SURGERY

OF THE

BRAIN AND SPINAL CORD

BASED ON PERSONAL EXPERIENCES

BY

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VOLUME I

ENGLISH ADAPTATION BY

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VOLUMES II AND III

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TRANSLATOR'S PREFACE

An effort has been made to preserve in the translation the peculiarly effective method of expression employed by the creator of the original work. The indulgence in involved phrasing is the outcome of this attempt. If this be in any sense difficult of interpretation, the added effort to clearly comprehend the text is justified on the ground that the original author's efforts should have this additional tribute shown. It is hoped, however, that the work here submitted is not materially depreciated in value as the result.

The translator wishes to express thanks to Dr. John F. Connors for valuable aid given in preparation of the manuscript and for his advice and friendly support.

The publisher is to be congratulated upon giving the English-speaking practitioner an opportunity to become acquainted with a work which may be properly regarded as setting a high standard of literary and artistic production.

THE TRANSLATOR.

New York.

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The Surgery of the Brain

INTRODUCTION

The combined efforts of anatomists, physiologists and neurologists have made possible the rapid advances in brain surgery. More accurate diagnoses have justified invasion of a heretofore unexplored domain, one which until twenty years ago was regarded as inaccessible to operative technique. However, it is proper to state that the possibilities in this direction have not yet been exhausted. While within recent years *E. v. Bergmann*, the German pioneer in brain surgery, led the way, invading the most important field, that of removal of neoplasms from the motor areas, we consider at present all portions of the cerebrum and cerebellum, the surfaces of which are susceptible of exposure as subject to legitimate operative attack. *Per contra* it is to be noted that tumors of the basal ganglia and medulla oblongata are still regarded as inaccessible to surgical manipulations.

In submitting herein my experiences in the surgery of the central nervous system I do not attempt to offer a text-book. Indeed, it would ill befit my office as a surgeon to invade a domain so manifestly that of the internist and neurologist. I endeavor, therefore, only to present numerous illustrations from nature which are destined to constitute an accurate picture of the status of the surgery of the brain and spinal cord as it stands at this writing, together with detailed clinical histories of cases and abstracts of my theme from the view-point of the clinician.

In order to obviate the disadvantages of this deviation from usual custom, I have divided the subject matter into chapters and subdivisions and added an exhaustive alphabetical register. A thorough perusal of the latter is recommended.

Our discussion begins with that of the useful methods of

Trephining

Approach to the brain is obtained by means of solution of continuity of the skull. The operation of trephining is one of the oldest measures known to surgery, and originates from prehistoric times. A study of the specimens in the Berlin ethnographic museum shows that the uncivilized races employed the measure, and though the technique must have been faulty enough, the outcome of cumbersome armamentarium, it is evident that favorable results were not uncommon.

Judging from the deposit of new bone surrounding the trephine opening it is fair to assume that a number of cases survived for a considerable period of time the operation. It is, of course, impossible to state what percentage of recoveries occurred. Still, the operation of trephining was until the middle of the last century regarded as extremely dangerous.

Dieffenbach, in his classic work, "Operative Surgery,"[1] states: "*For many years I have feared more the operation of trephining than the outcome of cases*

[1] *Dieffenbach*, Leipzig, 1848, II, p. 17.

of head injuries which have come under my observation. Indeed, I have regarded the operation as a certain method of killing my patient." In these cases the problem was restricted to lesions of traumatic origin which had left visible signs, leaving no doubt as to the location to be attacked. Brain surgery of to-day presents, however, the problem of recognizing lesions by methods of localization by symptoms, based on a knowledge of cerebral localization and involves opening of the unaltered skull, displacement of the dura and invasion of the brain substance in search of diseased areas.

The advent of asepsis, as in all operative endeavor, marked an epoch in the surgery of the brain. Indeed, as the result of its employment, *Richard Volkmann* through *Leser* reported twenty-three years ago, thirty-six cases of trephining for injury to the skull without a death traceable to the operation itself. The aseptic method of wound treatment engenders to-day a degree of security which enables the operator to regard trephining as quite devoid of danger. One menace, however, remains, *i. e.*, when the extent of bone trauma is great such as obtains in wide craniectomy, death is likely to occur from collapse and severe hemorrhage from the diploë.

