateral circulation should be ascertained by one of the methods described above. If it appears to be insufficient, the vein and its branches should be ligatured above and below, and circular suture of the artery should be performed. Or it may be necessary to introduce a venous graft between the two ends of the artery. Where the circulation appears to be adequate, double ligature of both artery and vein is indicated.

It sometimes happens that an aneurism becomes incorporated, by means of fibrous adhesions, with the surrounding tissues, and that its extirpation is impossible. In such a case the sac should be opened, hæmorrhage arrested, as much as possible of the sac resected, and the rest left in place.

# CONTUSION OF THE VESSELS

## CHAPTER III

### ANATOMICAL AND CLINICAL STUDY OF CONTUSIONS OF THE VESSELS

Rifle-bullets may, under varying conditions, cause contusion of an artery or a vein.

In certain exceptional cases a spent ball, or a ball which has been retarded by passing through a bone, may be arrested in contact with a large vessel, which is struck more or less violently but is not ruptured. More frequently an artery is struck tangentially, the ball encountering only the tunica externa or the perivascular fibrous sheath. In a few cases contusion of an artery is occasioned by the passage of a ball at some distance from the vessel.

Thus the mechanism of contusion varies. It may be the outcome of direct shock, as where an artery is struck by a spent ball. Direct shock is more frequent in association with wounds caused by shrapnel-balls than by bullets of small calibre. Contusion may result from hydraulic shock to the vessel, effected at the moment when the ball comes in contact either with it or with the tissues in its immediate neighbourhood. More frequently, however, contusion is due to the

elongation or stretching of the vessel. Elongation is responsible for subcutaneous arterial rupture, and it plays a preponderating part in the causation of vascular contusion by projectiles of war. Immediately after the passage of a bullet in the subclavicular fossa or the axilla I have more than once observed sudden and complete paralysis of the arm with suppression of the radial pulse. Immediate surgical intervention showed that neither nerve nor blood-vessel was divided. In two of these cases the injured portion of the axillary artery appeared as a fine cord uniting the two sound portions. This stretching of the artery is well shown in fig. 40. The external iliac is divided by a bullet near its lower extremity. At two points above the wound the internal coats are ruptured by over-stretching.

Vascular contusion is more frequently caused by fragments of shell, grenade,

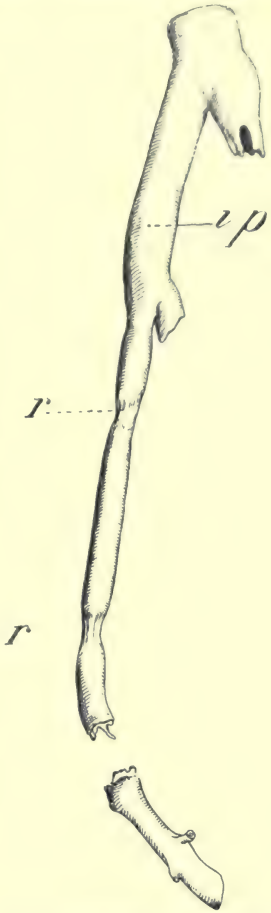


FIG. 40.—Section by a bullet of the right external iliac artery. Above the section the artery shows contractions due to rupture of the internal coats by over-stretching. Death ensued twelve hours after the injury. (Latarjet's case. Val-de-Grâce Museum.)

or torpedo than by bullets. Here again the mechanism of production is of three kinds: direct shock, indirect shock conveyed from a distance, and over-stretching of the vessel. Arterial contusion by a ball or shell-fragment is in many instances obviously due to either direct shock or elongation of the vessel. The missile has indeed been frequently discovered in actual contact with the injured artery. Grégoire has described a typical case of contusion of the posterior tibial, with rupture of its two inner coats, by a fragment of shell which was arrested at the posterior surface of the interosseous ligament. Cases of this description are far more numerous than is generally believed, and in many instances secondary hæmorrhage is attributable to this source alone. But indirect injury plays so large a part in the history of shell-wounds that it cannot fail to be responsible for a considerable number of vascular contusions. Shell-wounds are characterised by extreme contusion, which varies in degree from immediate and rapid gangrene at the site of injury to slight bruising at a distance. A vessel situated in the wall of a wound or very near it is contused in the same manner as the tissues by which it is surrounded. The degree of contusion varies with the volume and velocity of the projectile on the one hand, and its distance from the direct point of contact on the other.

## PATHOLOGICAL ANATOMY AND PHYSIOLOGY OF CONTUSIONS OF THE VESSELS

The Val-de-Grâce school has taught us that three degrees of contusion are to be differentiated :—

*In contusion of the first degree* the lesion affects the internal coat only. On opening the vessel " fine transverse striations are seen, which look as if produced by the point of a pin drawn over the surface of the vessel " (Delorme).

*In contusion of the second degree* both the internal and middle coats are injured. The fine lines upon the intima penetrate deeply into the media, the muscular and elastic fibres of which are ruptured here and there.

*In contusion of the third degree* the intima and media are ruptured circularly around the entire circumference of the vessel (fig. 41). They are retracted within the adventitia, and to so great a degree that, viewed externally, the artery presents a constricted appearance (fig. 40).

FIG. 41. — Diagram showing arterial contusion of the third degree. The internal and middle coats are ruptured.

These experimental findings have been confirmed by the results of surgical observation since the war.

Where it is the sole injury, contusion of the first or second degree is too slight a lesion to produce appreciable symptoms, or to point to any active treatment by operation. But as all vascular wounds by projectiles of war are contused wounds, it follows that even clean-cut arterial wounds are associated with contusion in a varying degree. When we have to deal with a wound of a large vessel exposed after provisional hæmostasis by

compression above the wound, the lumen of the vessel should be cleared of the remaining blood by the injection, very gently and without pressure, of a few cubic centimetres of physiological serum. The lacerations of the internal coat will then become visible over the entire circumference of the wound. They may start from the wound itself and radiate in all directions; or they may be situated at some distance from the wound, every stage of arterial contusion being represented. Fig. 42 shows a portion of the femoral artery which presents well-defined contusion of the second degree. The significance of these lesions in regard to the general indications for vascular suture was explained in an earlier chapter.

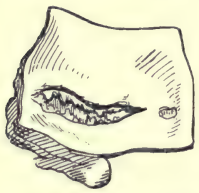

FIG. 42. — Contusion of the femoral artery by a shell-fragment. Resected portion of the artery, showing partial rupture of the internal and middle coats. (Latarjet's case. Val-de-Grâce Museum.)

Contusion of the third degree has been observed *de visu* in a certain number of cases. In some instances it appears as a narrow constriction corresponding to the site of retraction of the torn inner coats. More frequently, however, exposure reveals a species of fusiform dilation of the vessel corresponding to the contused portion, the wall of which is represented solely by the adventitia. In September 1914 a young lieutenant was brought into my ambulance who had been struck by a fragment of shell which had traversed the anterior wall of the axilla. The arm was cold, swollen, and insensitive. Incision of the anterior wall of the axilla and exposure of the vessels and nerves showed a fusiform dilation of the

axillary about 1½ inches long. The enlargement was of a doughy consistence, and did not pulsate (fig. 43).

The effect of these lesions upon the contents of the vessels varies considerably.

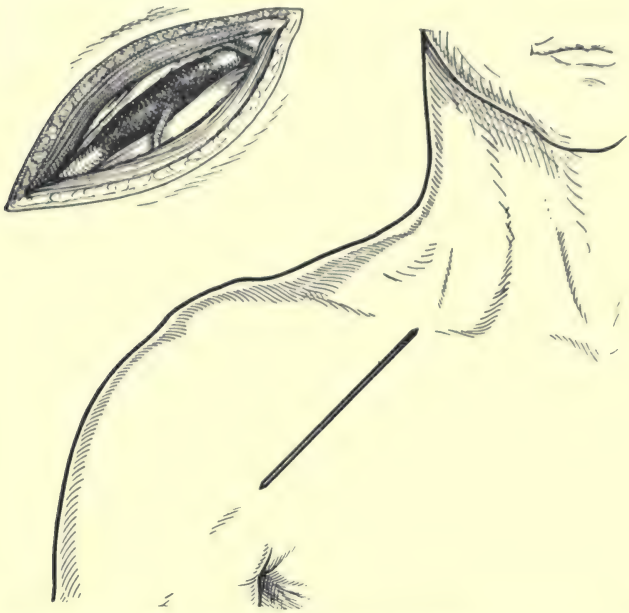

FIG. 43.—Contusion of the axillary artery by a shell-fragment. The contused arterial segment is dilated and thrombosed. (Author's case.)

The fine striation of the intima, which characterises contusion of the first degree, does not as a rule affect the circulation of the blood through the vessel. Contusion of the second degree is frequently accompanied by the formation of a thrombus. The thrombus may be lateral and very limited in extent, and it

may not occlude the lumen of the vessel. On the other hand, it may be extensive, obliterating the lumen of the vessel for a considerable distance and extending to the first, second, or even third collateral branch above.

A small parietal thrombus which does not obliterate the lumen of the vessel almost invariably escapes notice. The peripheral pulse is not suppressed, there is no circulatory derangement, and there are no signs suggestive of a vascular lesion. Even when the vessel is exposed to view there is no appreciable change in its external aspect. The presence of a thrombus is in such cases revealed only by the small emboli which proceed from it. A patient was brought to me with a shell-wound in the neck, but presenting no symptoms of vascular lesion. The wound was opened up and the vessels exposed. The common carotid and the internal jugular, which were in the immediate vicinity of the wound, were found to be intact. A few days later several successive embolisms occurred, giving rise to transient hemiplegia. There is no doubt that these emboli originated in a circumscribed thrombosis of the common carotid, which had been slightly contused by the passage of the projectile.

Complete thrombosis, obliterating the lumen of the vessel, may be confined to the contused area. On the other hand, it may extend for a considerable distance into the lumen. Grégoire describes a case of contusion of the posterior tibial with gangrene in which it was necessary to remove the leg. On dissecting the amputated limb he found a thrombus which extended from the contused site to the popliteus above and to the internal malleolus below. Throm-

bosis of this kind, as in the case described on p. 142, may present the appearance of a fusiform dilation of the artery several inches in length.

It is scarcely necessary to point out that contusion of the third degree, that is to say, sub-adventitial rupture of the internal coats, is invariably accompanied by arterial thrombosis. The blood coagulates above the constricted portion, and the clot extends upwards for a varying distance.

Primary thrombosis, the direct outcome of laceration of the internal coats, may be complicated by secondary thrombosis due to infection of the wound in the neighbourhood of the contused vessel. That simple denudation of the vessels under septic conditions facilitates the spread of infection to the vascular coats is known to everyone. This is particularly striking in cases where the vessels are exposed at the bottom of a tortuous and ill-drained wound, in which putrid fluid of a highly septic nature stagnates. Such wounds are frequently observed in the neighbourhood of the mouth and pharynx. Some time ago Morestin pointed out the danger of infection of the vessels of the neck when freely exposed at the bottom of a wound which is contaminated by the bucco-pharyngeal secretions. The danger is increased in cases where the arterial wound is contused, where the adventitia presents small erosions communicating with ecchymoses of the inner coats, and where there is circulatory disturbance of the vasa vasorum. Under such conditions infection is conveyed directly to the vessel, and there is an immediate increase in the size of the thrombus. Grégoire's case, in which the clot filled the lumen of the vessel from the soleus to the malleolus, is an excellent example.

### Clinical Considerations and Treatment of Contusion of Vessels

Contusion of the first and second degree is not actually a clinical entity, for it does not present a syndrome of sufficiently definite outline to establish a diagnosis. The sole evidence of its presence is supplied by certain secondary complications which proceed from it. These complications depend upon the migration of clots from the thrombosed portion of the vessel. The emboli are arrested either in the cerebral vessels (Sylvian or ophthalmic) or in the peripheral arterioles of the limbs (toes, fingers). Embolism of the cerebral vessels results in hemiplegia or monoplegia, which may be either transitory or persistent. Embolism of the arterioles of the limbs is followed by the appearance of cutaneous sloughs, or even of dry gangrene.

In an earlier chapter I described a case in which a shell-wound in the neck, unaccompanied by vascular lesion, was followed by successive hemiplegias undoubtedly due to emboli derived from a contused patch in the vessels. Four cases have been described by Makins in which embolism followed thrombosis due to arterial contusion. In three of these cases there was contusion of the common carotid; in one of the three, brachial monoplegia followed; in the second, hemiparesis with mental derangement; in the third, aphasia terminating in death. In the fourth case the femoral artery was involved; an embolus obliterated the popliteal artery, and gangrene of the foot ensued.

Contusion of the third degree is attended by immediate results which, from the outset, present a com-

bination of very characteristic symptoms. Arterial thrombosis is constant and rapid. The extension of the clot upwards may at once obliterate the openings of the principal collaterals. The circulation, both in the main artery and in the collaterals which should replace it, is thus suddenly suppressed. Ischæmic gangrene of the portion of the limb supplied by the artery results.

Immediately after injury the limb presents a diffuse swelling below the level of the wound. The skin is pale, cold, and occasionally cyanosed. Palpation shows a generalised œdema of the limb. Cutaneous sensibility is lost, and motility of the limb is entirely abolished. Several cases of this type have been described since the war, and I have myself observed three. Makins describes five, with two primary amputations.

In a certain number of cases the thrombus is confined to the injured segment of the artery. It does not invade the branches above, nor does it at first entirely suppress the collateral circulation. Gangrene is excluded, but other complications may arise during the clinical development of the wound. The demarcation and subsequent elimination of the slough in the vessel may, in such cases, cause the wound to open into the lumen of the vessel. Again, the clot may become infected and soften, when secondary hæmorrhage, either single or multiple, will result, and death may follow very quickly.

Thus contusion of the first and second degree, having no actual clinical individuality, is practically never recognised during the first few days after injury. A retrospective diagnosis, based upon the appearance later of complications due to embolism, is the most

that is possible in these cases. It is obvious that where there is no diagnosis there can be no treatment.

Where ischæmic gangrene is present, contusion of the third degree may be diagnosed from the start. In the absence of gangrene it may at first escape notice, to be recognised later when secondary hæmorrhage is provoked by the separation of the slough in the vessel. The problem of treatment is not the same in the two cases.

In the first case we are faced with a shell- or bullet-wound in the neighbourhood of a large vessel. There is no external hæmorrhage and no hæmatoma. Yet the swelling of the limb, its pallor and coldness, and the absence of the peripheral pulse, together with the intense pain and marked functional derangement, immediately suggest a lesion of vascular or nervous origin. The fact has already been emphasised that in cases such as these primary surgical intervention is indicated. Operation should be immediate, the object generally being the discovery of a wound of the vessels, for the idea of a simple vascular contusion rarely occurs to anyone.

Exposure of the artery establishes the diagnosis. The presence of circumscribed constriction or dilation points to severe contusion with thrombosis. What is the method of procedure ?

Whatever the method, the end in view is the removal of the thrombus, which obliterates the lumen of the artery and threatens the collaterals. Its extension must in any case be prevented.

It has been suggested that, to prevent embolism, the artery should be ligatured below the clot. The method does not appear to me to be practicable. In the first place, it is extremely difficult to ascertain

the extent of the clot, and there is no certainty that the ligature is actually below it, and that embolism is excluded. In the second place, the great danger in thrombosis lies in the extension of the clot upwards and the obliteration of the collaterals. Ligature below does not in any way prevent this. As a matter of fact, ligature above and below is open to the same objections, for here also there is no guarantee that the ligatures have been placed outside the clot.

For these reasons the ideal method seems to be arteriotomy and removal of the thrombus, followed by double ligature. Longitudinal incision permits of the removal of the clot and the clearing of the lumen of the vessel, while double ligature of the cleared artery excludes a recurrence of thrombosis. Suture of the artery after removal of the clot has been proposed by some, but I am of opinion that the method is rarely indicated. Badly contused tissues should never be sutured. Ligature is both sure and simple, and should always be employed in these cases.

Where gangrene is absent, the wound is invariably an old one in which a vascular lesion has passed unperceived. A day comes, however, when the vascular slough separates and formidable secondary hæmorrhage results. The treatment of secondary hæmorrhage has been described in an earlier chapter.

# *Part Two*

# Wounds of Individual Vessels

## CHAPTER IV

## WOUNDS OF THE VESSELS OF THE NECK

Wounds of the neck are usually described as superficial when the wounding agent does not penetrate beyond the deep cervical fascia. They are described as deep when the agent passes through the aponeurosis and reaches the deep layers of the neck.

*Superficial* wounds, involving the superficial vessels only, are not serious. Even when the anterior or the external jugular vein is involved, the hæmorrhage is quickly arrested by the slight compression of the dressing, and the venous lesions do not in any way complicate the progress of the wound.

Wounds may be *deep* and yet not involve the viscera or the great vessels. I have seen many deep cervical wounds which were not associated with serious injury; and I have frequently seen and removed projectiles lodged behind the pharynx or œsophagus, against the transverse processes of the cervical vertebræ, or in the thyroid gland, which had produced no vascular lesion. These cases are, however, exceptional, and in the majority of instances the large vessels of the neck are affected. It is proposed to consider successively wounds of the great vessels of the neck, and wounds of the vessels at

the root of the neck, together with the aneurisms occasioned by both classes of wound.

## I. *WOUNDS OF THE VESSELS OF THE NECK AND ANEURISMS OF THE NECK*

### A. WOUNDS OF THE VESSELS OF THE NECK

The great vessels of the neck may be injured by projectiles entering the body at such diverse points as the face, the nape, the back, and the anterior and lateral regions of the neck. The likelihood of vascular injury is, however, greatest when the orifice of entry is situated in the antero-lateral region, a little in front of or behind the sterno-mastoid.

The vascular lesions are extremely varied. They may be classified into two main groups, according to the position of the cutaneous wound and the course of the projectile, namely, wounds of the lower and middle part of the neck, and wounds of the upper part.

*Wounds of the middle and lower region* include all those situated between the clavicle and the upper border of the thyroid cartilage. They more particularly endanger the common carotid, the internal jugular vein, the vertebral, and the inferior thyroid vessels. In some cases one vessel only, either the jugular or carotid, is injured, but more frequently both artery and vein are struck. It is by no means rare to find that the inferior thyroid and the vertebral vessels have been injured by the same projectile. I once saw, *post-mortem*, puncture of the common carotid and section of the vertebral, both vessels having been injured by the same missile. The vascular lesion is

sometimes complicated by lesion of the pneumogastric or of the recurrent laryngeal nerve, or by lesion of a deep-seated structure, such as the pharynx, trachea, or œsophagus.

*Wounds of the upper region* are situated between the upper border of the thyroid cartilage and the upper portion of the parotid region. They especially endanger the internal carotid, the jugular vein, and the external carotid and its branches. Owing to their deep-seated position at the bottom of the maxillo-pharyngeal space, the internal carotid artery and the upper portion of the internal jugular vein are less exposed to injury than the external carotid, which approaches the surface at the upper part of the neck. Thus injury of the deeper vessels is usually associated with deep and extensive wounds of the parotid region ; with fracture of the ramus of the mandible ; or with wounds involving simultaneously the face, the bucco-pharyngeal cavity, and the upper part of the neck. Important nerve-trunks may be injured with the vessels—for instance, the pneumogastric, the glosso-pharyngeal, and the spinal accessory with the internal carotid, the hypoglossal with the external carotid, and the facial with both.

All the types of vascular wound-puncture by a minute and pointed splinter, partial or total division by a bullet or shell-fragment, perforation, extensive laceration or rupture of the vessel, are observed in connection with the vessels of the neck. Figs. 11 and 6, and fig. 2 on Plate II., show respectively perforation of the carotid bulb by a grenade-fragment, perforation of the common carotid by a bullet, and rupture of the internal carotid at its origin.

The clinical picture presented by these wounds

varies widely with the nature of the case. Where the wound is large and is associated with lesion of a great vessel, in the vast majority of cases death ensues rapidly upon the field of battle. Occasionally a man in a state of syncope is brought into the dressing station with a gaping wound in the neck, the vessel being temporarily obliterated by the formation of a clot, or hæmorrhage may recur during transit. But as a general rule, the cases which reach the surgeon are those in which the wound is perforating in character, and from which external hæmorrhage is naturally inconsiderable.

In wounds of this latter class the blood is effused into the cellular tissue surrounding the vessels and forms a diffuse hæmatoma. Occasionally, when the common carotid and internal jugular have been simultaneously struck by a projectile passing between them, there may be direct communication between the two vessels without appreciable periarterial hæmatoma. This constitutes a variety of " dry " wound. Again, in certain exceptional instances, the absence of both external hæmorrhage and hæmatoma is due to the temporary obliteration of the wound by the projectile itself, by débris of some kind, or by the collapsed and retracted edges of the vascular coats. This also constitutes a variety of " dry " wound.

Thus wounds of the vessels of the neck may be either with or without hæmatoma.

**1. With a Hæmatoma.**—The presence of a hæmatoma is revealed by a swelling, the position of which varies with the injured vessel. When a vessel in the lower or middle part of the neck is injured, the hæmatoma is situated at the base of the neck between

the clavicle and the thyroid cartilage. In the case of injury to vessels in the upper part, the hæmatoma is found near the angle of the mandible, in the parotid area, or the sub-mandibular region. The position of the tumour is extremely variable. An inferior hæmatoma extends towards the median line, pushing aside the larynx and trachea, and it sometimes reaches as high up as the mastoid and sub-mental regions. A superior hæmatoma, on the other hand, rarely extends down to the lower part of the neck. It tends to spread inwards, displacing the lateral wall of the pharynx and the tonsillar area, and sometimes even extends behind the pharynx and œsophagus.

The characteristics of the swelling vary according to whether the hæmatoma is venous (internal jugular), arterial, or arterio-venous in origin.

The swelling due to a *venous hæmatoma* is diffuse, soft, resistant, and without pulsation or murmur. It should be borne in mind, however, that when the common carotid is intact its pulsations are sometimes transmitted to the tumour with considerable clearness.

*Arterial and arterio-venous hæmatomata*, and particularly the former, are usually larger than venous hæmatomata. The swelling is harder and more tense, palpation reveals pulsation, and a characteristic murmur is observed on auscultation.

In addition to the physical signs, functional symptoms may be present. These may be due to pressure by the hæmatoma upon certain structures, or to a concomitant nervous lesion. A low hæmatoma may be associated with aphonia or hoarseness, due to lesion of the recurrent laryngeal nerve, and with extreme rapidity of the pulse, due to lesion of the vagus.

A high hæmatoma may be accompanied by dysphagia and intense dyspnœa, due in the case of peripharyngeal hæmatoma to compression of the faucial aperture.

2. **Without Hæmatoma.**—The mere presence of a cutaneous wound in the neighbourhood of the vessels and nerves of the neck always suggests a possible vascular lesion. The external wound may be very small, with little external hæmorrhage, which by the time the patient arrives at the dressing station is reduced to a thin trickle of blood. When the absence of external hæmorrhage and of a hæmatoma is due to the simultaneous injury of an artery and a vein leading to a communication between them, palpation will reveal a thrill, usually very slight, but unmistakable to a practised hand. When the absence of external bleeding and a hæmatoma is referable to causes other than this, there is nothing to show that there is a vascular wound. Its presence is first revealed later, by the appearance of violent secondary hæmorrhage, secondary diffuse hæmatoma, or embolism due to the lodgment of a clot in the brain.

How do these cases terminate ?

In a certain number reactionary hæmorrhage takes place whether a hæmatoma is present or not, and death may follow in a few moments. This reactionary hæmorrhage is due to the precarious nature of the hæmostasis, which is unable to withstand a sudden movement on the part of the patient, an ill-timed exploration of the wound, or even occasionally a mere rise in the blood-pressure. Repeated movements of deglutition render the neck an extraordinarily unfavourable site for the consolidation of the clot. Hence it is by no means infrequent for violent

Fig. 1.—Bullet-wound of the neck with diffuse haematoma.
Fig. 2.—Bifurcation of the carotid and pneumogastric nerve from patient shown in Fig. 1.

Fig. 3.—Section of the external iliac artery with lateral wound of the vein. Constrictions of the artery above the section due to rupture of the inner coats by over-stretching.
Fig. 4.—Arterial contusion. Destruction of the inner coats with preservation of the adventitia. When opened, this artery presented every degree of arterial contusion. (Latarjet's case. Val-de-Grâce Museum.)

PLATE I.

reactionary hæmorrhage, either from the external wound or from a wound of the mouth or pharynx, to occur two or three hours after the injury, at a time when all danger appears to have passed off. I again draw attention to the fact that the clot is frequently loosened and hæmorrhage precipitated by the untimely exploration of the wound. In a case of shell-wound behind the sterno-mastoid, the introduction of a finger into the wound provoked formidable hæmorrhage by the mouth and nose, which terminated fatally within a few seconds (Maisonnet).

In a second group of cases the patient escapes reactionary hæmorrhage as he has already escaped primary hæmorrhage. The progress of the wound then depends solely upon the question of its infection or non-infection.

A wound produced by a missile which has traversed the nose, mouth, or pharynx is infected from the start. The first signs of a circumscribed or diffuse cellulitis of the neck, gaseous or non-gaseous, make their appearance the day after the injury has been received. Swelling appears or becomes increased; œdema occurs over the whole of the front of the neck and spreads to the subclavian region; and a brownish, sometimes fœtid, discharge escapes from the wound. The temperature rises, and all the general symptoms of severe infection make their appearance. The almost inevitable consequence of infection of the hæmatoma is secondary hæmorrhage.

Secondary hæmorrhage is chiefly seen in association with badly infected wounds of the upper part of the neck, the parotid region, and the sub-mandibular triangle, which are often complicated by wounds of the mouth and pharynx and by fracture of the jaw, all of

which are eminently septic, and predispose to a rapid and destructive gangrenous infection. In other words, wounds of the suprahyoid part of the internal jugular vein, of the internal carotid, or of the external carotid and its facial, lingual, and internal maxillary branches are extremely liable to secondary hæmorrhage. Secondary hæmorrhage may be direct, the blood escaping from the skin wound, but when the hæmatoma is in communication with the upper digestive tract, the nose or the mouth, the blood may be extravasated into these cavities. Sometimes it invades the respiratory passages, causing death by suffocation. When a nerve injury has caused laryngotracheal anæsthesia, and thus abolishes the reflexes of warning and defence, the trachea and bronchi may become filled with blood. Makins has published a case in which death followed secondary hæmorrhage from a wound of the common carotid involving the pharynx. The hæmorrhage took place into the larynx and trachea without provoking the slightest symptom. The autopsy showed that the pneumogastric had been severed.

If the wounding agent is a bullet or minute shell-fragment, if the skin wound is punctiform, and the digestive passages are not involved, the wound in the vessel may be regarded as primarily aseptic. These wounds tend towards arterial or arterio-venous aneurism, both of which conditions are prone to grave complications, such as sudden and rapid increase in size, infection of the sac, and cerebral embolism.

It is evident then that those patients with a wound of the great vessels of the neck, who escape death from primary hæmorrhage on the battlefield, are liable to either reactionary or secondary hæmorrhage. In

the case of shell-wounds these complications are almost invariable, but they are far from exceptional in connection with bullet-wounds.

**Indications for Treatment.**—The object of treatment in large, lacerated wounds is to arrest primary or reactionary hæmorrhage; in infected punctured wounds, the object is to prevent secondary hæmorrhage. The methods of achieving these objects are as follows:—

As a general rule, extensive wounds of the neck are not amenable to surgical treatment. It occasionally happens, however, that either at the dressing station or during transport a wound of the neck temporarily closed by clots gives rise to a sudden reactionary hæmorrhage of most alarming profuseness. What should be done by the orderly who happens to be at hand when the bleeding occurs, or by the medical officer in charge of the first field-dressing station where surgical conveniences are usually so restricted? The common carotid should be immediately compressed, either against the spinal column in front of the sterno-mastoid, or by pinching it in the manner shown in fig. 44. If this does not stop the hæmorrhage, direct pressure should be exercised by a finger thrust into the wound. Digital pressure must, however, be regarded as a dangerous makeshift, to be used in any case for a

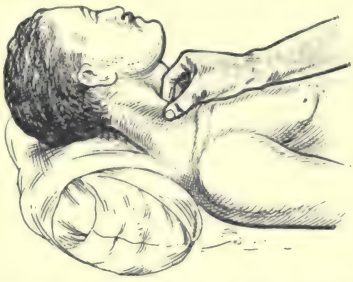

FIG. 44.—Compression of the carotid. (After Farabeuf.)

few moments only until more efficient measures can be devised. Personally, I infinitely prefer to close the skin wound with one or more pair of clamp-forceps. It is true that this gives rise to a hæmatoma which must be dealt with immediately the patient reaches the field ambulance, but it prevents him from dying of hæmorrhage on the way there. I have already referred to a case in which primary hæmorrhage from a large wound with section of the common carotid was arrested by closing the skin wound with a Kocher's forceps. The patient arrived at the dressing station with an large hæmatoma of the neck, but at any rate he arrived there alive. Closure of the skin wound is a simple, easy, and efficient way of arresting the formidable hæmorrhage which occurs in extensive wounds of the neck.

At the Field Ambulance the surgeon may have to deal with either a lacerated and bleeding shell-wound, or with a bullet-wound the punctiform orifices of which are already almost closed.

In the case of the shell-wound, there is no doubt as to the method of procedure. Whether a hæmatoma is present or not, we have to do with an infected wound which must inevitably become the seat of septic complications of the most serious kind, with all the risks of grave secondary hæmorrhage. Immediate operation is imperative. Free exposure of the wound is the only way to prevent infection, and direct hæmostasis is the only preventive of secondary hæmorrhage.

Where the wound has been made by a bullet or minute shell-fragment the question is not so simple. Here, as elsewhere, immediate operation is indubitably called for in the case of a large hæmatoma,

which is increasing steadily and rapidly, compressing the air-passages, distending the skin, and threatening to burst externally. Such cases as these, however, are exceptional; as a general rule, the hæmatoma is either small or medium in size, or it may be absent altogether.

Take the case of a medium-sized hæmatoma, due to a bullet-wound in the neck. One might say that the obvious course is to wait until the hæmatoma becomes encapsuled and diminishes. After all, there is no hurry to operate. A venous hæmatoma due to a wound of the internal jugular vein will get smaller and gradually become absorbed, and if this is so, spontaneous recovery will be rapid and complete. An arterial hæmatoma will tend also to become encapsuled, and to end as a smaller and more circumscribed aneurism, during the formation of which the wound will become healthy and the collateral circulation will be established. Should it be necessary to operate upon this aneurism, late operation will be far less serious than a primary one, for it is well known that the mortality in primary ligature of the common carotid is 50 per cent., while in aneurism of the carotid it is only 15 per cent.

This train of reasoning appears even more plausible when it is applied to a circumscribed arterio-venous aneurism. It seems so much better to postpone operation until after the hæmatoma has contracted and the arterio-venous circulation has settled down; in other words, to await the formation of an arterio-venous aneurism. Again, in simple communication between an artery and a vein why not postpone operation until after cicatrisation of the wounds, an operation which perhaps time and rest may render unnecessary?

Generally speaking, I do not agree with this line of argument. In the first place, primary operation is the sole means of guarding against possible complications, such as infection of the hæmatoma, sudden increase in its size, and cerebral embolism. But even assuming that in association with bullet-wounds these secondary complications are sufficiently rare to be disregarded, I believe early operation to be easier and, in the majority of cases, less dangerous than one at a later date.

The contraction and consolidation of the hæmatoma is accompanied by contraction of the neighbouring cellular tissue ; by compression, sclerosis, and matting together of the adjacent structures ; and by adhesion of the jugular vein, the pneumogastric and recurrent laryngeal nerves, etc., to the peripheral layers of the sac. The more complete the matting, the more difficult and dangerous will be the dissection of the sac. It may even happen that, whereas incision of the primary hæmatoma would have been a simple matter, extirpation of the subsequently formed aneurismal sac is impossible. The transformation of an arterio-venous hæmatoma into an arterio-venous aneurism is accompanied not only by the intimate fusion of the sac with all the neighbouring structures, but by dilatation and occasionally thinning of both ends of the jugular to such an extent as greatly to increase the difficulties of operation. Even a simple communication between artery and vein becomes daily more difficult to operate upon. The two vessels become gradually more firmly adherent, and the vein is distended to excess and becomes matted to the adjacent tissues. The aneurism will have thus become impossible to extirpate, although it

originated in two small arterial and venous wounds which might so easily have been repaired. A case of Rouvillois is very instructive in this connection. He waited six weeks before operating upon an arterio-venous hæmatoma which, in the first instance, demanded no more than ligature of the common carotid and of the internal jugular vein. He found an intimate fusion of the vessels which were firmly matted to the surrounding structures. He was obliged to ligature the common carotid, the internal carotid, the external carotid, and the jugular vein, and even then he was compelled to abandon the attempt to extirpate the sac.

To those who advance the gradual establishment of the collateral circulation as a plea in favour of the later operation my reply is as follows : The lesion of the carotid has from the first resulted in the formation of either a peri-arterial hæmatoma, which compresses the vessel and interrupts the circulation ; or an arterio-venous hæmatoma, which conveys the blood intended for the periphery into the central end of the jugular vein ; or it has not produced a hæmatoma owing to the obliteration of the vessel by the projectile, a portion of débris, or a clot. In any case, the circulation at the level of the carotid wound is arrested in exactly the same way as if the vessel had been ligatured, and ligature merely converts the temporary arrest of hæmorrhage into a permanent one. Thus if no signs of cerebral derangement are present when the patient first comes under observation, it is highly probable that ligature of the vessel will not produce them. Moreover, early operation is compatible with the obliteration of a very limited vascular segment, whereas the later operation

necessitates the obliteration of a very much larger one —for instance, ligature of the internal and external carotids in addition to ligature of the main trunk. Extensive obliteration such as this greatly increases the risk of cerebral complications. For these reasons I believe that in cases of wounds of vessels of the neck, even when produced by projectiles of small calibre, immediate surgical intervention is indicated.

Having disposed of the general indications, we now arrive at the choice of method.

**1. WOUNDS OF THE MIDDLE AND LOWER PARTS OF THE NECK.**—A wound in the middle or lower part of the neck with subhyoid hæmatoma suggests a wound of the common carotid, the internal jugular vein, the vertebral, or the inferior thyroid vessels. Desirable as it undoubtedly is to ascertain before operation which vessel is wounded, such a preliminary diagnosis is rarely possible. A subhyoid hæmatoma which is not tense, and has neither pulsation nor murmur, suggests a venous hæmatoma. A hæmatoma with pulsation and murmur suggests an arterial hæmatoma, either carotid or vertebral, but it is practically impossible to distinguish which. The obvious course is to practise digital compression of the common carotid against the carotid tubercle, but this manipulation reveals nothing, and, generally speaking, operation is the sole means of diagnosis. It must be admitted, however, that nine times out of ten the source of the trouble is in the carotid.

The first operative step is to provide for temporary hæmostasis by securing the common carotid low down in the neck.

*Ligature of the common carotid low down in the neck.*—A longitudinal incision is made along the

anterior border of the sterno-mastoid muscle, beginning 3 inches above the clavicle and terminating at the level of that bone. Beneath the skin and platysma is the anterior border of the muscle in its sheath of deep cervical fascia. The fascia is incised either along the anterior border of the muscle or, very lightly, outside it, and the muscle is retracted outwards, and the larynx and trachea inwards. The carotid is then exposed by incision of the deeper layer of the fascia enclosing the sterno-mastoid. To isolate the vessel and pull it up on a temporary ligature is a simple matter.

*Exposure and incision of the hæmatoma.*—When all immediate risk of grave hæmorrhage has thus been obviated, attention is turned to the hæmatoma. As a general rule, the incision already made for the ligature is insufficient, even if it be prolonged upwards. The retracted edges of the wound and the muscles form a deep trench, at the bottom of which it may be possible to ligature a normal vessel, but which does not give enough room to expose and properly deal with a wounded one. Free exposure is essential, and the best way to get this is to raise a skin flap and temporarily divide the sterno-mastoid. A perpendicular incision should be made from the centre of the longitudinal one, running upwards towards the chin (Morestin). Or two incisions, starting from the same point, should be made, one upwards and forwards towards the chin, the other downwards and backwards towards the supra-clavicular fossa. In the first case the incision will resemble a triradiate star (Morestin), in the second it will be crucial (fig. 45). The entire lateral region of the neck can thus be easily exposed, and trans-

verse section of the sterno-mastoid will expose the vessels freely (fig. 46).

Before opening the hæmatoma an attempt should be made to determine which vessel is wounded. If

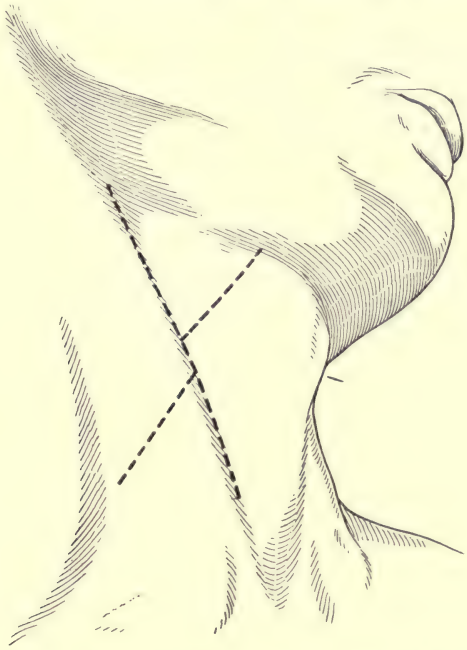

Fig. 45.—Crucial incision to expose the vessels of the neck.

a pulsating hæmatoma ceases to beat on temporary occlusion of the carotid, it is certain that the hæmatoma is of carotid origin. If it continues to pulsate, the lesion is probably in the vertebral. It is best to make certain by digital compression at the bottom of the wound exactly over the foramen in the transverse process of the sixth cervical vertebra. If the pulsa-

tions cease, lesion of the vertebral is certain. It occasionally happens that transmitted pulsations are mistaken for true pulsations, the hæmatoma being of purely venous origin, due to lesion of the jugular vein.

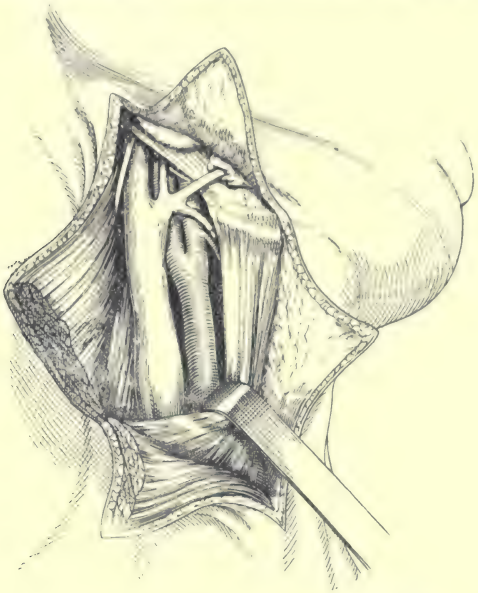

FIG. 46.—Exposure of the vessels of the neck.

The true state of the case is not perceived until after incision of the hæmatoma.

The second stage of operation consists in the free incision of the hæmatoma. To remove the blood and clots is the work of a few seconds, and the wound is well sponged out, when the wound in the vessel is usually easy of discovery.

(*a*) *Wound of the internal jugular vein.*—The vessel is dissected out and ligatured above and below

the wound; if necessary, the intervening portion is divided. It is sometimes necessary to ligature the vein at the junction of the great thyro-facio-lingual branches. In such a case the latter should also be tied, either *en bloc* or each branch separately.

Ligature of the internal jugular is a simple, certain, and safe operation. I use the word "safe" advisedly, for the cerebral complications which were formerly attributed to this ligature are quite exceptional unless infection is present. The case described by L. Bazy, in which a fatal hemiplegia followed ligature of this vein, is striking in its rarity. Modern surgery of the neck and aural cavities has shown that the internal jugular may be divided, ligatured, and resected without provoking the slightest complication. These experiences are confirmed by the results of war-surgery. I have twice tied this vein for primary or secondary hæmorrhage without the least untoward symptom. The simplicity of ligature does away with any necessity for lateral or circular suture of the vein. These methods have been attempted two or three times since the beginning of the war, but there is no certainty that the permeability of the vessel was preserved in any case. To suture the internal jugular is uselessly to prolong operation, and the method should be rejected in favour of ligature.

(*b*) *Wound of the common carotid.*—Wounds of this artery may be either sutured or tied.