The classic instrument, the trephine, so long employed for the purpose of opening the skull, has gradually fallen into disuse, except in those instances where it is certain that only a restricted area of brain tissue need be exposed for the intended purpose, as for instance, for drainage of the lateral ventricle in hydrocephalus internus or for the purpose of injecting the antitetanus serum. However, for these purposes we have now the *Doyen* burr, which meets quite perfectly the indications. As there are four sizes of this instrument obtainable it is feasible to make the opening of the desired size and thus avoid unnecessary trauma to the dura.

The trephine crown makes but a meager opening and permits only of restricted inspection of the brain surface, making it necessary to remove several contiguous areas of skull in order to obtain sufficient space for trustworthy inspection and to gain sufficient exposure for the application of measures of relief. Again, the button of bone removed by the trephine is sacrificed while, when large bone flaps are employed, they may be, and in the writer's opinion should be, replaced.

The osteoplastic method was first employed on the human being by *Wagner*-Koenigshuette, after the measure had been shown to be feasible on the lower animal by *J. Wolff*.

Nourishment of the soft parts of the osteoplastic flap is obtained through the wide base of the flap, which in the majority of instances should be directed toward the base of the skull. The lines of incision are shown in the illustrations (Fig. 2, page 11, and Fig. 10, page 20) and on the various plates. The osteoplastic method is employed by the writer in the vast majority of cases, the exceptions being few and are made the subject of special mention in the text. The method permits of application together with the various other procedures which have been exploited within the last few years.

Quite recently the chisel and hammer method was still in vogue. Indeed, with these simple instruments flaps are readily fashioned to suit the taste of the operator and meet the indications of the surgical problem. However, the cutting of the groove must be executed with great care, consumes much time, and is attended with considerable loss of blood from the diploë. I do not use the chisel because I have better instruments at my disposition, but in the event of necessity, in case no other trephining instruments are available, I regard the chisel and hammer as exceedingly useful agents, and employ them under these conditions with reasonable assurance of favorable outcome.

In chiseling the cranium the impact from the hammer should not be imparted vertically but tangent to the skull, in order to obviate as much as possible the inevitable concussion conveyed to the brain, an objectionable factor which should be eliminated from the technique of brain surgery.

Before entering into a discussion of trephining a few remarks are prefaced regarding

Temporary Control of Hemorrhage,

as in extensive opening of the skull the loss of blood from the scalp is an important matter and may have a determining influence upon the outcome of the operation. The application of a rubber band or rubber tube to the base of the skull does not offer sufficient security in this connection, and indeed may increase venous hemorrhage. Somewhat more satisfactory is the application of a pneumatic tourniquet[1] to the base of the skull as its distention makes most complete compression.

The writer prefers to make compression in the immediate vicinity of the trephine opening, and for the purpose regards the methods of *von Haidenhain* and *Kredel* as meeting more certainly the indications.

The former[2] introduces to either side of the contemplated lines of incision a continuous suture (backstitch) which he draws very tight. These sutures are allowed to remain *in situ* for eight to ten days after the operation, and are removed simultaneously with the approximation sutures employed for holding the edges of the wound in apposition. The sutures are introduced with a medium-sized half-curved needle, and the needle is caused to come in contact with the largest possible area of bone.

I apply the suture around the area of proposed operation, only on one side (the outer), and include the base of the flap. (See Plate, observation 1, 4.) After completion of the operation I make replacement of the flap and accurate apposition of the edges of the wound with suture of the scalp, aponeurosis and periosteum. I remove the compression sutures before applying the protective dressing.

Secondary hemorrhage has never occurred, although be it said that all blood-vessels are carefully ligatured and the wound carefully compressed for a considerable time after the approximation sutures are introduced. The only disadvantage observed from this method was in a single case in

[1] *Harvey Cushing*, Pneumatic Tourniquets, etc., *The Medical News*, March 26th, 1904.