Ligature above and below the wound is both simple and easy. If the common carotid artery and the internal jugular vein are injured, both artery and vein should be tied. If, as in a case described by Guibal, the venous wound is situated at the junction

of the jugular with the subclavian vein, it may even be necessary to tie the innominate vein at the root of the neck. Cases such as these, however, properly come under the heading of wounds at the root of the neck, and these will be dealt with separately. Under normal conditions, when these ligatures have been tied, the temporary ligature is removed from the common carotid, and permanent hæmostasis is completed where necessary by supplementary ligatures.

What are the results of this operation ?

It has long been recognised that ligature of the common carotid may provoke *complications*, both *immediate* and *remote*.

*The immediate complications* are due to ischæmic necrosis of the cerebral cells and of the ocular nerve cells. They are manifested by *hemiplegia* and *amblyopia* or *amaurosis*, and are the outcome of extreme anæmia of the brain. It is quite possible for ligature of the common carotid to result in sudden arrest of the blood-supply of the corresponding hemisphere of the brain. Reliable clinical observations have shown that such accidents do take place immediately the ligature has been tied. They are, however, extremely rare, and there are grounds for believing with Guinard and others that these complications do not arise where the normal anastomotic communications are intact. It is certain that the normal anastomoses between the right and left carotid regions are very free. After section of the facial, lingual, or external carotid arteries it is a common event for the blood to be projected as forcibly from the peripheral as from the central end of the divided vessel. Under such circumstances the reversal of the blood-stream by arrest of the circulation through the right external carotid

may be instantaneous, and the re-establishment of the circulation to the brain by way of the internal carotid may, in consequence, be immediate. Thus after ligature of the common carotid the blood will rapidly and easily resume its course, provided that the anastomotic branches of the external carotids are normal. Sudden complications are favoured by arterial abnormalities, atheroma, previous or simultaneous ligature of the arterial branches of the face —by all the factors, in fact, which are liable to impede the circulation in the collateral vessels. In young subjects free from atheroma these complications are undoubtedly exceptional.

Simultaneous ligature of the internal jugular does not increase the risk of cerebral complications ; it appears indeed to diminish them. Several authors state that immediate cerebral complications are relieved by measures which tend to drive blood to the brain (moderate elastic pressure round the base of the neck, nitrite of amyl inhalations, etc.). More efficacious still is ligature of the internal jugular vein.

*Remote complications* are observed some hours after ligature, generally from the end of the first day to the end of the third (de Fourmestraux). They are the outcome of arterial thrombosis of infective origin, which starts at the site of ligature and spreads upwards, by way of the internal carotid, to the sylvian and ophthalmic vessels.

Only very few cases of wounds of the common carotid operated upon in field ambulances and front-line hospitals have been published. I operated upon one very interesting case in which recovery was complete and uneventful. Lerat operated upon a large

hæmatoma in the lower and middle region of the neck. He ligatured the common carotid, the superior thyroid, and the internal jugular. The patient showed some torpor and somnolence, but recovered without trouble. In a similar case Moiroud ligatured the common carotid and internal jugular without complications. On the other hand, a patient of Maisonnet's died two hours after ligature of the common carotid, superior thyroid arteries, the internal jugular, and thyro-facio-lingual veins. Makins reports two cases of ligature of the common carotid for diffuse hæmatoma, with one recovery and one hemiplegia. I am well aware that so restricted a number of observations cannot be regarded as furnishing conclusive evidence as to general results. Nevertheless, I think that there is justification for the belief that in the case of a young and vigorous subject, where hæmorrhage has not been excessive, ligature of the common carotid is rarely accompanied by complications.

Suture of the common carotid may be lateral or circular, with or without venous transplantation. After free exposure of the vascular wound, lateral suture is simple and easy, provided always that the wound is not larger than a lentil. Circular suture is a longer and more delicate operation. Suture offers the great advantage of securing arrest of hæmorrhage while excluding cerebral complications. The method is said, however, to carry with it the danger of cerebral embolism. The suture site is supposed to form a centre of thrombosis from which clots are conveyed to the brain. This objection is purely theoretical. Aseptic suture is no more subject to thrombosis than ligature. Out of six cases of lateral suture of the

common carotid collected by Monod and Vanverts in 1910, not one was accompanied by cerebral complications. The sole objection to suture of the carotid is its difficulty. In order to render lateral suture safe and efficacious the edges of the vascular wound must be carefully cut away until all trace of endothelial laceration has been removed. This frequently results in a gap which exceeds the limits of possible lateral suture, necessitating circular suture, which is not only more difficult but is a longer and more hazardous procedure. This fact explains the infrequency of vascular suture; indeed, I cannot cite a single instance of its employment in recent injury. I attempted lateral suture in one case of perforation of the carotid bulb by a shell-fragment, but was compelled to abandon the operation owing to the friability of the edges of the wound.

The choice of method, then, lies between ligature of the vessel, a simple, easy, and efficient method rarely attended by complications, and vascular suture, a method which, though undoubtedly easy in its simplest form, is more often tedious and delicate. The inferences are that, where lateral suture appears simple and easy of execution, it should be performed; in all other cases, ligature is indicated.

**2. WOUNDS IN THE UPPER PART OF THE NECK.**—A wound in the upper part of the neck or its immediate neighbourhood, with a hæmatoma about the angle of the mandible or in the sub-maxillary region, suggests a lesion of the internal jugular vein, the bifurcation of the carotid, the internal or the external carotid or its branches. Here also it would be expedient to determine which vessel is wounded before operating, but this is rarely possible. A deep-seated

swelling, invading the isthmus of the fauces or the wall of the pharynx, suggests a lesion of the internal carotid; a superficial hæmatoma, associated with absence of the temporal pulse, suggests one of the external carotid. But these suggestions are very vague, and it is only by operation that the precise site of the vascular injury can be determined.

Here again the first operative step consists in temporary hæmostasis by provisional ligature of the common carotid at the root of the neck.

Exposure of the hæmatoma constitutes the second step, and here also a simple longitudinal incision is usually insufficient to expose the branches of the carotid.

I would remind my readers that the classic method of exposing the internal and external carotids is by an incision along the anterior border of the sterno-mastoid, starting from the angle of the jaw and terminating at the level of the superior border of the thyroid cartilage. The platysma is divided, and beneath it the deep cervical fascia along the anterior border of the sterno-mastoid. The muscle is retracted outwards, and the greater cornu of the hyoid bone is located with the finger at the bottom of the wound. The deep layer of the deep cervical fascia immediately above the cornu is divided. Under this layer lie the thyro-facio-lingual veins below, the hypoglossal nerve above, and between the two a large arterial trunk, the external carotid. The artery is recognised by its collateral branches.

This simple longitudinal incision is insufficient for the exposure of a large hæmatoma in the upper part of the neck. It should therefore be supplemented either by a transverse incision across the sterno-

mastoid, producing a crucial incision, or by Morestin's triradiate incision. By either method the whole of the region in question is freely exposed. The next step is to open the hæmatoma, and, after this has been well cleared out, the vascular wound is readily seen.

(*a*) *Wound of the internal jugular vein.*—I should not return to this subject were it not that the extreme upper part of the neck possesses certain anatomical peculiarities which render these jugular wounds exceedingly difficult to treat. Up to the level of the lower border of the parotid gland the jugular vein is easy of access, and may be seen at the bottom of the wound. To catch the two ends and tie them is the simplest matter. But higher up, beneath the base of the skull and near the jugular bulb, a lesion of this vessel may be extremely difficult to manage. Even when the jaw is pulled well forwards and the parotid is retracted backwards and outwards it is not possible to obtain a clear view of the bottom of the wound whence the hæmorrhage proceeds. By catching the bleeding point at hazard with the forceps one runs the risk of pinching the pneumogastric, glossopharyngeal, or spinal accessory nerves without arresting the hæmorrhage. The hæmorrhage being of venous origin a pad may be applied in the mandibulopharyngeal space, but this is merely a measure of expediency. In one case of the kind I followed the method recommended by Lannois and Patel, which consists in arresting hæmorrhage from the internal jugular by compression or ligature of the corresponding lateral sinus. The sinus is exposed by either the mastoid or post-mastoid route.

The mastoid operation, of which I have personal experience, is carried out as follows :—

The post-auricular tissues are incised as in the operation for opening the mastoid. The mastoid antrum is opened in the usual manner. By enlarging the opening backwards with the mallet and chisel and removing the remaining mastoid cells with the curette the sinus is reached. It is exposed to the extent of one square centimetre, and is then either tied or compressed against the bony groove by means of a plug of aseptic gauze in such a way as to arrest the circulation. The skin is then sutured over the plug, the ends of which are allowed to emerge from the lower end of the wound. At the end of a week the plug is removed. An insignificant cicatrix is the sole trace of an operation which should not take more than a quarter of an hour.

Experience shows that this operation is quite free from danger; complications are as rare as after ligature of the jugular vein. It has the advantage, moreover, of being absolutely effectual. After plugging the lateral sinus, the jugular bulb and the subjacent portion of the jugular vein become flaccid and flattened and cease to bleed. The arrest of hæmorrhage is immediate. I consider ligature or obliteration of the lateral sinus by Lannois and Patel's method a most valuable operation in wounds of the upper part of the neck with lesion of the jugular bulb or the portion of the vein immediately below it.

(*b*) *Wound of the internal or external carotids or their branches.*—The wound may be single, but is generally multiple. Where one vessel only is injured it may be either the internal or external carotid, or it may be a branch of the external carotid, the lingual, facial, or internal maxillary. I have seen very large hæmatomata in the hyoid region, with enormous elevation

of the floor of the mouth, compression of the base of the tongue, and threatened asphyxia due to a wound of the lingual. In one case immediate tracheotomy was necessary. As a general rule, however, the carotid trunks themselves are injured.

Having exposed the arterial wound, what is the next step ? It goes without saying that if a branch of the carotid is injured it should be tied. Nothing could be easier or more free from danger. The conditions are not the same, however, when the carotid trunks are injured.

If the wound is in the carotid bulb or in one of the two main branches, but is situated so close to the common trunk that it is impossible to place a ligature upon the vessel between its origin and the wound, it will be necessary simultaneously to tie the common carotid below the wound and the external and internal carotids above. What is the result of the triple ligature ?

In view of what has been said in a previous paragraph concerning the re-establishment of the cerebral circulation by way of the anastomoses of the external carotid, triple ligature of the carotid bifurcation should considerably endanger this re-establishment. Indeed, might not the resulting complications prove fatal ? Experience shows, however, that this is not the case. It is true that triple ligature has not been employed in recent injury. I was unwilling to attempt it in a case of perforation of the carotid bulb by a shell-fragment, which came into my hands less than an hour after injury. I at first attempted suture, but was forced to abandon it owing to the damaged condition of the edges of the wound. I then performed anterior and posterior lateral ligature, after having to

divide the superior thyroid, which prevented me from rotating the vessel. Recovery followed without incident. The temporal pulsation could be distinctly felt after operation and until after recovery. Out of seventeen cases of carotid hæmatoma collected by Monod and Vanverts in 1910, three were wounds of the bifurcation of the carotid, and necessitated triple ligature. In two of the three cases cerebral complication ensued, but eventual recovery took place in all three. Since the war, Duval in one case ligatured the common and the external carotid ; no complications ensued. Hallopeau ligatured the external carotid, the internal carotid, and the internal maxillary without provoking complications. Finally, both Quénu and Rouvillois have performed triple ligature with recovery in certain old injuries resulting in arteriovenous aneurism. Quénu's patient presented a slight hemiplegia, which disappeared in the course of half an hour. All these facts go to show that cerebral complications do not necessarily follow ligature of the bifurcation of the carotid. Such complications are, however, none the less to be dreaded, and the possibility of their arising should never be lost sight of. My own view is that in such cases it is advisable to practise lateral suture where possible and lateral ligature where necessary, resorting to triple ligature only as a last resource.

What is the best method of dealing with cases where the wound is situated in the external or internal carotid, at such a distance from the bulb that double ligature is possible ? Double ligature of the external carotid is simple and safe, and should always be performed. Ligature of the internal carotid is, on the contrary, a very serious operation. The

appearance or absence of cerebral symptoms depends solely upon the poverty or the profusion of the cerebral anastomotic communications, and it is not possible to ascertain their condition beforehand. For this reason I urge, even more strongly than in the case of the common carotid, that lateral suture should be attempted wherever possible before recourse is had to double ligature, the prognosis of which is so uncertain.

**Summary.**—Wounds of the neck, whether lacerated or punctured, should be treated by free exposure of the site, incision of the hæmatoma after temporary control of the common carotid, and direct arrest of hæmorrhage in the wound. Wherever possible, arrest of hæmorrhage should be obtained by arterial suture. This applies particularly to wounds of the carotid bulb and of the internal carotid. In all other cases permanent double ligature should be performed.

## B. ANEURISMS OF THE NECK

**1. Arterial Aneurism.**—Arterial aneurism following wounds of the vessels of the neck due to projectiles of war is extremely rare. The immediate gravity of these wounds is such, that in the absence of early surgical treatment the vast majority of cases succumb, and very few arrive at the stage of true traumatic aneurism. Within the last two years, however, a few cases have come under observation.

The aneurism may be situated in any region of the neck.

An aneurism situated in the middle and inferior region is connected with the common carotid. The

tumour may be either immediately above the clavicle, or as high up as the superior portion of the larynx. As a general rule it is inconsiderable in size. On two occasions during the year 1915 Walther showed a patient before the Société de Chirurgie with an aneurism of the common carotid following a shell-wound. The tumour was in process of diminution, and, when it first came under observation, was not larger than a hazel-nut. In appearance the aneurism is an ovoid tumour, with its long diameter parallel with the direction of the vessel. It is situated in front of the sterno-mastoid, which it pushes backwards and outwards. The tumour is immobile both transversely and longitudinally. It is soft and resistant, and both pulsation and expansile movements are very marked. The characteristic murmur is heard on auscultation.

Aneurism of the upper part of the neck is in connection with either the internal or the external carotid. The tumour is situated in the upper part of the sterno-mastoid area below the mastoid process, occupying the parotid and submaxillary regions and about the angle of the mandible. It may extend towards the pharyngeal wall along the prolongation of the parotid gland, especially if it originates in the internal carotid.

The course of these tumours is generally progressive and rather rapid. Spontaneous recovery is exceptional. As a general rule the initial slight functional troubles increase progressively. These are due to disturbance of the cerebral circulation ; they are manifested by vertigo, insomnia, throbbing pains over the whole of the side of the head corresponding to the site of injury, somnolence, etc. Pressure upon

the nerves in the neighbourhood of the tumour shows itself by pains in the neck and arm, due to compression of the cervical and brachial plexuses; ocular disturbance due to compression of the sympathetic; hoarseness and dyspnœa due to compression of the recurrent, pneumogastric, and phrenic nerves; and dysphagia and dyspnœa due to compression of the deep structures of the neck. The intensity of these derangements alone may endanger life; as a general rule, however, the catastrophe is precipitated by a sudden increase in the size of the tumour, its inflammation, or its rupture either externally or into the digestive or air passages.

For these reasons arterial aneurisms of the neck should be operated upon unless they are very small and unaccompanied by symptoms.

In a previous chapter it was laid down that the treatment of choice for arterial aneurism in general is extirpation. This applies equally to arterial aneurism of the neck.

The first step in the operation is exposure of the tumour. Here, as in cases of recent wounds, simple longitudinal incision is replaced by either a triradiate or a crucial incision with section of the sterno-mastoid (see p. 167). When the tumour has thus been exposed, the next step is to ascertain which vessel has been wounded. Aneurism of the common carotid at the root of the neck is recognisable at a glance. Those situated higher up, especially if the sac extends rather low, are less easy of diagnosis. It is only by exposing the common carotid and its bifurcation, and by stopping the pulsation of the aneurism by temporary compression of the arterial trunks in turn, that a diagnosis can be established.

When this point has been satisfactorily ascertained the afferent and efferent trunks are temporarily secured as close as possible to the two poles of the sac, which is then carefully dissected out; the jugular, the vagus, the hypoglossal, and other nerves and vessels more or less adherent to its wall are carefully freed; by this means the tumour is gradually isolated until it is only attached to the wounded vessel by a narrow pedicle, which is then severed and the aneurism removed. All that now remains to be done is to deal with the wound in the vessel left by excision of the tumour. In some cases there is only a slight lateral loss of substance; more frequently, however, there is a circular loss of half an inch or more.

Here again the choice lies between ligature and suture, as far as the common and internal carotids are concerned. Monod and Vanverts have shown that out of eleven cases of extirpation of aneurism of the common carotid with ligature of both ends of the vessel, collected by them in 1910, in one case only did death occur thirty-one days after operation as the result of pneumonia. Two cases of extirpation of aneurism of the internal carotid were both successful. It is evident then that ligature is not much to be feared, and this is not remarkable in view of the ample time allowed for establishment of the collateral circulation.

That complications may, however, occur is shown by a case of Morestin's, published since the war, in which extirpation of an aneurism of the internal carotid was followed some hours after operation by cerebral complications ending fatally. Notwithstanding, suture under such conditions is rarely indicated, and indeed I do not know of an instance

in which it has been employed. In arterio-venous aneurism the case is different, as will be shown later.

Extirpation, which is not in reality a very serious operation, is unfortunately not always practicable. Removal of the tumour is sometimes obviously impossible from the start, and if the operation is attempted it may be impossible to terminate it. In such cases recourse is had either to proximal ligature, or to combined proximal and distal ligature. Proximal ligature is a very simple operation, and, according to figures given by Monod and Vanverts, it has a definite value in the treatment of carotid aneurism. These authors collected seven cases of proximal ligature of the common carotid, six of which were successful and one doubtful.

**2. Arterio-venous Aneurism.**—Arterio-venous aneurism of the neck is more frequent than the arterial form. In the majority of cases it is associated with either the middle or inferior portion of the common carotid.

It frequently assumes the form of aneurismal varix. Out of fourteen wounds of the carotid vessels observed by Makins, in seven there was aneurismal varix. In the last two years twenty cases have been operated on and described in France alone. When the lesion assumes the form of varicose aneurism the sac is comparatively small. In a case of Soubbotitch's, however, it attained the dimensions of a hen's egg. Fig. 47 shows an arterio-venous aneurism of the internal carotid the size of a mandarin orange. Like arterial aneurism, arterio-venous aneurism appears as a small, soft, immobile, ovoid tumour, over which there is the characteristic thrill and a continuous murmur which becomes stronger at the

systole. A feature peculiar to arterio-venous aneurism of the neck is the consciousness by the patient of a perpetual humming or vibration in the head. This symptom may become sufficiently pronounced to cause intense suffering.

The course of these tumours is usually very slow. Spontaneous recovery is exceptional. Nevertheless both Pozzi and Routier last year showed patients before the Société de Chirurgie who had presented a marked aneurismal thrill some months previously, which had completely disappeared under the influence of rest. As a general rule, the pain and vertigo due to circulatory disturbance of the brain, as well as the cardiac troubles, become progressively more intense, necessitating surgical intervention.

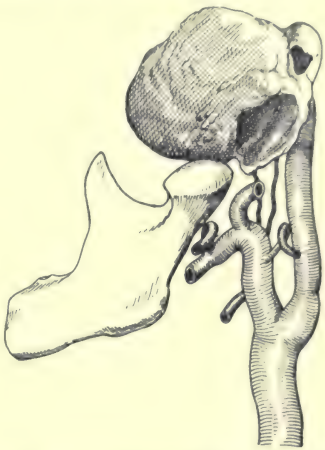

Fig. 47.—Arterio-venous aneurism of the internal carotid artery and the internal jugular vein at the base of the skull. (Latarjet's case. Val-de-Grâce Museum.)

It has already been laid down that the aim of all treatment of arterio-venous aneurism is the permanent separation of the two currents of blood which have become pathologically intermixed. The ideal operation consists in exposing the communication, separating the two vessels by careful dissection, and repairing each of them.

During the last two years this operation has been

performed a certain number of times on the vessels of the neck.

The first step consists in the free exposure of the lesion. Here, as in the cases already dealt with, a flap should be raised and the sterno-mastoid divided. When the tumour has been well exposed, an attempt should be made to identify the anastomosed vessels. Arrest of pulsation on compression of the common carotid or one of its branches constitutes a valuable diagnostic sign. An artery-clamp is placed on the afferent artery as near to the communication as possible ; in the case of a varicose aneurism, as close as possible to the inferior pole of the tumour. Where practicable, the efferent artery should be compressed in a similar manner quite close to the superior pole of the aneurism.

In the case of simple aneurismal varix the two vessels are gradually separated from one another and from the surrounding tissues. In the course of this manipulation the surgeon comes upon a little fibrous channel uniting the jugular and the carotid. If this channel is sufficiently long it may be tied ; a better method is to divide it between two ligatures. If it is short, it is merely divided. The surgeon has now to deal with a lateral arterial and a lateral venous wound. The artery should be repaired by a fine continuous suture. Suture of the vein is inexpedient ; the best method of treating the venous lesion is by double ligature.

In the case of a varicose aneurism the sac is dissected out and detached. Its removal involves complete section of both artery and vein, with or without loss of substance. The venous wound is treated by double ligature. When the loss of substance is very

small, the arterial wound should be repaired by circular suture; when it is more extensive, a venous segment cut from the jugular should be grafted in between the cut ends of the artery.

Reparative operations of this nature have during the last two years been performed with some frequency. In a case of aneurismal varix Soubbotitch isolated the common carotid and the jugular, both of which presented an orifice the size of a haricot bean. He sutured both wounds, and his patient recovered. In a case of jugulo-carotid varicose aneurism, Hotz extirpated a large portion of the tumour when he discovered that both artery and vein had been divided. He tied the two ends of the jugular and united the artery by circular suture, in spite of a loss of substance of half an inch. The circular suture held perfectly. On the ninth day slight secondary hæmorrhage occurred, and the wound was reopened. The carotid suture held well, and the pulsation of the artery was normal. Nevertheless the artery was ligatured. In another case, after extirpation of a jugulo-carotid arterio-venous aneurism, Hotz found that 2 inches of the common carotid were missing at the bifurcation. He tied the external carotid and implanted a venous segment 3 inches in length, obtained from the internal saphena vein, between the internal and the common carotid. The patient recovered.

These results cannot be regarded otherwise than as extremely encouraging. Unfortunately, however, the methods by which they are obtained are not invariably practicable. It is not certain, moreover, that even where practicable these methods are always indicated. Much depends upon the site of the

aneurism. Where the arterio-venous connection or aneurismal sac situated on the common carotid is sufficiently far below the bifurcation to admit of the main trunk being tied below it, experience has shown that ligature is attended by very slight risk. In 1915 Quénu collected ten cases of arterio-venous aneurism of the neck, in which the common carotid was resected and tied under these conditions without complications. Since the war the operation has been performed without complications by Duval, Soubbotitch, Guibal, and no doubt by others. Even in cases where the ligature is close to the bifurcation of the carotid the complications are not fatal. It is probable that the fall in the blood-pressure at the peripheral end of the carotids, due to derivation of arterial blood by the vein, results in re-establishment of the cerebral circulation from the opposite side. However this may be, out of five cases of ligature of the bifurcation of the carotid collected by Quénu, in three only were there transient complications. Since then Bérard, Duval, and Rouvillois have all tied the three branches of the carotid fork without complications.

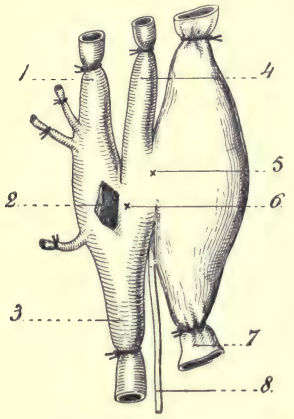


FIG. 48.—Jugulo-carotid arterio-venous aneurism. (Unpublished case of Bérard.)

1. External carotid. 2. Portion of shell extracted from the external carotid, which had also wounded the internal carotid. 3. Common carotid. 4. Internal carotid. 5 and 6. Points at which the arterio-venous communication was effected. 7. Dilated internal jugular vein. 8. Pneumogastric nerve.

It is evident, then, that when suture of an arterial aneurism is in the least difficult, the vascular segment may be extirpated and the four trunks tied. Further, that an aneurismal varix may also be extirpated and the affected trunks tied without provoking serious cerebral complications.

It must however be borne in mind that, in a certain number of cases, extirpation of the aneurismal sac is discovered, either before or during operation, to be impracticable. In such a case partial extirpation and quadruple ligature should be performed—that is to say, ligature of both artery and vein above and below the anastomosis. Where it is necessary to tie the carotids above the bifurcation, or simultaneously to ligature the jugular and subclavian veins below the junction of the jugular with the subclavian vein, quintuple ligature is indicated. When the branches of the external carotid or of the internal jugular participate in the constitution of the sac, multiple ligature is indicated. In one case of this kind operated upon by Bérard, ligature of the common, internal, and external carotids was insufficient to dry the sac; blood was returned to it by the thyroid, facial, and lingual branches, and it was necessary to tie these in order to arrest the hæmorrhage (fig. 48).

## *II. WOUNDS AND ANEURISMS OF THE VESSELS AT THE ROOT OF THE NECK*

### A. WOUNDS OF THE VESSELS AT THE ROOT OF THE NECK

The innominate, the subclavian, and the origin of the carotid arteries, together with the corresponding

veins, may be injured by bullets or shell-fragments, which either graze the upper border of the clavicle and penetrate the neck horizontally from back to front, traversing the shoulder or upper part of the back; or which penetrate the neck from front to back and from above downwards, traversing the upper part of the neck and face. These vessels may also be wounded by splinters from a comminuted fracture of the clavicle. Walther saw a case of injury to the subclavian vessels after simple fracture of the clavicle by the base of a shell.

Lacerated wounds of the vessels at the base of the neck usually cause death from hæmorrhage on the battlefield, and for this reason they are rarely observed in field ambulances. Up to the present only a few cases with small skin wounds have come under observation.

Occasionally the vascular lesion is marked by copious internal hæmorrhage. This occurs when, simultaneously with the vessel, the dome of the pleura is wounded. Hæmorrhage is sometimes so profuse as to interfere with the action of the thoracic organs. Occasionally the intra-pleural pressure is sufficient to arrest the hæmorrhage, and the patient survives. Among seven cases of wounds of the subclavian vessels collected by Makins from the British Army returns, there was hæmothorax in two cases, and both patients survived. I have already mentioned a case of my own in which a wound of the subclavian vein opened into the pleura; hæmorrhage was not arrested until both ends of the vein had been tied and the pleural wound sutured.

In the absence of a pleural wound the hæmorrhage takes place into the cellular tissue at the base of the

neck. The arterial or arterio-venous hæmatoma which forms at the base of the neck spreads either towards the median line, forming a supra-sternal tumour; or towards the base of the neck, forming a supra-clavicular swelling. Occasionally the tumour pushes the sterno-mastoid upwards and backwards and reaches the upper part of the neck, extending to the hyoid bone or the mandible. Or it may be diffused either downwards beneath the clavicle into the axilla, or backwards beneath the trapezius and into the upper dorsal region.

Cases occur in which neither hæmatoma nor hæmorrhage is present. A dry wound of the subclavian artery is rare, but it is occasionally observed. Makins has described a case in which complete division of the third portion of the subclavian artery resulted in only an insignificant hæmothorax. The central end was retracted between the scaleni, and arrest of hæmorrhage occurred spontaneously. Amputation of the arm was necessitated by gangrene. In another case described by the same author the wound in the subclavian was blocked by a fragment of shell; removal of the fragment was followed by formidable hæmorrhage which was not immediately controllable, and the subject died. The immediate formation of a connection between the artery and vein may from the first exclude hæmorrhage. Makins describes two cases of this type.

Wounds of the vessels at the base of the neck are frequently accompanied by lesions of the neighbouring nerves and plexuses (brachial plexus, phrenic nerve. cervical sympathetic). The nervous lesions give rise to complete or partial anæsthesia and paralysis of the arm, symptoms of irritation and paralysis of the

diaphragm, ocular disturbance, etc. It has happened that, in the absence of supra-clavicular swelling, attention has been confined to the paralytic symptoms in the arm, the vascular lesion being discovered only at the operation. Makins saw a case of complete brachial monoplegia due to a wound by a bullet which grazed the upper border of the clavicle. There was no hæmorrhage, either external or internal. Suspecting no more than a nervous lesion, he made an incision over the clavicle in order to expose the roots of the brachial plexus. He found that the second portion of the subclavian artery had been divided; the upper end had retracted beneath the anterior scalene and was obliterated, while the lower end had retracted beneath the clavicle.

If untreated, wounds of the large vessels at the base of the neck almost invariably prove fatal. Death may occur very suddenly as the result of reactionary hæmorrhage, either externally or into the pleura. When a hæmatoma is present, death may result from its sudden enlargement with compression of the structures in the vicinity—the axillary vein, the collateral branches of the artery, and the nerves and structures at the base of the neck (pneumogastric and phrenic nerves, trachea and œsophagus). The direct results of this pressure may be gangrene of the arm, or functional derangement according to the structure compressed. The hæmatoma may become so large that it ruptures, either externally by way of the wound, into the pleura, or into the œsophagus or trachea. But here, as elsewhere, the great source of danger lies in the infection of the wound, involving as it does formidable secondary hæmorrhage, which may result in death within a few seconds.

The therapeutic indications are in accordance with the nature of the lesion.

Lacerated wounds are even less frequently observed at the base of the neck than in the middle and superior regions.

I have already referred to the fact that, under exceptional circumstances, one might be called upon to arrest reactionary hæmorrhage from a lacerated wound of the neck, either during transport or upon arrival of the patient at the aid-post. In the case of hæmorrhage from a wound in the supra-clavicular region an attempt should be made to compress the subclavian vessels upon the first rib by pressing the fingers hard down in the direction of the first rib behind the clavicle (fig. 49). If the hæmorrhage continues, a pad should be applied as tightly as possible to the wound, or the cutaneous wound should be temporarily closed by one or more clamps until the patient can be got to the surgeon.

Fig. 49.—Digital compression of the subclavian. (After Farabeuf.)

Most frequently, if not invariably, however, the wounds at the base of the neck which reach the ambulance surgeon are narrow perforating wounds. Here again the indications for treatment vary with the nature of the projectile—in other words, with the likelihood of infection. When it is a wound by a shell-fragment, there is no doubt as to the right course to adopt. Operation, and immediate

operation, is indicated. In the case of a bullet-wound with punctiform orifices we are on more debatable ground. Nevertheless I am of opinion that here also the method of choice is early operation.

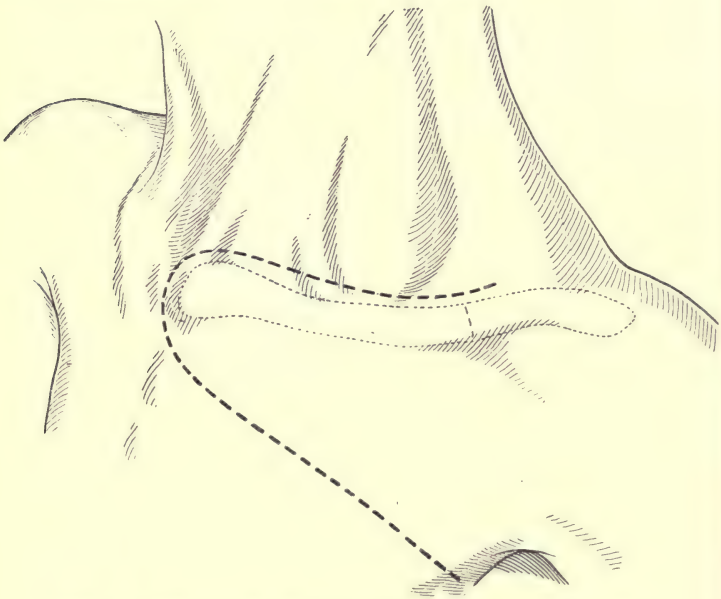

Fig. 50.—Skin incision for exposure of the large vessels at the root of the neck.

The method of access to the large vessels at the root of the neck, and the treatment of the vascular wounds when exposed, will now be described.

1. *Method of access to the great vessels at the root of the neck.*—All surgeons who have had to operate upon the vessels at the base of the neck are agreed that it is essential to expose them very freely. The principal obstacle to exposure is the clavicle, with the sterno-

mastoid muscle above it and the pectoralis major below. The idea of resecting the bone and dividing

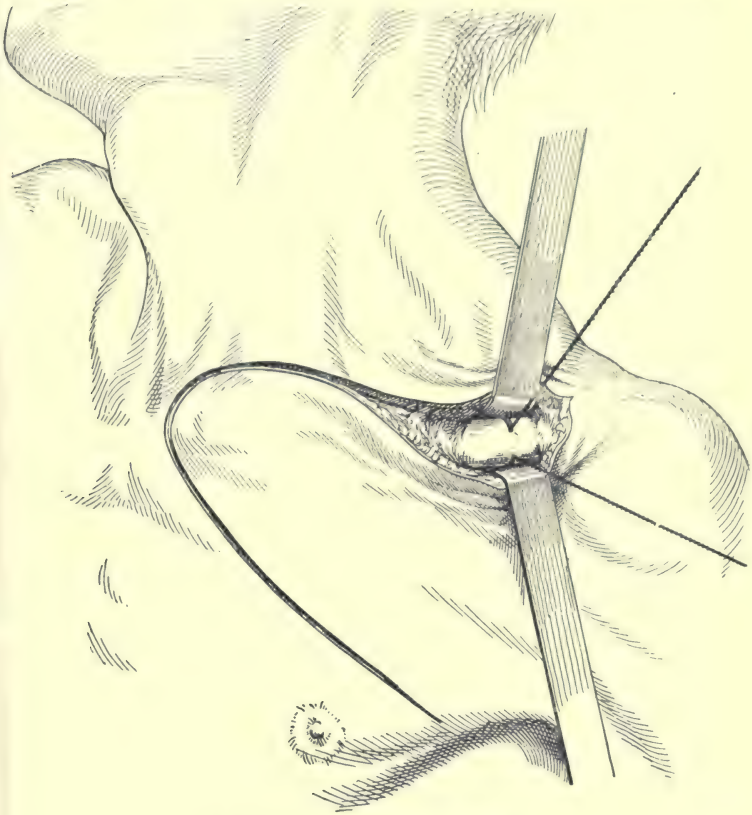

Fig. 51.—Section of the clavicle.

the muscles is not a new one. The following method, which is little known in France, presents very great advantages :—

Two fingers-breadths above the clavicle a horizontal

incision is made, parallel to its upper border and running from its outer third to an inch beyond the sterno-clavicular joint of the same side (fig. 50). The clavicle is exposed at the outer end of this incision, and is divided at the junction of the middle with the outer third by means of a Gigli's saw (fig. 51). At the inner end of the incision the clavicular head of the sterno-mastoid is divided and the sterno-clavicular articulation exposed. The joint is opened and the sternal end of the clavicle is completely disarticulated, leaving the inter-articular fibro-cartilage adherent to the sternal surface. The skin incision is now continued from its inner end in a curve downwards and outwards towards the axillary fold in such a way as to trace out a large flap with a broad external base. The skin and cellular tissue are divided, together with the pectoralis major, which is cut across about an inch from its costal origin ; deeper still, the pectoralis minor is divided close to its thoracic origin. The nerves to the pectoralis major and pectoralis minor are left intact, and are lifted with the muscles in the flap. The loose portion of the clavicle is raised with the flap, and is turned outwards. The large vessels are now admirably exposed (fig. 52). At the upper and inner part of the wound the sternal extremity of the first rib is seen, upon which lies the subclavian vein and, immediately internal to it, the junction of the jugular with the subclavian vein. Close to this point is the vertebral vein, running from above downwards and from behind forwards. Immediately outside this vein, and separating it from the subclavian artery, is the scalenus anticus muscle. The anterior surface of this muscle is crossed by the transverse scapular artery and the phrenic nerve. Immediately internal to the

muscle the first or ascending portion of the subclavian, with its branches, the vertebral and thyroid

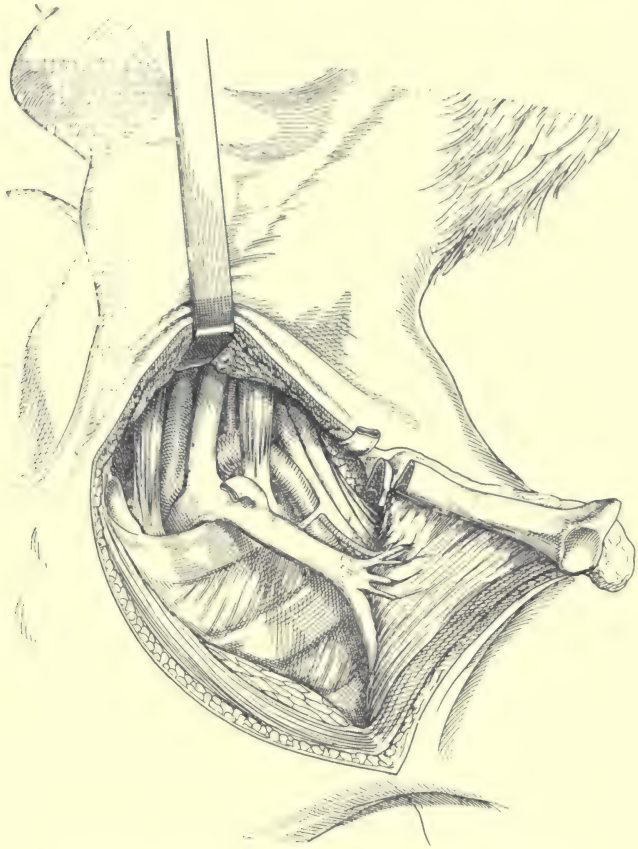

FIG. 52.—The great vessels at the root of the neck.

axis, is seen. Beyond it the origin of the common carotid is visible, and deep in the wound is the innominate artery.

Exposure of the region in this manner gives free access to the origin of the common carotid, the three parts of the subclavian, and to some degree to the innominate artery. To expose the latter more completely, half of the inter-clavicular notch should be resected. Section of the manubrium may, if preferred, be performed at an earlier stage of the operation, and in that case the resected portion is turned back with the resected portion of the clavicle without disarticulation.

2. *Treatment of the exposed vascular lesion.—The first stage of the operation* consists in temporary arrest of hæmorrhage by a ligature or an artery-clamp placed on the proximal side of the wound. An exact knowledge of the site of injury is essential; it is, however, frequently very difficult to obtain.

Certain guides are provided by the clinical examination. A hæmatoma without murmur or pulsation is a venous hæmatoma, due to lesion of the subclavian vein or of a tributary of the jugulo-subclavian. A large pulsatile hæmatoma, the principal extension of which is towards the neck, which presents a murmur which is transmitted towards the parotid, and which suppresses the temporal pulse, is probably due to a wound of the lower part of the common carotid. A hæmatoma which develops chiefly in the direction of the subclavian hollow, extends beneath the clavicle, presents a murmur which is transmitted towards the axilla, and suppresses the radial pulse, is probably of subclavian origin. But the clinical appearances are by no means always clear and well defined, and in the majority of instances clinical examination does not establish a diagnosis. Even after free exposure of the site, it is frequently difficult to detect the

bleeding point. Under such circumstances how is temporary arrest of hæmorrhage to be effected ?

Carefully, slowly, and with infinite precautions the upper and inner part of the field of operation is dissected out, until the common carotid, the first portion of the subclavian, and the innominate artery are disclosed. Diagnosis is effected by compression of each artery in turn until the hæmatoma ceases to pulsate. The vessel in question is immediately controlled, and hæmorrhage during operation is thus excluded. This is the first, indispensable, stage of the operation.

The next step is the free incision of the hæmatoma. The clots are rapidly evacuated, and the site is well cleaned and plugged. The plugs are removed one by one, when the vascular lesion is readily detected.

In the case of a single wound of the subclavian vein or of the jugulo-subclavian junction the vessel is calmly and steadily dissected out, and a ligature is placed above and below the wound in the vessel. Where dissection and isolation of the venous trunk is a matter of difficulty, in certain exceptional cases the wound in the vein may be closed by forceps left *in situ*. Ligature and forci-pressure are the two methods most commonly employed. Suture of a large venous trunk such as this is not a difficult matter, but I do not believe that anything is gained by it. In one case of supra-clavicular and supra-sternal hæmatoma Pauchet exposed a wound behind the clavicle on the inner aspect of a large venous trunk which he took to be the innominate artery, and which he successfully sutured. For my own part, I regard venous suture, here as elsewhere, as a useless

operative complication. In so far as air-embolism is concerned, an accident which was formerly much dreaded, I can only say that it has never come under my observation.