[2] *Zentralblatt für Chirurgie*, 1904, p. 249.

which œdema of the scalp occurred two days after an operation, involving opening of the central fossa of the skull. The swelling extended to the eyelids and cheek but subsided spontaneously at the end of forty-eight hours. *v. Hacker* executes the hemostatic suturing in much the same manner as the writer but uses overlapping button sutures which extend over a portion of the base of the flap.

Haidenhain's hemostatic suture is applicable to all portions of the skull where there is not much muscular tissue, such as near the neck. At this point it is rarely effectual, though a lessening of hemorrhage is accomplished by its employment. It will be found necessary to deligate several spurting vessels. With this exception I have had satisfactory results even in operations exposing the cerebellum provided the sutures are deeply introduced and firmly tied. The original *Haidenhain* suture, which comprises stitches on either side of the contemplated lines of incision, does not leave sufficient room for the manipulations necessary to exposure of the cerebellum.

Another valuable method of control of hemorrhage is that of *Kredel*,[1] described as follows: Immediately contiguous to and distal from the contemplated lines of incision, a heavy silk suture is introduced with a large, flat or slightly curved needle. The needle penetrates the scalp and is caused to slide along the bone for a distance of from 5 to 7 cm., when it is made to emerge. The distance traversed is, of course, modified in accord with the size of the contemplated flap formation. If the flap is to be a

[1] *Zentralblatt für Chirurgie*, 1906, p. 1137.

large one it will be found expedient to emerge the needle at half the distance and reënter it somewhat backward from the place of exit. The silk ligature is now firmly tied over a curved metal plate. It is wise to make the points of entrance and exit slightly nearer each other than the length of the metal plate so as to be able to make firmer tension on the scalp. This procedure is repeated upon all sides of the operation field, effectually walling off the area and controlling quite thoroughly the bleeding.

The curved metal plates (Fig. 1) measure 1 cm. in width, and ½ cm. in thickness. The length is modified to suit the dimensions of the area to be denuded. The lengths most commonly found useful are the 5 cm. and 7 cm. sizes. To assure close apposition to the scalp the plate should be slightly bent, the extent of the bend being controlled by the situation in which they are to be applied. It is also feasible to curve the plates to conform to the incisions; however, too great a modification of outline in this respect interferes with the tension of the suture, as the latter has a tendency to exaggerate the bowing of the appliance. This may be overcome by encircling the plate together with the tension suture with a stitch encompassing the scalp which attaches firmly the appliance. *Nicolai*, an instrument maker in Hanover, makes the plates with a central perforation which permits of more certain fixation as the encircling suture is liable to slip, an occurrence which is obviated by passing the suture through the opening.

Fig. 1
Kredel Metal Plate

In order to possess plates which are applicable to all situations on the skull, I have had the appliance constructed of pliable tin. I surround the entire operation field in the form of a quadrant with four