In the case of a wound of the subclavian artery the vessel is dissected out and ligatured above and below the wound. This double ligature is placed either outside, between, or inside the scaleni. The method may necessitate division of the scalenus anticus ; in that case care must be taken to avoid the phrenic nerve, which crosses the anterior surface of the muscle and then runs down its anterior border. Ligature of the subclavian artery does not as a rule endanger the vitality of the limb. The number of the collateral branches of this vessel assures the re-establishment of the circulation, and gangrene is exceptional. Out of sixteen cases of ligature of the subclavian artery collected by Monod and Vanverts in 1911, gangrene of the arm occurred in one case only. Makins reports that out of seven cases of injury of the subclavian diagnosed or operated upon in the British Army since the war, in one case only did gangrene occur. Out of eight cases operated upon in the German Army in the last two years, there was in one case partial gangrene of the fingers (Lexer). Soubbotitch has ligatured the subclavian four times and Duval twice without complication. Le Jemtel's case developed gangrene, but here the hæmatoma was infected, and his operation was for secondary hæmorrhage.

The comparative harmlessness of ligature of the subclavian justifies the exclusion of lateral and circular suture. In the case of a small lateral wound, however, lateral suture is perhaps advisable. In the case of

a large wound demanding circular suture, the method is never permissible.

The wound of the subclavian artery is not infrequently accompanied by injury of one of its branches —the vertebral, thyroid axis, or the internal mammary. Before it passes between the scaleni muscles, the subclavian artery gives off numerous branches, which, as a matter of fact, are more exposed to injury than the trunk itself. The multiplicity of these vascular wounds may render operation extremely difficult. In spite of preventive measures, the blood escapes profusely from the wound, and complete arrest of hæmorrhage may become an extremely complicated matter.

Finally, hæmatoma at the base of the neck may be due to an isolated wound of a branch of the subclavian, more especially of the vertebral artery. Pre-operative diagnosis of this lesion is practically impossible, and operative diagnosis is very difficult. As a general rule it is only by compression of the common carotid and the subclavian that the pulsation of the hæmatoma is ultimately referred to the vertebral. Error is very frequent. Monod and Vanverts have collected eighteen cases of surgical intervention in hæmatoma at the base of the neck due to lesion of the vertebral. In nine cases the common carotid was ligatured in error and the patient died. In one case the vertebral was successfully tied. In the eight remaining cases the hæmatoma was first opened, and in five of these plugged, with death in three cases and recovery in two. In three cases ligature or forci-pressure of the vertebral was employed, and all these cases recovered. Since the war I know of only Soubbotitch's case, in which

the vertebral was ligatured after incision of the hæmatoma, death following as the result of primary hæmorrhage.

The difficulties of operation—namely, the multiplicity of the vascular wounds and the difficulty of controlling the hæmorrhage—combine to render the free opening of a hæmatoma at the base of the neck an operation of extreme gravity. Among eight cases operated upon in the German Army since the war, there were three post-operative deaths. At the German Medical Congress in 1915, Bier reported upon the first hundred cases of operation of arterial hæmatoma since the war. There were eight post-operative deaths, and of these four were cases of hæmatoma at the base of the neck. Hence the fear of primary hæmorrhage has induced a certain number of surgeons to reject incision of the hæmatoma in favour of proximal ligature. Duval adopted the method in two cases. It is certain that, generally speaking, this method is infinitely less effectual than incision and ligature in the wound. Is it less dangerous ? Out of sixteen subclavian hæmatomata collected by Monod and Vanverts before the war, four were treated by proximal ligature with two deaths, eleven by incision and direct hæmostasis with three deaths. These figures speak in favour of the latter method, and although the number of observations since the war is very small, I am convinced that, if carried out in the manner which I have described, incision and ligature in the wound constitutes, here as elsewhere, the method of perfection.

## B. ANEURISM AT THE ROOT OF THE NECK

Traumatic aneurism at the root of the neck is extremely rare. It is due either to a lesion of the innominate, carotid, or subclavian arteries at their origin, or to lesion of the two latter vessels some distance beyond it.

In aneurism of the first type the tumour develops immediately above the clavicle and extends downwards, upwards, and backwards. In a case which I saw with M. Bérard, and which is shown in figs. 1 and 2, Plate II., the tumour extended downwards beneath the clavicle and upwards to the extreme upper part of the neck. The infiltration was continued backwards beneath the trapezius, forming a posterior prolongation which extended to the angle of the scapula. The apparent dimensions of the tumour are not always as large as this. In such cases the effusion of blood downwards may result in the formation of a thoracic tumour. In many of these cases it is practically impossible to define the outline of the tumour and arrive at the precise situation of its upper pole. In other words, there are practically no clinical means of determining whether the aneurism originates in the innominate artery or the first part of the common carotid or subclavian.

In aneurism of the second type the tumour is more circumscribed. If of carotid origin, it develops vertically towards the neck, in front of the sterno-mastoid, above the supra-sternal fossa. If of subclavian origin, it develops in the supra-clavicular space towards the shoulder and below the clavicle.

The surgical treatment of aneurism at the root of

the neck is an extremely difficult undertaking. From this point of view a distinction must be drawn, however, between isolated aneurism of the common carotid and subclavian, and deep-seated aneurism at the origin of these vessels or of the innominate artery.

In the latter case the usual method by extirpation of the aneurismal sac is impracticable in the great majority of cases. This operation involves, as a preliminary step, the exposure of the cardiac pole of the aneurism and the temporary ligature or clamping of the afferent arterial trunk. The dissection of the sac should only be undertaken after this. Now it is extremely difficult, if not impossible, to approach the proximal pole of the tumour from this point. The large incision described above gives access to the middle part of the innominate artery and permits of its ligature. But to isolate behind the sternum the cardiac pole of an aneurism, the wall of which is not only behind the great trunk of the innominate vein, but may also be adherent to the trachea or to the mediastinal pleura, is an operation of extreme peril, and one which may terminate badly. For this reason the ideal method, namely, extirpation, is not indicated in the rare case of aneurism at the root of the neck.

Arterial ligature, usually inferior to extirpation, is here the sole method possible. The ligature may be placed either proximal to the aneurism on the innominate artery, or distal to it on the common carotid, the third portion of the subclavian, or on both.

When the aneurism is supra- or retro-sternal, proximal ligature of the innominate artery, or of the carotid and subclavian arteries near their origins, is

FIGS. 1 and 2.—Arterial aneurism at the base of the neck. (Unpublished photograph by Bérard.)

FIG. 3.—Fracture of the mandible. Division of both internal and external carotids by a bullet. (Latarjet's case. Val-de-Grâce Museum.)

PLATE II.

an extremely dangerous procedure which has been attended by disastrous results. Monod and Vanverts collected five cases, of which four ended fatally. These figures are not encouraging.

For this reason distal ligature is the method adopted in the vast majority of cases. The ligature may be placed at a suitable spot upon the carotid or subclavian, or simultaneously upon both vessels. In the latter case the vessels are ligatured at the same operation, beginning with the carotid. By adopting this sequence cerebral embolism, due to the back-eddy of the blood in the aneurism after ligature of the subclavian, is excluded. It is hardly necessary to point out that this method is infinitely less dangerous than proximal ligature. Monod and Vanverts have collected sixty-five cases of distal ligature in which the mortality did not exceed 15 per cent. The actual figures are as follows: permanent improvement, 30 per cent.; permanent cure, 22 per cent.; operative failure ending in death, 30 per cent.

Isolated aneurisms of the common carotid immediately above the sternum, and of the subclavian outside, between, or immediately inside the scaleni, are very much more amenable to surgical treatment.

Carotid aneurism has already been dealt with. Subclavian aneurism, whether arterial or arterio-venous, is best treated by extirpation. The operation includes the free exposure of the vessel by raising an osteo-cutaneous flap in the manner already described, ligature of the artery immediately above and below the tumour, and the removal of the sac. To the seven cases of extirpation collected by Savariaud in 1906, Monod and Vanverts in 1910 added four. Of these eleven cases, ten recovered and

one died. Traumatic aneurism of the subclavian from wounds produced by projectiles of war is, however, so rare, that no case of extirpation of such an aneurism has come to my notice since the outbreak of war.

A large number of surgeons have, however, remained faithful to the method by ligature, either simple proximal ligature or ligature above and below. The proximal ligature may be placed either outside, between, or immediately inside the scaleni. The simplest and least dangerous operation is extra-scalenic ligature. Monod and Vanverts describe ten cases, with nine recoveries and one relapse. Inter-scalenic ligature appears to be equally favourable. The same authors describe six cases in which the method was employed, with five recoveries and one death. Inter-scalenic ligature, on the other hand, is far more difficult of execution. Owing, moreover, to the fact that it destroys the branches, it endangers the circulation of the arm. In ten cases collected by Monod and Vanverts there were two deaths. Since the war the operation has been performed without complication by Duval, who ligatured the first part of the subclavian. Soubbotitch operated successfully upon an arterio-venous aneurism of the subclavian vessels; he employed double ligature of the artery and lateral suture of the venous wound.

## CHAPTER V

# WOUNDS OF THE VESSELS OF THE AXILLA

### *WOUNDS OF THE AXILLA*

Wounds of the axillary vessels are more often seen in the field ambulances than wounds of the subclavian or the carotid. Eleven cases of the kind have come under my own care.

In some instances there is a large gaping wound of the shoulder or of the axilla, entirely filled with clots beneath which the hæmorrhage has become spontaneously arrested. It may even happen that in extensive destruction of the shoulder or after an arm has been torn off, the vessels are seen in the stump widely gaping, but not bleeding. I have on several occasions seen the arm almost completely severed from the trunk with the skin much torn in the neighbourhood of the axilla, and in the wound the axillary vessels lay stretched and ruptured but completely dry.

The majority of lesions are, however, perforations by bullets or shell-fragments. In such cases there may be internal hæmorrhage into the pleura, or interstitial hæmorrhage with the formation of an axillary hæmatoma. In exceptional cases there is little or no hæmorrhage.

Internal hæmorrhage presupposes an accompanying thoracic wound ; it is of fairly frequent occurrence. Out of fourteen cases of wounds of the axillary artery collected by Makins in the British Army, there was a pleural wound with hæmothorax in five. I have only seen the condition once in eleven cases. Wounds of the vessels in the axilla are more commonly accompanied by a hæmatoma, which rapidly reaches considerable dimensions. It raises the anterior wall of the axilla, producing a large forward bulge ; it extends upwards to the clavicle, downwards along the internal surface of the arm, and along the thoracic wall. It may be of enormous size. In one case upon which I operated, a diffuse swelling occupied the entire left side of the thorax and extended down the arm as far as the elbow. An enormous ecchymosis covered the internal surface of the arm and forearm and the lateral surface of the trunk as far as the iliac crest. An arterial hæmatoma presents very decided expansile movements ; the pulsation and the murmur are usually very marked. An arterio-venous hæmatoma is much less voluminous. Aneurismal varix is considerably less frequent in the axilla than in the neck ; Makins has only seen one such case. In exceptional cases the wound of the vessels shows no sign of hæmorrhage when the patient comes into the field ambulance. In the days when the opening up and systematic exploration of wounds was less practised than it is now, wounds of the axillary vessels were sometimes passed over at the ambulance, only to be revealed later by the appearance of a diffuse secondary hæmatoma or secondary hæmorrhage. Cases of this sort have been described by Auvray, Le Jemtel, J.-L. Faure, and others.

A frequent complication of wounds of the axillary vessels is lesion of the nerves of the brachial plexus. In nine cases out of fourteen, Makins found more or less complete brachial monoplegia. There may be partial or complete section of one of the branches of the plexus, more especially the median nerve. Two very typical cases came into my hands, both of which I sutured.

The indications for the treatment of wounds of the axillary vessels do not differ from those of vascular wounds in general.

In the case of arterial hæmorrhage from an axillary wound during transport or at the dressing station digital pressure upon the first rib should be employed. One or two fingers should be pressed into the supra-clavicular fossa well against the clavicle. If the blood continues to flow, the wound should be firmly plugged or, better still, the cutaneous wound should be temporarily closed with pressure forceps.

In the case of a wound of the axilla with a diffuse hæmatoma the vessels should be immediately exposed and direct hæmostasis effected.

**1. Methods of access to the Axillary Vessels.**— The first part of the axillary artery is easy of access by the classic subclavian incision, and the third part by the axillary incision. The second part cannot be exposed by the usual methods. Moreover, the parts of the vessel exposed by these methods are not very freely displayed. They lie at the bottom of a deep and narrow trench which permits of their ligature, but does not give sufficient room for their satisfactory isolation and exploration and, when it is indicated, their suture. Here, as elsewhere, it is necessary to add to the classic methods supplementary incisions, giving

plenty of room in the direction of the axilla. The simplest plan is to cut across the entire anterior wall of the axilla.

A horizontal incision is made along the lower border

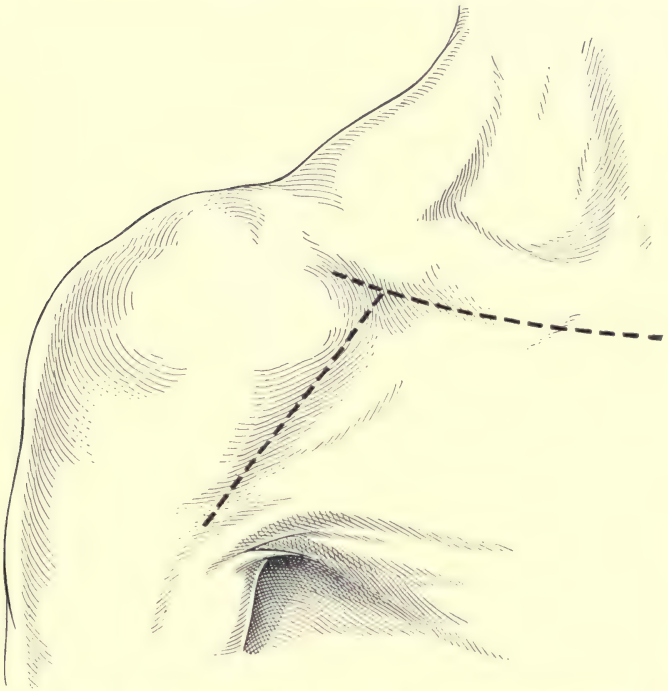

Fig. 53.—Skin incisions for exposure of the axillary vessels.

of the clavicle from the coracoid process externally to within an inch of the sterno-clavicular articulation internally. The skin and the cellular tissue are incised; the anastomosing veins between the cephalic and the external jugular are tied, and the clavicular fibres of the pectoralis major divided down to the fascia running

from the clavicle to the thorax and axilla. This fascia is cut through, care being taken to incise it over the subclavian, which it encloses. The lower lip of the incision is turned back, revealing the axillary artery as it emerges from beneath the middle of the clavicle.

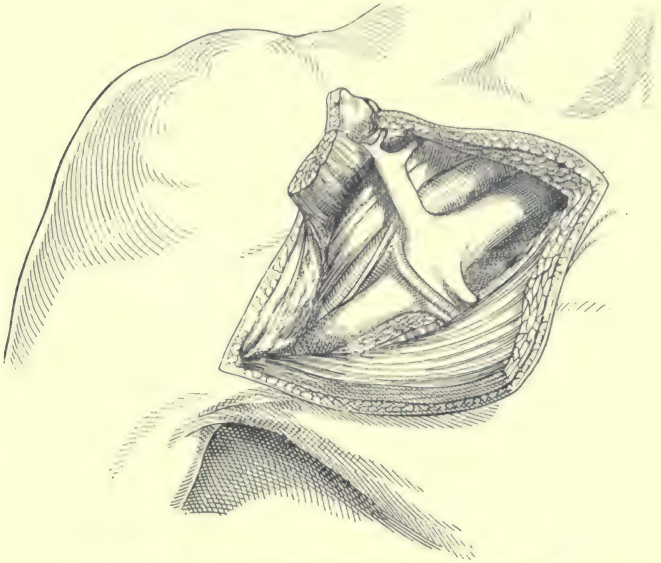

Fig. 54.—Exposure of the great vessels of the axilla.

It is now easy to isolate the artery and raise it on a thread.

From the outer end of the transverse incision an oblique incision is now made downwards and outwards. It follows the groove between the deltoid and pectoralis major, and runs down to the lower border of the latter muscle (fig. 53). The cephalic vein and the acromio-thoracic artery are retracted outwards ; the pectoralis major and minor are divided

transversely, care being taken to avoid their vessels and nerves, which are retracted either outwards or inwards. The axilla is now completely exposed, and its vessels and nerves are readily accessible (fig. 54).

**2. Treatment of the Vascular Injuries disclosed.**—The sac is freely opened, the clots removed, and the wound dried. The wound of the vessel is now visible, and may be in the axillary artery, in the artery and vein, or, more rarely, in one or more branches of the former.

If there is a wound of the axillary artery, should double ligature be performed, or should suture be attempted ?

It is an axiom that ligature of the axillary artery does not in itself endanger the circulation of the limb, provided always that the vessel is not tied at its lower end immediately below the circumflex branches. The branches given off above this point are so numerous that, in whatever part of the vessel the ligature is applied, the circulation below is rapidly re-established. At the lower end of the vessel, on the contrary, the sole collateral is a small anastomotic branch running from the circumflex to the profunda. Hence ligature at this point is regarded as extremely dangerous. Bearing in mind the harmlessness of ligature of the axillary in general, it is obvious that the choice of the precise method of treatment must be largely influenced by the site of injury. If this be in the middle part of the artery, the two ends of the vessel may be safely tied in the wound. If it be in the lower part, lateral suture should be performed for a lateral wound, and circular suture for complete division where possible. Recourse should only be had to ligature when circular suture is impracticable.

Before the war Monod and Vanverts collected eighteen cases of free incision of an axillary hæmatoma with double ligature in the wound. The results included fourteen recoveries, three cases of gangrene, and three deaths. As far as could be gathered from the histories of the cases, the three cases of gangrene occurred after ligature of the lower end of the artery. Since the war a certain number of operations of this kind have been done at the front. I have performed immediate operation in eleven cases. In six, there were either large lacerations, or punctured wounds accompanied by a small hæmatoma or without hæmatomata. In no case did complications arise, though in two at least the lower part of the vessel was tied. In one case there was severe contusion of the artery with extensive thrombosis. The limb was swollen and cold; gangrene was imminent, when the patient died from a pulmonary lesion. On one occasion, one of my assistants operated for extensive laceration of the vessels by a bullet fired point-blank. Double ligature was not immediately followed by any complication, but on the sixth day secondary hæmorrhage took place, and the patient died while I was transfusing blood into his veins. I also operated upon three enormous axillary hæmatomata. In one case, in which a double ligature was placed upon the lower end of the artery, there was rapid gangrene of the hand and forearm, which necessitated amputation of the arm above the elbow. The patient recovered. The compression by the hæmatoma of the only anastomotic communication of the lower part of the vessel renders the re-establishment of the circulation extremely hazardous, and greatly increases the chances of gangrene. Out of twenty-five cases of operation

for axillary hæmatoma published since the war, there were five cases of circumscribed or extensive gangrene, that is to say, 25 per cent.

Suture of the axillary artery was performed in a certain number of accidental wounds before the war. Monod and Vanverts describe fifteen cases, twelve of lateral, three of circular suture. In all cases the results were excellent. As far as my knowledge goes, neither lateral nor circular suture of the axillary artery has been performed immediately after injury since the war. It is evident from this that in the vast majority of cases vascular contusion and other causes, which have already been described, combine to render this suture a matter of extreme difficulty. Nevertheless, my own opinion is that lateral suture is indicated for small wounds of the lower end of the vessel.

## *ANEURISMS IN THE AXILLA*

Traumatic aneurisms in the axilla are, as a general rule, arterio-venous. Makins has, however, observed five cases of the arterial variety.

Arterial or arterio-venous aneurism in the axilla shows itself as a circumscribed tumour, which either pushes up the anterior fold of the axilla or pushes down its base. The tumour is fixed, more or less soft, and pulsates ; the arterial or arterio-venous murmur is very distinct. It is almost invariably accompanied by circulatory and nervous troubles in the arm, forearm, or hand. In the majority of clinical histories it is remarked that the hand and forearm are cold and cyanosed, and that the sensation and movements of the fingers are affected either as a whole or in the areas supplied by one of the nerves (median, ulnar, radial).

Trophic, vasomotor, secretory, and sensory derangements are observed with quite special frequency. Their association has been studied by Leriche, and his results have recently been published in an excellent work by Mme. Athanassio-Benisty.

The skin of the hand is either smooth, shiny and tense, or dry and scaly; eruptions and ulcerations are frequent. The nails are uneven, furrowed, and irregular in shape. The hairs are scanty and poor. The cellular tissue presents a species of hard, elastic, sub-dermal infiltration, resembling that of chronic trophœdema. The muscles are sometimes the seat of a fibrous and fibro-sclerotic degeneration, which may be accompanied by retraction of the tendons. In such cases the hand may assume the classic attitude characteristic of Volkmann's ischæmic paralysis. The joints become stiff, and in time the bones may become deformed.

The vasomotor disturbances are shown by a red-violet discoloration of the skin of the hand, and by a lowering of the local temperature.

The secretory and sensory derangements are diminution of local perspiration and pain. The pain is sometimes extremely severe, and gives the patient no rest. According to Leriche, it is due to inflammation of the peri-arterial sympathetic plexuses. There is also a certain degree of disturbance of objective sensation, which is manifested by complete anæsthesia of a varying region entirely unrelated to the distribution of the peripheral nerves.

The ideal method of treatment of axillary aneurism is by extirpation. Monod and Vanverts describe fourteen cases, in all of which recovery was complete. All surgeons insist upon the necessity for minute and

very careful dissection of the sac, in the wall of which the median, ulnar, and radial nerves are all more or less intimately incorporated. This care forms the chief surgical difficulty, but it is also the factor that lends to operation the whole of its therapeutic value.

Proximal ligature of the artery, formerly the method of choice, has to-day fallen almost entirely into disuse. A few surgeons still tie the subclavian; but this allows the sac to persist, and fails to relieve the pain, trophic derangement, and paralysis. For this reason it should be abandoned in favour of extirpation.

The method of treatment *par excellence* of arterio-venous aneurism is by extirpation of the anastomosed arterio-venous segment. In the case of aneurismal varix, resection as close to the communication as possible is indicated. Where a sac is present it should be completely dissected out, care being taken to release the nerves by which it is surrounded (heads of the median, the ulnar, and the internal cutaneous).

Removal of the aneurism leaves an arterial or arterio-venous wound, which may be treated either by double or quadruple ligature, or by reparative suture.

Ligature of the vein and the artery is a comparatively safe method of treating these aneurisms. The establishment of the collateral circulation materially reduces the danger of ligature of the lower end of the axillary, but does not altogether do away with it. Mériel's case, in which ligature was followed by partial gangrene of the fingers, is an instance in point. Even when there is no gangrene, motor troubles in the arm, the outcome of defective circulation, frequently persist; the circulation is just sufficient to assure the

nutrition of the arm, but not its perfect function. This is the explanation of the fact that, in certain cases, there is persistent paresis of the limb, a certain degree of general loss of power which is not always accounted for by the nature of the nervous lesions. It is essential that the functions of the arm and hand shall remain intact, and gangrene is not the only possibility which it is necessary to take into consideration. If examination by the various methods which have been described in connection with aneurism in general seems to show that perfect re-establishment of the circulation is doubtful, lateral or circular arterial suture should be attempted.

Ligature has been performed in France in a certain number of cases since the war. Quénu, Mériel, Mauclaire, Duval, Bérard, have all extirpated arterio-venous aneurisms of the axilla and ligatured the ends of the vessels. Their patients have not only recovered, but the nervous troubles have largely disappeared. One of Mauclaire's cases is interesting from the fact that the subclavian had been tied without result six months previously. Surgeons other than the French are more generally in favour of complete repair of the vessels. Soubbotitch describes his treatment of eight axillary aneurisms. Of these seven were arterial aneurisms, which he treated by extirpation and ligature, with five recoveries and one death. He employed lateral and circular suture each once, and both cases recovered. In one case of arterio-venous aneurism he employed circular suture of the artery and ligature of the vein; the patient recovered. Out of four arterio-venous aneurisms of the axilla treated in the German Army, the results of which I was able to ascertain, in two cases circular

suture of the artery and ligature of the vein was employed, both recovering; two cases were treated by venous grafts after resection of a large portion of the artery, and both recovered. In both instances the venous graft was taken from the cephalic vein. These results must be regarded as extremely encouraging, and they confirm the views which I expressed above. As a general rule, then, ligature is indicated; but when there is reason to doubt the complete re-establishment of the collateral circulation of the limb, suture may be employed—indeed, it ought to be employed—wherever it appears easy or even possible.

## CHAPTER VI

## WOUNDS OF THE VESSELS OF THE ARM, FOREARM, AND HAND

Wounds of the principal trunks of the arm, forearm, and hand are extremely frequent.

Wounds of the arm, with or without fracture of the humerus, frequently affect the brachial or the superior profunda in the musculo-spiral groove (fig. 55). Such wounds produce either severe external hæmorrhage or a diffuse hæmatoma of the arm. The frequency of external hæmorrhage would be considerable if it included all the cases in which a tourniquet has been applied to the arm. In the majority of instances, however, the tourniquet is superfluous, its removal at the dressing station being followed by no bleeding from the wound ; a simple venous flow has been mistaken for arterial hæmorrhage, frequently with disastrous results. In an earlier chapter I pointed out the danger of the tourniquet. On more than one occasion I have seen rapid gangrene of the arm result from the prolonged application of a tourniquet which the absence of any arterial wound rendered superfluous. A tourniquet should be employed only in cases where there is unmistakable arterial hæmorrhage which is not arrested by plugging

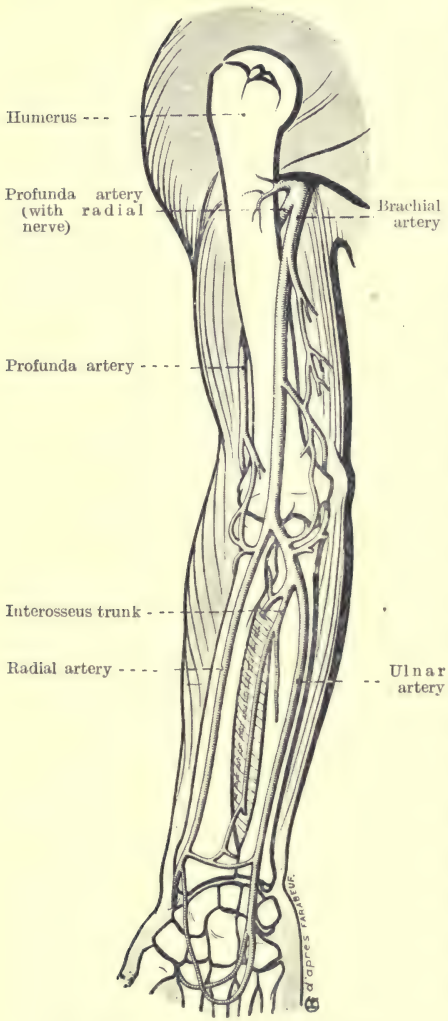


Fig. 55.—Arterial topography of the upper limb. (Broca.)

(fig. 56). When a tourniquet is employed the patient should be got at the earliest possible moment to a field ambulance, and there direct hæmostasis in the wound should be at once secured.

Diffuse hæmatoma anywhere in the arm is frequent. It has no surgical interest, however, unless it is situated in the extreme upper end of the limb and proceeds from an arterial wound between the origin of the circumflex and the superior profunda. Here the anastomoses are very scanty, and should the hæmatoma attain dimensions sufficient to compress the neighbouring

vessels, gangrene of the arm is a possible termination. Two such cases have been described by Murard. It should be noted, however, that the gangrene in these two cases was both mechanical and septic—a variety in the etiology of which infection is a preponderating factor.

Lower down the arm the anastomoses are numerous. At the elbow they form a peri-articular net-

Fig. 56.—Digital compression of the brachial artery. (After Farabeuf.)

work of considerable importance. It follows that ligature of the main trunk at this point is of only slight importance, for the circulation of the arm is assured in advance. A further consequence of the complexity of the vascularisation of the arm and elbow lies in the frequent multiplicity of the vascular wounds. In addition to the brachial artery and vein, it may be necessary to tie the median basilic vein, one or more radial or ulnar recurrent, or the interosseus vessels. Arterial wounds of the arm are sometimes accompanied by nervous lesions. In association with a wound of the brachial artery there may be a

lesion of the median or ulnar nerve ; in the case of the superior profunda, of the radial (musculo-spiral).

The clinical course of wounds of vessels of the arm is uneventful. All that has been said concerning the clinical development of aneurism in general and its therapeutic indications applies here. It is not necessary to recapitulate.

The method of exploring the brachial varies slightly according to whether the lesion is situated in

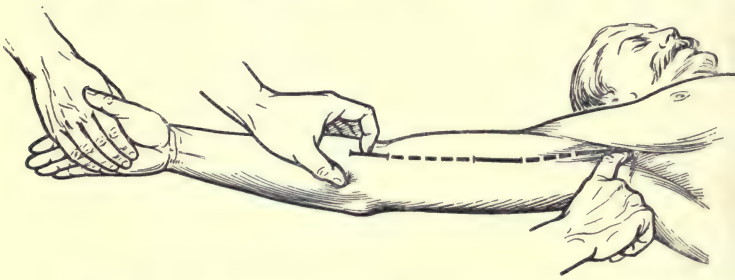

FIG. 57.—Line of the axillary and brachial arteries. (Broca.)

the upper and middle parts of the arm or at the bend of the elbow.

To expose the brachial at about the middle of the arm an incision should be made either along or slightly in front of the line of the vessel—in other words, a line running from the axillary apex to the middle of the bend of the elbow (fig. 57). The deep fascia is exposed and incised well over the biceps. The outer edge of the deep fascia is caught in the forceps, the biceps is freed, raised, and retracted upwards and outwards. Beneath a thin aponeurotic layer the vasculo-nervous bundle is seen, the median nerve in front, the artery behind it. The nerve is raised, and the brachial artery is then fully exposed.

To expose the artery at the bend of the elbow a slightly oblique incision is made from above downwards and from within outwards, the centre corresponding exactly to that of the ante-cubital fossa. Beneath the skin the median basilic vein is either divided or pulled inwards. The deep fascia is then divided, and the bicipital fascia is exposed; the artery is immediately beneath it. The fascia is divided, either directly or on a grooved director, and the artery is easily discovered between the tendon of the biceps externally and the median nerve internally.

When the vascular lesion has thus been exposed, should the vessel be ligatured or sutured? The dangers of ligature are so infinitely remote that there is no necessity to attempt suture. Before the war, gangrene after ligature of the brachial was unknown. Yet this vessel has been sutured more frequently than any other. Monod and Vanverts have published eighteen cases, thirteen of lateral and five of circular suture. In war practice I have ligatured the brachial six times without untoward result, and I know of twenty-five to thirty similar cases. Suture was once attempted, and abandoned by Duval. Soubbotitch has performed circular suture three times, and Hotz lateral suture once. In such cases as these the method does not appear to me to serve any useful purpose, and surgical complications which are not absolutely indispensable should always be avoided.

Wounds of the forearm and hand are frequently complicated by lesion of the ulnar or the radial. It is expedient to draw attention here to the frequency of diffuse hæmatoma of the upper part of the forearm. Owing to the deep-seated position of the

vessels in this region the blood is effused for some distance from the wound into the muscular interspaces. There is no tumour, *i.e.* no localised swelling, but there is a generalised swelling of the limb, which is easily recognised by an experienced

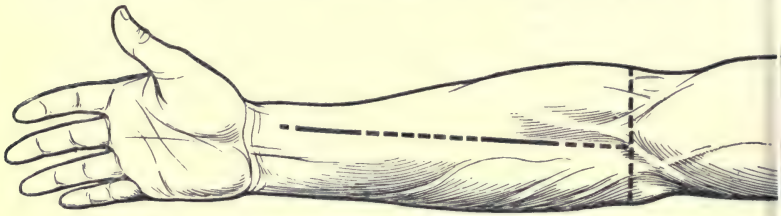

FIG. 58.—Ligature of the radial artery. (Broca.)

surgeon. Diffuse swelling with pain in wounds of the forearm is very suggestive. In nine cases out of ten these symptoms point to the presence of a diffuse hæmatoma, which should receive immediate surgical treatment if ischæmic and septic gangrene of the forearm and hand are to be prevented.

FIG. 59.—Ligature of the ulnar artery. (Broca.)

To expose the radial artery at the upper part of the forearm an incision should be made along a line running from the centre of the ante-cubital fossa to the line of the pulse (fig. 58). The upper end of the incision is three fingers-breadths below the ante-cubital fossa. The deep fascia is exposed and divided along the inner border of the supinator

longus, and the muscle is pulled outwards. In the space beneath the vessels are seen, covered by a thin aponeurotic layer from which they are readily freed.

To expose the ulnar artery the incision should follow a line running from the tip of the inner condyle to the outer border of the pisiform bone (fig. 59), commencing three fingers-breadths below the antecubital fossa. The deep fascia is exposed, the hand is extended in order to stretch the tendons and muscles, and an incision is made over the space between the flexor carpi ulnaris and the flexor sublimis digitorum. The incision is continued lightly across the flexor, which is recognised by the fact that, not being adherent to the aponeurosis, its fibres protrude through the incision. A grooved director is slipped into the space between the two muscles; relaxation of the muscles by flexion of the wrist relaxes the flexor and opens up the space. At the bottom of the space the ulnar nerve is seen, and between it and the axis of the limb, quite close to the nerve lying on the flexor profundus, is the artery.

Arterial and arterio-venous aneurisms of the arm, forearm, and hand are rarely observed at base hospitals. This is due to the fact that the class of injury from which these lesions proceed comes under early treatment at front-line stations. The symptomatology and therapeutics of these aneurisms possess no special points of interest, and are included under the heading of aneurisms in general.

## CHAPTER VII

## WOUNDS OF THE PELVIC VESSELS

Deeply buried as they are in the abdomino-pelvic cavity, the iliac vessels rarely present isolated uncomplicated wounds. Such wounds are usually complicated by fracture of the pelvis, or by a perforating wound of the abdomino-pelvic cavity—in other words, they are observed only in connection with extensive traumatic lesions, such as usually result in death on the battlefield. This is the explanation of their extreme infrequency at front-line stations. The immediate and formidable hæmorrhage is followed very rapidly by death, as in the case shown in fig. 5. Is it possible for a sub-peritoneal hæmatoma capable of arresting the hæmorrhage to form ? The close relation of the vessels with the peritoneum renders this extremely unlikely. Is primary communication of a simultaneous wound of the artery and vein a possible contingency ? From a case upon which I operated with Cotte for arterio-venous aneurism of the hypogastric (internal iliac) vessels it would seem that it is. In December 1915 this man was hit by a bullet which traversed the abdomino-pelvic cavity obliquely, running from the left flank to the right trochanteric region. Laparotomy had

been immediately performed, and several intestinal perforations had been sutured. Several months later symptoms of pelvic arterio-venous aneurism made their appearance, and became progressively more marked. Operation revealed an arterio-venous aneurism of the hypogastric vessels. The original laparotomy had revealed no abnormal condition of these vessels, and it is certain that at that time there was no hæmorrhage from the vascular wound.

In spite of exceptional cases of this kind, wounds of the pelvic vessels which are amenable to treatment must be regarded as extremely rare.

I do not know of a single case of operation during the last two years upon wounds of the common or internal iliac arteries. On the other hand, several cases of lesion of the external iliac, as well as of the extra-pelvic branches of the hypogastric, have been observed and treated. The results are briefly as follows :—

The external iliac and its companion vein have been injured by bullets traversing the iliac fossa either obliquely or from front to back, or by spent shell-fragments arrested by contact with the vessels. Tuffier has reported a case of this description to the Société de Chirurgie, which was observed by Letoux. A fragment of a bomb entered at the level of the anterior superior iliac spine. The opening-up of the wound did not reveal the vascular injury, which was manifested fifteen days later by the appearance of a secondary diffuse hæmatoma. The external iliac was ligatured ; death followed, however, as the result of secondary hæmorrhage. I saw a case in which a ball which entered the buttock near the ischium and came out a little above Poupart's liga-

ment shattered the lower end of the artery. I was able to open the hæmatoma and effect direct hæmostasis. One of my colleagues recently sent me an account of a wound of the external iliac by a shell-fragment. Ligature was followed by gangrene of the entire limb, necessitating disarticulation at the hip two days later. Soubbotitch has reported two cases to the Société de Chirurgie in which hæmatoma resulted from a wound of the external iliac. Double ligature of the vessel was followed in one case by recovery, in the other by death.

These scanty results do not afford sufficient material for the construction of a clinical history of wounds of the external iliac in general. They do, however, show that, excluding those cases—probably the most numerous—in which injury is immediately followed by formidable internal or external hæmorrhage, there are instances in which the vascular wound gives rise to arterial or arterio-venous hæmatoma.

This hæmatoma appears as a voluminous swelling situated immediately above Poupart's ligament, which raises the anterior abdominal wall and extends upwards beyond the iliac crest towards the lumbar region. In the case of my own, to which I referred above, the tumefaction was enormous ; it was almost as large as the head of an adult. The ecchymosis covered the iliac fossa, the buttock, and the entire external surface of the thigh. Arterio-venous hæmatoma is naturally much less voluminous. In certain dry wounds the absence of hæmorrhage is explained by the presence of primary aneurismal varix ; three such cases have been observed by Soubbotitch.

It is hardly necessary to point out that all lesions

of the iliac vessels demand immediate surgical intervention. The operative measures comprise temporary occlusion of the commencement of the external or common iliacs, free incision of the hæmatoma, and direct treatment of the vascular wound. I remind my readers that, to expose the root of the external or common iliac a long incision should be made a finger's-breadth above Poupart's ligament and parallel to it, commencing a little outside the external abdominal ring, following the arch of the ligament as far as its centre, then gradually curving upwards until it runs perpendicularly to the ligament. The cellular tissue and the aponeurosis of the external oblique are incised until the internal oblique is reached; the inferior border of the latter is found with the finger, and the muscle is severed transversely and vertically against the finger with the scissors. The transversalis is dealt with in a similar manner. The peritoneum is then gradually separated by means of a finger introduced into the wound, and is retracted upwards. Quite at the beginning of this manipulation the external iliac artery is found, and the separation of the peritoneum is continued along its course until its commencement is reached, where the vessel is either provisionally ligatured or clamped.

The second stage of the operation consists in the free exposure of the vascular wound and the evacuation of the hæmatoma. The third stage comprises direct arrest of hæmorrhage. Statistics taken before the war show that ligature of the external iliac is not a very dangerous undertaking. According to Monod and Vanverts, the proportion of gangrene is 3·8 per cent. Before the war, however, suture of

this vessel was performed six times. Of these, five were lateral sutures and one circular. The method was successful in four cases, unsuccessful in one, and there was one death. I do not know of any case of suture of a recent wound of the external iliac since the war. Except in the case of a small lateral suture, the extensive and comprehensive exposure of the wounded vessel necessitated by the method renders its employment inexpedient in the surgery of war. The occasions for its employment are very rare.

Wounds of the gluteal and sciatic arteries are more frequently observed at field ambulances than wounds of the external iliac. They usually result from shell-wounds, rarely bullet-wounds, of the buttocks. Vast lacerated wounds of the buttocks by large projectiles are very common. I have frequently seen pieces of iron as large as a hen's egg which had ploughed up the muscles and were still embedded in them. On one occasion I saw a shell-fuse which had traversed the buttock and penetrated the iliac fossa into the pelvis, where it had injured the rectum. During its course the spring attached to the fuse had become uncoiled, and when the patient came into my hands 2 inches of it were projecting from the external wound. These extensive injuries are extremely serious, and their gravity is enhanced by the presence of co-existing vascular lesions.

Wounds of the gluteal and sciatic arteries rarely give rise to serious external hæmorrhage. In the vast majority of cases they produce a diffuse hæmatoma, the very diffuseness of which militates against its recognition. The buttock becomes voluminous and tense; there are no other signs of vascular

injury. This symptom alone, however, is a sufficient indication for immediate surgical intervention.

Exposure of the gluteal artery at the upper part of the great sacro-sciatic notch, and of the lower part of the sciatic artery, is effected by means of a large incision, which commences two fingers-breadths below the posterior superior iliac spine, runs upwards and outwards to the level of this spine, and from there runs directly outwards and downwards, following a line joining the posterior superior iliac spine to the trochanter. Having exposed the gluteus maximus, one of its muscular interspaces is penetrated until the loose cellular tissue beneath it is reached. To facilitate the turning back of the inferior flap of the muscle the insertions of the muscular fibres to the outer border of the great sacro-sciatic ligament are divided. The muscle is then turned back, and at the bottom of the wound the pyriformis muscle is seen, at the upper border of which, close to the bony arch, the gluteal artery is situated. The sciatic artery is found at the lower border of the muscle, close to the spine of the ischium.

It is not always easy to place a ligature upon the gluteal above its bifurcation. The artery is closely adherent to the periosteum, and is very difficult to isolate and secure. In many cases it is necessary to abandon ligature and employ a long pair of artery-forceps, which are left on for forty-eight hours. Where the artery is so adherent to the periosteum, or so retracted within the pelvis that it is not possible to get hold of it, should ligature at a distance, namely, ligature of the hypogastric (internal iliac) by way of the abdomen, be resorted to? Before having recourse to this supplementary operation, I think

that it is better to try and free the artery *in situ*, removing where necessary a more or less extensive portion of the bony arch by means of a gouge-forceps. Although it has long been proved that ligature of the hypogastric is free from danger, I advise that every effort be made to ligature the gluteal in the wound before resorting to laparotomy upon a patient whose general condition is usually very feeble.

## *PELVIC ANEURISM*

Pelvic aneurism due to war-wounds is extremely rare.

Before the war a few isolated cases of arterial *aneurism of the common iliac* had been observed. In the last two years, however, I do not think that a single case of aneurism of the common or internal iliac has come under operation. The first and only case of operation for a pelvic aneurism is one which I saw with Cotte and reported to the Société de Chirurgie. This was an arterio-venous aneurism of the hypogastric (internal iliac) vessels following an abdomino-pelvic wound. When the patient came under observation we found a loud thrill, which was particularly clear in the neighbourhood of a distended cicatrix left by laparotomy. The patient presented all the clinical signs of a large arterio-venous aneurism. The symptoms of marked circulatory derangement of the left lower limb and the intense cardiac symptoms —palpitation, oppression, pain—were clear indications for surgical treatment.

Laparotomy revealed the existence of a tumour the size of the fist, filling the entire space of the true pelvis, and displacing the pelvic colon upwards and

towards the right. It was adherent in front to the bladder, at the back to the hollow of the sacrum, and on the left to the external and internal iliac vessels close to the common iliac. The tumour was very markedly pulsatile. After successive isolation and temporary command of the common, external, and internal iliacs I found that the aneurism was in communication with the two last-named vessels. This finding was confirmed by ligature of the hypogastric, and I then undertook the dissection of the sac. After several attempts I was compelled to abandon its complete extirpation and content myself with incision. I was then able to secure permanent arrest of hæmorrhage by means of a forceps left *in situ* on the peripheral end of the hypogastric, which I had found it impossible to tie. The remainder of the sac was marsupialised, and the abdomen closed without drainage. The patient died in the evening. The post-mortem findings did not reveal the cause of death. The tumour was an enormous varicose aneurism; the sac was derived from the wall of the vein only; the artery was slightly dilated, and opened into the sac by an orifice large enough to admit the tip of the index finger (fig. 60). This is the only known case of operation for pelvic aneurism.

Aneurism of the external iliac and of the gluteal and sciatic vessels is less rare.

Before the war twenty-four cases were collected by Monod and Vanverts. In six cases only was extirpation attempted; of these, three recovered and three died. It is hardly necessary to point out that its situation, its anatomical associations, and the nature of the adhesions which it forms with the

peritoneum, combine to render extirpation of *aneurism of the external iliac* a matter of extreme difficulty. The sub-peritoneal method does not, after all, effect complete exposure; it yields only a restricted operative field, within the limits of which manipulation is very difficult. It is not surprising under

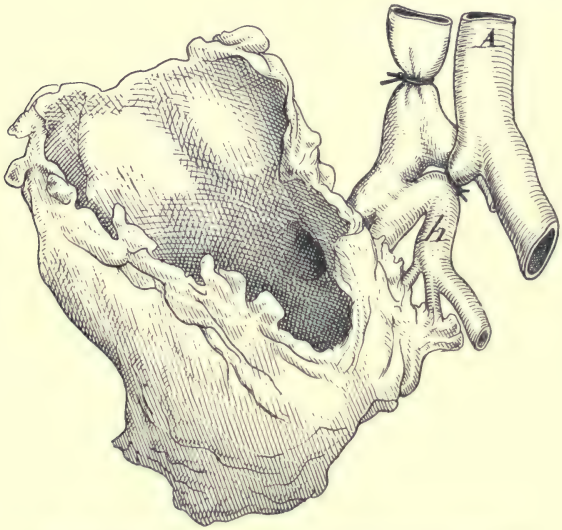


FIG. 60.—Arterio-venous aneurism of the hypogastric (internal iliac) vessels. (Sencert and Cotte.)

these circumstances that aneurism of this class has most frequently been treated by indirect methods, either ligature above or ligature above and below. Ligature above has been performed on the aorta, the common iliac, and the external iliac at its point of origin. Three cases of ligature of the aorta resulted in three deaths, four of ligature of the common iliac in two deaths (Monod and Vanverts); of seven

recent cases of ligature of the external iliac, none ended in death. Gangrene of the limb is exceptional.

It is obvious, then, that it is not always possible to decide in advance upon the method of treatment for an aneurism of the external iliac. The ideal method here, as elsewhere, is by extirpation, but the difficulty of the operation is frequently so great as to constitute a contra-indication. The best method is first to secure the artery above; an attempt is then made to ascertain the anatomical conditions of the tumour, its relationship to neighbouring organs, and the nature of its adhesions. If it is readily extirpable, it should be removed; if not, treatment should be confined to ligature above.

*Gluteal aneurism* may be either exclusively gluteal, or both gluteal and pelvic. It is unfortunately very difficult to ascertain the exact topography of these tumours in advance, and, in the majority of cases, the conditions are revealed only by operation.

Extirpation, the method of perfection, is rendered infinitely more difficult and more complex by the prolongation of the gluteal sac into the pelvis. In such a case extirpation must be abandoned, and ligature at a distance by Hunter's method adopted. Monod and Vanverts have collected twenty-four cases of extirpation of gluteal aneurism, with a mortality of 20·7 per cent. This high mortality is due to the extreme danger of operation in cases where the aneurism has spread into the pelvis. The chief difficulty is to assure efficient hæmostasis, and in several cases of persistent hæmorrhage from the gluteal it has been necessary to resort to ligature of the hypogastric.

Ligature of the internal iliac, usually a temporary expedient in gluteal aneurism, is in certain cases the method of choice. The benignancy of this ligature renders it an eminently suitable preliminary to extirpation, and, where it is adopted, extirpation is easier and much more sure.

## CHAPTER VIII

## WOUNDS OF THE FEMORAL VESSELS

### *DIFFUSE FEMORAL HÆMATOMA*

Owing to the great length and the superficial position of the femoral vessels they are frequently wounded. The majority of wounds are situated in the neighbourhood of Scarpa's triangle, for here the vessels approach the surface of the limb. Next in frequency are lesions of the lower end, where the vessels are firmly fixed in the popliteal space and are immovable. It is said that the middle part so frequently escapes injury owing to its mobility.

When brought into the field ambulance, in exceptional cases these injuries appear as large lacerated wounds filled with clots, beneath which the hæmorrhage is temporarily arrested. Such are certain wounds at the root of the thigh complicated by considerable loss of the tissues of the hip or buttock, and certain comminuted fractures of the upper third of the femur. I remember one case in which the femur was shattered by a bullet which entered at the gluteal fold and emerged in front at the apex of Scarpa's triangle ; the artery was torn by a splinter from the bone. At the operation it was still fixed between the two segments of the vessel. Occasionally the limb

is literally smashed up, or almost completely torn off at the middle of the thigh, with rupture of the vessels. It is superfluous to point out that such injuries are of extreme gravity. The traumatic shock is intense, and the majority of cases succumb shortly after their arrival. Nevertheless I have known a few recover.

In the vast majority of cases, however, the wounds are perforating in character, and may be caused by either bullets or shell-fragments. The vascular wound is commonly accompanied by a diffuse hæmatoma, and the amount of blood effused is sometimes enormous. This is explained by the superficial position of the artery in its upper third, and by the nature of the cellular tissue of the thigh, which is capable of considerable distension. An enormous hæmatoma is formed, which raises the skin of the front of the thigh from Poupart's ligament to the knee. The swelling is not always confined to the anterior aspect; not infrequently it spreads to the antero-internal region, and is infiltrated between the adductors. This is due to the fact that either the course of the bullet naturally gives rise to effusion of blood beneath the quadriceps, or (and this is more frequent) that the deep as well as the superficial femoral artery is injured (fig. 61). It may happen that the swelling is bilocular, one sac being formed from the lesion of the superficial, the other from the lesion of the deep femoral. The hæmatoma may even invade the posterior portion of the thigh by following the course either of the projectile or of a perforating artery. A point to which it is expedient to draw attention is the possibility of the appearance of a voluminous diffuse hæmatoma of the thigh, due not to injury

FIG. 61.—Arterial topography of the thigh. Anterior view. (Broca.)

FIG. 62.—Arterial topography of the thigh. Posterior view. (Broca.)

of a main artery but to injury of one of its branches. In front it may proceed from the circumflex, the artery to the quadriceps, or a perforating artery at its point of origin. Behind it may come from one of the perforating arteries (fig. 62). A wound of one of these vessels alone may give rise to a very considerable hæmatoma, which may to all appearance come from the femoral itself. The treatment of this type of lesion is sometimes a difficult matter; we shall return to the subject later.

The femoral vein is frequently injured with the artery. The resulting arterio-venous hæmatoma is generally less voluminous than one of arterial origin alone. Simple primary direct connection between artery and vein is rare; Makins has, however, observed five cases.

The indications for the treatment of lesions of the femoral vessels are similar to those of vascular wounds in general. At the first aid-post, or even in the trenches, the medical officer who is called upon to deal with severe hæmorrhage from a large thigh wound should effect temporary arrest of hæmorrhage as rapidly as possible. It is essential that he should not allow himself to become confused, and that he should distinguish, above all, between hæmorrhage of arterial and venous origin. It has frequently happened, even during this war, that a wounded femoral vein has continued to bleed after the ill-judged application of a tourniquet above the wound, when a simple pad would have controlled the hæmorrhage. When, however, it is certain that the hæmorrhage is of arterial origin, a tourniquet should, if possible, be applied above the wound. If the wound is situated in Scarpa's triangle, the tourniquet is

useless, and the hæmorrhage must be controlled by digital pressure in the wound (fig. 63). If this measure is unsuccessful, the cutaneous wound should be closed by the application of one or more forceps. A special label should be attached to the patient calling the attention of the surgeon to the case, which should be at once dispatched to a field ambulance with directions to keep the patient as still as possible during transport. In an earlier chapter I described a case in which hæmorrhage from the femoral had been arrested by means of a pad, but the patient insisted upon getting out of the ambulance unaided; hæmorrhage recommenced, and he died in a few seconds.

FIG. 63.—Digital compression of the femoral artery. (After Farabeuf.)

At the field ambulance the surgeon finds either a large wound filled with clots or, more frequently, a penetrating wound and a diffuse hæmatoma. In the case of the first, immediate operation with the object of controlling the hæmorrhage is indicated. In the case of the second, immediate operation is also indicated with the object of evacuating the hæmatoma and preventing its recurrence. The necessity for immediate intervention in diffuse hæmatoma of the thigh cannot be too strongly emphasised. The size of the hæmatoma exposes the limb to the danger of rapid gangrene. In the case of a shell-wound the imminence of grave infection and of gas

gangrene is so menacing, that operation should not be postponed for even a few hours.

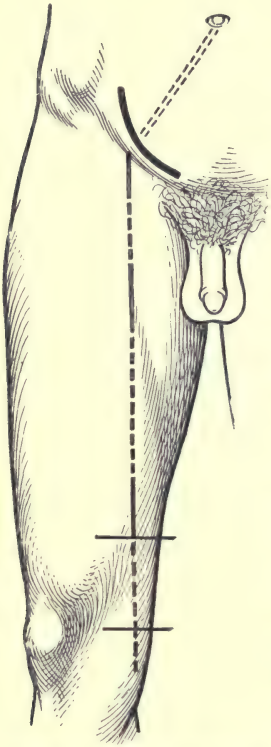

Fig. 64.—Line of the femoral artery. (Broca.)

The first stage of operation consists in temporary hæmostasis by securing temporarily the arterial trunk above the wound. If the hæmatoma is in Scarpa's triangle, the temporary ligature is placed on the external iliac. The method has already been described. In the case of a hæmatoma of the middle or lower part of the thigh, the femoral is secured at the base of Scarpa's triangle. The method is as follows: The skin over Scarpa's triangle is incised for 2 inches along the line of the femoral, that is to say, along a line from the centre of the fold of the groin to the back part of the internal condyle (fig. 64). The incision should commence half an inch above the fold of the groin.

The white fibres of Poupart's ligament should be well exposed. Then the fascia lata should be carefully divided, preferably upon a grooved director introduced through a hole in the cribriform fascia. The edges of the incised aponeurosis are retracted, exposing the artery with the vein close to its inner side. The portion of the artery immediately

beneath Poupart's ligament should be cleared and the thread passed. By placing the temporary ligature in this position the circulation in both the superficial and deep femoral is arrested.

When temporary control of hæmorrhage has thus been assured the hæmatoma is incised. The incision should be a long one, and follows the femoral line. The sartorius is easily recognised; should it hinder exposure of the whole extent of the blood-filled cavity, it should be divided transversely. The cavity should be well mapped out and the exact position of the vascular wounds ascertained. The injury may be in the femoral artery, femoral vein, or in both; there may be multiple wounds of the artery and vein and their branches. The exposure of these wounds frequently demands long and careful examination, the difficulties of which are well known to surgeons at the front.

In the case of a wound of the femoral artery or vein, or of both, what is the method of procedure?

Ligature of the artery, even before the war, had lost much of its bad reputation. In 1909 it was generally admitted that gangrene followed in 20 per cent. of cases. Yet in 1910, Monod and Vanverts observed only a single case of gangrene among twenty-one cases of ligature of the femoral artery for diffuse hæmatoma. In five cases the ligature was on the common femoral, and in all five cases recovery was complete. Simultaneous ligature of the artery and vein preserved its evil reputation somewhat longer. Before the war gangrene was said to follow in 50 per cent. of cases.

I am of the opinion that ligature of the femoral artery is not as dangerous to the vitality of the limb

as it is commonly believed to be. The frequency of gangrene depends very much upon the clinical conditions under which ligature is performed, and varies according to whether the lesion is a large and lacerated wound or a voluminous hæmatoma. In the case of the first, gangrene is extremely rare. I have ligatured the femoral artery eleven times in recent injury without large hæmatoma; in three of these cases the common femoral was tied; in seven the superficial femoral, with, in two cases, concomitant lesion of the deep femoral. In no case did gangrene follow. In at least two cases out of three the vein was also injured. On the other hand, I have operated nine times upon large diffuse hæmatoma of the thigh. In one case gangrene of the entire limb followed, a gangrene which was both mechanical and septic, and which necessitated amputation high up the thigh. Contrary to expectation the patient recovered. In one case there was gangrene of the leg, and in two cases circumscribed necrotic patches appeared on the toes, sole and dorsum of the foot. In addition to these personal observations, I have found scattered through the literature of war-surgery about twenty cases of ligature of the femoral vessels for hæmatoma of the thigh. Monod and Baumgartner, Baudet, Lapeyre, Le Moniet, have not observed gangrene. Out of three cases observed by Soubeyran, one case of gangrene, chiefly of septic origin, occurred. Sébileau alone has had a series of unfortunate experiences. Gangrene followed operation for diffuse aneurism of the thigh in each of his four cases. It should be remembered, however, that these operations were performed at the beginning of the war. Makins observed gangrene in only five out of thirty-five

cases, and in two of these gangrene was present before operation. It is evident then that although ligature of the femoral artery does not entirely deserve its unfavourable reputation, it is nevertheless associated with a certain amount of risk.

Suture of the femoral artery was performed on several occasions before the war. Monod and Vanverts describe thirty-two cases, twenty-six of lateral and six of circular suture. In no case was operation followed by circulatory disturbance in the limb. Before the outbreak of war I performed lateral suture of the femoral artery four times. In one case there was infection and secondary hæmorrhage, necessitating ligature in the wound; the patient recovered. In war practice, on the other hand, I have not once had occasion to suture the femoral artery, the anatomical conditions in every case which has come into my hands constituting a contra-indication. Pauchet performed lateral suture of the femoral in the case of a small wound the size of a lentil. But of twenty-five cases of arterial hæmatoma operated upon by Soubbotitch, ligature was performed twenty times, with three gangrenes and one death; suture five times, three being lateral, with two successes and one failure, and two circular, with two recoveries.

These results are encouraging. Where, in diffuse hæmatoma of the femoral, there is reason to anticipate gangrene—that is to say, if the limb is pale and cold, if the lower end of the artery does not bleed, if the lower end of the vein does not fill when closed by the forceps—in such cases lateral suture and, where necessary, circular suture should be attempted. Where suture is impossible, recourse must be had to ligature.

## *FEMORAL ANEURISM*

Femoral aneurism consequent upon wounds of war is extremely rare. I have been able to discover only three cases of arterial aneurism, though arterio-venous aneurism is somewhat more frequent.

An arterial aneurism observed by Le Jemtel appeared as a small tumour situated in the fold of the groin. In the two cases described by Hotz the tumour was more voluminous ; it was as large as the fist, and was situated in one case in Scarpa's triangle, in the other, in the middle of the thigh. The aneurisms were regular in shape, rounded, smooth, and of varying consistency. They presented all the stethoscopic characteristics of arterial aneurism.

The method of treatment *par excellence* is by extirpation of the sac. Before the war Monod and Vanverts had collected thirty-six cases of arterial aneurism of the superficial femoral, twenty-seven of which were treated by extirpation, with twenty-four recoveries, one gangrene, and two deaths. But within the last two years operations of this type have become very rare. In Le Jemtel's case operation included the ligature of numerous vessels, and gangrene, terminating in death, ensued. In one of his two cases Hotz attempted repair of the femoral artery by implanting a portion of vein $2\frac{1}{2}$ inches in length obtained from the forearm. In the second case he performed circular suture of the artery. Both cases made an uncomplicated recovery.

Taking into consideration the possibility of wounds of more vessels than one, both in the neighbourhood of Scarpa's triangle and all along the line of the femoral artery, extirpation of a femoral aneurism may

well be a complex operation, and the preliminary measures to control the hæmorrhage particularly long and difficult. Owing to the infrequency of gangrene after ligature of the femoral, the best method of dealing with the loss of substance consequent upon extirpation of the sac is by double ligature. Circular suture must be regarded as an exceptional measure, and venous transplantation even more so.

In the case of the femoral as of other great vessels, arterio-venous aneurism is more frequent in war-surgery than arterial aneurism. I have seen the histories of fourteen cases in the French literature of the subject published since the war. Soubbotitch has described twenty-one personal cases, and Makins eleven. More than half of the cases which have come under operation have been those of aneurismal varix in every variety of position upon the femoral vessels. The varicose aneurisms observed have varied from the size of a plover's egg (Walther) to an enormous tumour extending from Poupart's ligament to Hunter's canal. The characteristic symptoms of arterio-venous aneurism were very marked in all the cases.

The best method of treatment is undoubtedly by extirpation of the anastomotic arterio-venous segment. In the case of aneurismal varix, it has never yet been possible to ligature the small canal between the two vessels. Soubbotitch has twice performed lateral suture of the arterial wound with ligature of the vein, and once lateral suture of both artery and vein. In the majority of cases aneurismal varix has been treated either by quadruple ligature or by extirpation of the anastomotic segment. This is due to the fact that, owing to the very extensive adhesions by which the vessels are united, it is frequently very difficult

to discover the precise neighbourhood of the communication. In one case Makins was unable to find the track, and was compelled to operate again later. Moreover, branches almost invariably start from the point of anastomosis or its immediate vicinity. These conditions demand a more complex operation than simple removal of the communication; extirpation of the anastomotic vascular segment or, failing that, quadruple ligature is indicated. The same indications apply to varicose aneurism. Extirpation has been successfully performed by Walther, Broca, Mauclaire, Pozzi, Auvray, Bousquet, and probably by others. Bérard, Duval, Soubeyran, Quénu, Arnaud, have all employed quadruple ligature.

The venous and arterial wounds left by extirpation of the aneurismal sac have been treated variously by either ligature or suture. Ligature has been employed in the greater number of cases. Soubbotitch has, however, performed circular suture of the artery with lateral suture of the vein. In one case circular suture was followed by death. Hotz resected $\frac{1}{2}$ inch of the femoral artery and replaced the resected portion by a segment 2 inches in length obtained from the femoral vein. The pedal pulse immediately reappeared. Makins has once successfully performed lateral suture of the arterial wound after extirpation of the intervascular sac.

Arterial reconstruction of this kind is extremely tempting, but the indications for its employment, especially in the class of case under consideration, are reduced by the extreme benignancy of double ligature of the femoral vessels. Among the cases mentioned in the preceding paragraph, there was no instance of gangrene after extirpation of the

aneurism and ligature of the vessels. It must not be imagined, however, that gangrene is not a possible contingency. Are we to assume, moreover, that recovery is as satisfactory after permanent occlusion of the femoral vessels as after their repair? Mauclaire as well as Bousquet have given it as their opinion that after occlusion of the vessels œdema and a certain degree of loss of power persist. It is true that the circulation may suffice to stave off gangrene, and may yet be insufficient to assure the perfect function of the limb. In such a case the subject, though quite comfortable in repose, may yet be unable to walk half a mile; movement induces pain, œdema, and intermittent claudication, which testify to insufficiency of the distal circulation. Soldiers who have been operated upon in this manner are unfitted for active service. I think that this is a factor which should be taken into careful consideration in cases where the choice lies between ligature and suture. My own view is that, when operation is undertaken at the base, with every surgical facility, and under conditions approximating to those of times of peace, vascular suture is practicable in a far larger proportion of cases than was formerly believed to be possible.

When extirpation of the aneurism is impracticable, recourse must be had to multiple ligature. In some instances it is necessary to tie four, six, or eight vessels. In cases such as these operation becomes a matter of extreme gravity and difficulty. A patient of Duval's died, and another recovered only after disarticulation at the knee. When, owing to the multiplicity of the vascular lesions and fusion with the neighbouring tissues, extirpation of the aneurism is impossible, the case is one of extreme gravity.

## CHAPTER IX

# WOUNDS OF THE POPLITEAL VESSELS

### *DIFFUSE HÆMATOMA*

Wounds of the popliteal vessels are seen in association with lateral or posterior wounds of the knee, or with penetrating bullet-wounds of the knee joint. They are usually accompanied by considerable damage to the limb, but are occasionally seen in connection with simple wounds of the soft parts.

In large wounds of the popliteal space with injury to the vessels spontaneous arrest of hæmorrhage is rare. The rigid walls of the popliteal space keep the wound wide open, and the conditions are not favourable to spontaneous hæmostasis. Occasionally, however, the hæmorrhage is temporarily arrested by involuntary flexion of the leg upon the thigh, and the patient arrives in this condition at the ambulance. In the majority of cases the external wound is small, and a diffuse hæmatoma forms and rapidly acquires characteristics of considerable gravity. Owing to the rigidity of the structures forming the popliteal space the collateral vessels rapidly become compressed, and a hæmatoma of apparently small dimensions may soon produce coldness of the limb followed by gangrene. Makins states that out of eight cases of

injury to the popliteal vessels, in seven gangrene followed very rapidly before intervention was possible. The hæmatoma is confined to the popliteal space, its diffusion being hindered by the fibrous bands which limit the region above and below. Occasionally it invades the knee joint, producing a variety of pulsatile hæmarthrosis. In exceptional cases the hæmatoma is very small, and may pass unperceived.

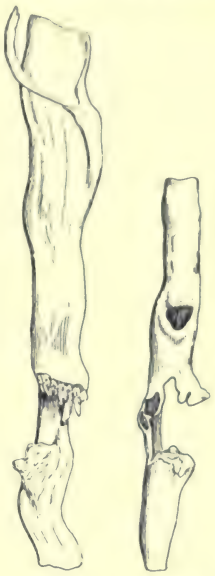

FIG. 65.—Wound of the popliteal vein by a rifle-bullet. Partial section of the internal popliteal nerve. Death was almost instantaneous. (Latarjet's case. Val-de-Grâce Museum.)

Wounds of the popliteal vessels are frequently accompanied by lesion of the sciatic nerve (fig. 65). From its position in immediate contact with the vessel the internal popliteal nerve is more exposed to injury than the external branch. Clinical experience shows, however, that paralysis of the internal popliteal is practically never observed alone, but is almost invariably accompanied by paralysis of the external popliteal.

The extreme gravity of the symptoms of compression provoked by the hæmatoma is an urgent indication for immediate surgical intervention.

The first stage of operation consists in securing temporary hæmostasis by means of Esmarch's bandage

applied at the root of the thigh, or by temporary occlusion of the artery above the tumour, either in Hunter's canal or at the upper angle of the popliteal space.

To expose the femoral in Hunter's canal, the limb is extended and rotated outwards, and an incision $3\frac{1}{2}$ inches in length is made along the femoral line down to four fingers-breadths above the internal condyle. After the deep fascia has been incised, the outer border of the sartorius is defined and pulled inwards and downwards. The thigh is now somewhat abducted, and rotated outwards with the leg flexed; this exposes the anterior wall of Hunter's canal, from the lower part of which the internal saphenous nerve emerges. A grooved director is introduced into the canal along the orifice of exit of the nerve, and is insinuated upwards by pressing it against the outer aspect of the adductor tendon; the anterior wall of the canal is then incised on the director, and the femoral vessels are exposed between the two edges of the incision.

To tie the artery in the upper part of the popliteal space a longitudinal incision 4 inches long is made along the median line of the popliteal space, the lower extremity of which does not extend beyond its centre. The skin, cellular tissue, and deep fascia are directly incised. Beneath the outer edge of the incision the external popliteal nerve is seen, and this is freed and retracted outwards. By separating the loose cellular tissue deeper down in the popliteal space, the vessels are exposed in the median plane close to the bone. The vein is first seen; the artery lies on its inner aspect and quite close to it.

Temporary hæmostasis having been assured, the

hæmatoma is freely incised and the vascular lesion exposed. If it is a wound of the vein only (and these are frequent) the vessel is tied. The operation is simple, easy, and entirely free from risk. On three or four occasions I have tied the popliteal vein without untoward consequences. Should there be a wound of the artery or of the artery and vein, should ligature be performed, or should an attempt be made to repair the vessels by suture ?

Ligature of the popliteal artery has long been regarded as a very serious operation. Statistics show that before the war gangrene followed in a proportion of cases, which varies with different authors from 33 to 54 per cent. Ligature is particularly dangerous when placed upon the lower part of the vessel in the neighbourhood of the bifurcation.

The gravity of ligature of the popliteal artery depends, firstly, upon the small number of collateral branches ; and, secondly, upon the fact that those that exist do not readily assume the functions of the main trunk.

Although they are not

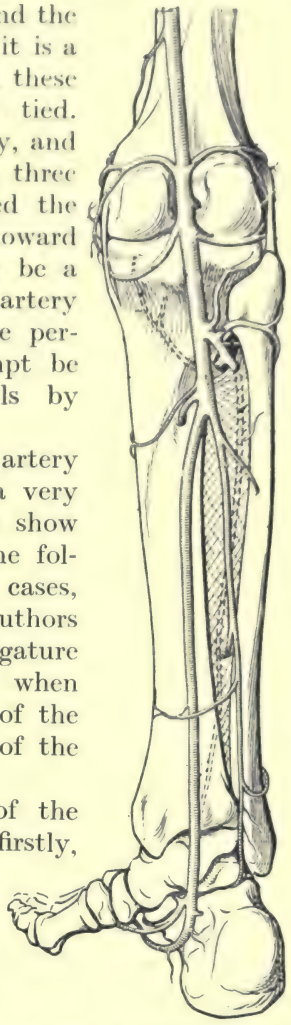

Fig. 66.—Arterial topography of the leg and foot. (Broca.)

very numerous, there are a certain number of branches of the popliteal which anastomose lower down with the terminal branches, the posterior and anterior tibial. These are the anterior and posterior tibial recurrents and the peroneal recurrent (fig. 66). All these vessels, however, arise quite close together near the lower end of the popliteal, and a ligature which obliterates the posterior and anterior tibial also suppresses these branches. Hence the danger of ligature of the lower end of the artery.

Moreover, these branches do not readily assume the functions of the main artery. It is a general law in human anatomy that tissues and organs are vascularised in accordance with their functional activity. The muscles and viscera are supplied by large arterial trunks, the tendons and aponeuroses by very small vessels. Further, in view of the very considerable variations in volume presented by the muscles when active and when in repose, the arteries by which they are supplied should be capable of responding to a varying demand. In the parts of the body where the arteries are called upon to feed groups of powerful muscles, they are furnished with numerous large branches. In the regions where they supply tendons or fibrous capsules, the vessels are few in number and small in size. The latter condition obtains in the case of the knee. Between the muscles of the thigh, which are supplied by the femoral and its branches, and the muscles of the leg, which are supplied by the tibial arteries, there is an anatomical region composed solely of tendons and a fibrous capsule, all of which are very slightly vascular. Hence the poverty in numbers and the attenuation in calibre

of these branches of the popliteal. Should the popliteal trunk be obliterated, its slender branches are frequently unable to take its place. The results are not always expressed by gangrene ; the impaired circulation, though sufficient to preserve life in the leg and foot, is yet insufficient adequately to maintain their functions. The poverty of the circulation is enhanced by compression of the vessels by the hæmatoma, and the vitality of the limb is further compromised by lesion of the nervous trunks. Under these circumstances it would not be surprising if gangrene, though not frequent, were yet more common than we have hitherto thought it.

I have ligatured the popliteal six times in cases of lacerated wound or small hæmatoma, and have once observed gangrene of the leg and foot. Out of five ligatures in cases of large hæmatoma, I have twice observed partial gangrene of the limb. Makins has observed gangrene eight times out of nine in cases of large hæmatoma, in seven cases before operation, and in one after. Soubbotitch had two cases of gangrene out of seven ligatures for hæmatoma. Soubeyran, Maisonnet, Oudard have each observed a case of gangrene. On the other hand, gangrene did not occur in cases described by Picqué, Frédet, J.-L. Faure, Le Moniet.

These results confirm the views expressed in the preceding paragraph. Ligature of the lower end of the popliteal artery is an operation which, though it does not deserve the bad reputation formerly attaching to it, is yet attended by a certain degree of danger, seeing that gangrene follows in 25 per cent. of cases. Moreover, and this point cannot be too strongly emphasised, absence of gangrene does not imply a

perfect circulation, for the functional activity of the limb may be very much impaired.

Here also ligature has sometimes been replaced by suture. In one case of diffuse popliteal hæmatoma Pauchet performed lateral suture of an arterial wound the size of a lentil. Soubbotitch performed lateral suture of the popliteal artery three times, with one failure, one death, and one result unknown. Lenormant describes a case of lateral suture of the popliteal artery in which gangrene followed, necessitating amputation. The clinical material provided by these histories is meagre indeed—a very small number of cases of suture attended by very mediocre results. Here, as elsewhere, the indications for primary vascular suture are extremely rare.

## *POPLITEAL ANEURISM*

In times of peace a popliteal aneurism is one of the forms of aneurism which are most frequently met with. Popliteal aneurism following on a war-wound is, on the contrary, extremely rare.

Popliteal arterial aneurism appears as a tumour of varying size, moulded into the popliteal space and bulging outwards and upwards. The bands of fascia by which the space is bounded usually prevent the extension of the tumour into the thigh or calf. Confined as it is in a circumscribed area, the tumour rapidly produces marked symptoms of compression. There is compression of the popliteal and external saphena veins, giving rise to œdema and cyanosis of the limb; and compression of the branches of the sciatic nerve, inducing sensory and motor disturbances as well as trophic derangements.

The best method of treatment is undoubtedly by extirpation of the sac. Monod and Vanverts collected ninety such cases, with five gangrenes and one death. Within the last two years, however, the operation has become exceedingly rare. Quénu undertook the extirpation of a popliteal arterial aneurism, but was compelled to abandon total excision of the sac owing to its adhesion to the surrounding structures. Even when incomplete, however, here as elsewhere extirpation is superior to simple proximal ligature. Since the war, Matas' endo-aneurismorraphy has been successfully performed by Soubbotitch once. Is the method preferable to extirpation? The clinical material at our disposal is too scanty to furnish a categorical answer to this question.

Arterio-venous aneurism is more frequent than arterial aneurism. In rare cases it assumes the form of a simple union between artery and vein. Makins has observed two such cases out of eight, and one case has been observed in France by Pauchet. In the majority of instances there is an intermediate sac. It is important to note the frequency in these cases of nervous troubles (pain, neuritis).

The ideal treatment of popliteal arterio-venous aneurism is by extirpation of the anastomotic segment, a method which has been frequently employed during the last two years. The deep-seated position of the vessels, their adhesion to the back of the joint, and the association of the sac with the sciatic nerves, all combine to render this operation a delicate one. It has been successfully carried out by Auvray, Rocher, Estor, Le Moniet, Cauchois, Duval, Soubbotitch, and others.

After excision of the sac the double vascular wound

may be treated by either ligature or suture. In one case Pauchet was able to separate the two vessels and to perform lateral suture of each wound. Soubbotitch performed lateral suture of the artery with ligature of the vein; the patient recovered. In another case he sutured both artery and vein; gangrene followed as the result of embolism, and the patient died. Hotz has twice implanted a venous segment in the arterial gap after wide resection of both artery and vein. In both cases recovery followed. With these few exceptions ligature is the method employed, and no case of complication by gangrene has been reported.

## CHAPTER X

## WOUNDS OF THE VESSELS OF THE LEG AND FOOT

Wounds of the vessels of the leg and foot are very common ; *wounds of the posterior tibial vessels*, which constitute so grave a complication of injuries of the calf, are particularly so. They are commonly observed in cases of comminuted fracture of the tibia and fibula. The wound is widely gaping and filled with clots. The wound in the vessel, temporarily closed by a clot, by shreds of clothing, or by a splinter, is disclosed only after minute cleansing of the damaged area.

In the majority of instances wounds of vessels of the leg are complications of small penetrating shell-wounds of the calf. The leg is distended from the knee to the ankle by a diffuse swelling, and the patient complains of severe continuous pain. These symptoms all point to a diffuse hæmatoma of the calf. Not infrequently auscultation reveals a murmur over the back of the leg. On the other hand, in opening up a wound of the calf it is by no means exceptional to discover fortuitously a wound of the posterior tibial, the presence of which was unsuspected. This is an experience which must have befallen all

surgeons who have operated at the front. The arterial wound being blocked by the projectile or by a fragment of clothing, there is no trace of hæmatoma. Careful excision of the wound is the sole means of discovering and treating the arterial injury.

Diffuse hæmatoma of the calf is a condition of considerable gravity. Deeply situated as they are beneath the soleus, and confined between it and the posterior surface of the leg bones, the posterior tibial and peroneal arteries give rise to effusions of blood which infiltrate the entire length of the leg along the interosseous membrane, and which displace the muscles and compress the nerves in its vicinity. In such a case the vitality of all the muscles of the calf is rapidly interfered with, and should anaerobic organism have been conveyed by the projectile to the deeper parts of the wound, gangrene, both ischæmic and septic, is practically inevitable.

*Wounds of the anterior tibial* are less frequent. The vessel is well protected by the tibia, and these wounds are observed only in association with more or less extensive shattering of the tibia.

In the case of diffuse hæmatoma of the calf, the wound should be well opened up and the bleeding vessel exposed. Hæmorrhage may be controlled by Esmarch's bandage; it is, however, nearly always superfluous.

To reach the posterior tibial or the tibio-peroneal trunk the leg is placed in semi-flexion and semi-abduction, and is somewhat rotated outwards, with the calf unsupported. An incision 4 inches long is made from the level of the anterior tubercle of the tibia down along a line a thumb's-breadth behind the inner border of the tibia (fig. 67). The

integument, cellular tissue, and deep fascia are divided, and the inner border of the inner head of the gastrocnemius is exposed. The muscle is pulled down until 2 inches of the tibia are exposed. In the space thus created the soleus is incised along the entire length of the surgical wound, about $1\frac{1}{2}$ inches internal to the tibia. The incision is deepened until the intra-muscular aponeurosis is reached. This is split; after cutting and retracting some of the deep muscular fibres of the soleus, the

FIG. 67.—Incision for ligature of the posterior tibial in its upper third. (Broca.)

cellular plane in which the vessels are situated is reached. The nerve is first exposed, and then the artery.

Having exposed the vascular wound, the vessel is tied above and below it. It goes without saying that arterial suture is here quite superfluous.

Diffuse hæmatoma of the antero-external region of the leg due to *injury of the anterior tibial* is as rare as diffuse hæmatoma of the calf is frequent. I have, however, seen two or three such cases. The hæmatoma developed in both the antero-external and posterior regions of the leg as the result of a large perforation of the interosseous membrane by the projectile. In such a case it is extremely difficult

to diagnose the wounded vessel in advance. It will be remembered that the anterior tibial line starts from the ante-peroneal hollow and runs to the middle of the instep (fig. 68). Deeply situated as it is, especially in its upper half, the artery is sometimes very difficult to expose. Incision should follow the line just quoted, beginning three fingers-breadths below the level of the knee joint. The fascia is divided, and the inter-muscular septum between the tibialis anticus on the inside and the extensor longus

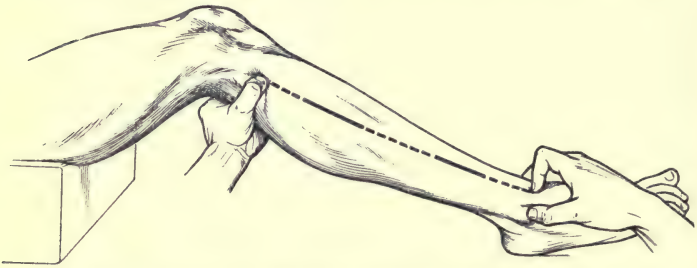

Fig . 68.—Incision along the line of the anterior tibial. (Broca.)

digitorum pedis on the outside is found. This interspace is not easy to find ; it should be remembered that it is curvilinear in form, and that the director should be first passed backwards, then horizontally, and afterwards forwards. The artery is at the bottom of the inter-muscular septum close to the interosseous membrane.

*Arterial and arterio-venous aneurisms of the leg* and foot possess little surgical interest. During the last two years some twenty arterio-venous aneurisms of these regions have come under operation. In all cases extirpation has been attempted. Where complete extirpation was impossible, recourse has some-

times been had to multiple ligature. In no case has either method been followed by circulatory disturbances of the foot and toes.

. . . . . .

This concludes this short study of wounds of the individual vessels. I hope that the young ambulance surgeon will find in it what it has been my endeavour to convey, namely, a clear idea of what should be done in each class of case, and a brief account of the best method of doing it. My own observations during two years of war-service are supplemented by such of the experiences of others as I have been able to find in the home and foreign publications which have come into my hands. If I have omitted to mention observations which would have proved instructive, I crave the pardon of their authors.

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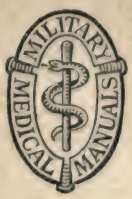


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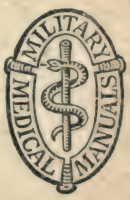


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Of all the infections which threaten our wounded men, tetanus is that which, thanks to serotherapy, we are best able to prevent. But serotherapy, when it is late and insufficient, may, on the other hand, tend to create a special type of attenuated and localised tetanus ; in this form the contractions are as a general rule confined to a single limb. This type, however, does not always remain strictly monoplegic ; and if examples of such cases are rare this is doubtless because physicians are not as yet very well aware of their existence.

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But the treatment of syphilis has, during the last six years, undergone considerable modifications ; the new methods are not yet very familiar to all physicians ; and certain details may no longer be present to their minds. It was therefore opportune to survey the different methods of treatment, to specify their indications, and their occasionally difficult technique, which is always important if complications are to be avoided. It was necessary before all to state precisely and to retrace, for all those who have been unable to follow the recent progress of the therapeutics of venereal diseases, the characters and the diagnostic elements of the manifestations of syphilis.

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