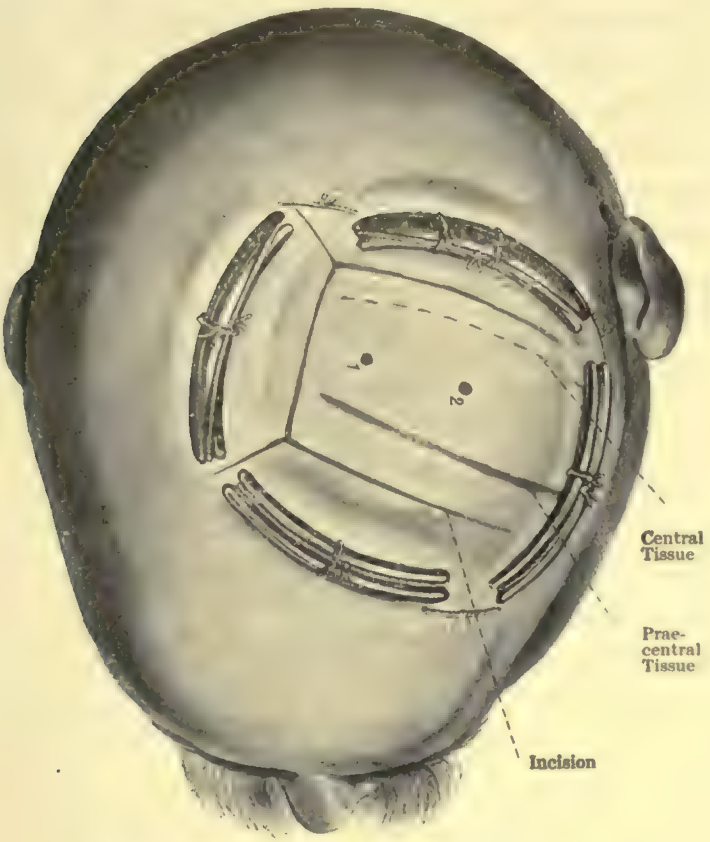


Fig. 2
Application of the *Kredel* Plates (Observation III, 4)
***Neisser's* Puncture Points. XD 1 Leg Center, 2 Arm Center**

long plates (Fig. 2), and in order to control the circulation at the corners I introduce small tension sutures or employ the short metal plates suggested by *Kredel*, as of use during removal of cavernous angiomas. These plates are from 2 cm. to 3 cm. in length.

The effectiveness of the *Kredel* plates varies; it is certain, however, that they are of great service in operations upon the skull in situations where there is not much muscular tissue. At times, even under these circumstances, the method will be found effective. In one of my cases of epilepsy the head presented a condition of marked cyanosis which ordinarily would have caused considerable hemorrhage from the wound; however, the application of the metal plates controlled very effectually the bleeding. The bleeding from the scalp was practically nil, and that from the bone very slight.

I have employed the measure unaer exceedingly unfavorable conditions. In a case of abscess of the frontal lobe I made a quadrilateral osteoplastic flap, the base of which was directed toward the left side of the forehead. The plates were applied above and to either side of the area. The lower side was not included, as there was not room enough above the eyebrow. Although the control of hemorrhage was not complete, it being necessary to deligate three spurting arteries, one of which was at the median side, it was evident that the procedure was considerably aided by employment of the measure.

In operating on the forehead I prefer the *Kredel* method for the reason that scarring is less than with the *Haidenhain* measure. In the case of a young lady, where I removed a traumatic cortical brain cyst, this was an important consideration. The skin-bone flap was so fashioned as to direct its base to the frontal eminence. The patient ultimately recovered with two barely perceptible linear scars, which were easily concealed beneath the hair.

I also employ the measure in extirpating the ganglion of *Gasser* and in exposure of the middle fossa of the skull for extirpation of tumors, applying a plate above and to either side. Control of the lower side is achieved by the introduction of the *Haidenhain* suture in a transverse direction immediately below the zygoma. In eight cases of extirpation of the ganglion the hemorrhage from the soft parts was exceedingly moderate after ligature in contiguity of a few small blood-vessels, and the bleeding from the bone very slight.

However, in a case of a man of 53, the measure failed entirely, and the bleeding was as severe as though the precautionary measure had not been employed. This may have been the result of uneven bone surfaces, upon which, of course, the plates are ineffective for obvious reasons. For this reason I like to employ a combination of the *Kredel* and *Haidenhain* methods, as the latter is susceptible of universal application and does not interfere with the breaking out of the bone flap.

I have had similar experiences in exposing the cerebellum. In this situation the *Kredel* method will rarely be found to control completely the bleeding. Of course, oozing from the divided muscles of the neck is controlled, but arteries, especially the occipital, will bleed quite actively. The latter contingency may at times be obviated by the introduction of a tension suture at the posterior edge of the sterno-mastoid muscle close to its insertion into the skull.

Formation of the Bone Flap

After the execution of one of the methods of control of bleeding described above, the soft parts are incised and the knife carried to the bone at once. The periosteum is loosened on the flap side of the incision with a raspatorium. Irrespective of what means of opening the skull is employed, the next step of the procedure is to make several drill openings which go down to the dura. For this purpose the instruments of *Doyen* are universally employed. The drill shown in Fig. 3 is attached to the so-called trephine brace, and a hole is drilled through the skull to the dura, which is then enlarged with the *Doyen* spherical burr (10–13 mm. in diameter, Fig. 4). As

Fig. 3
Nat. Size *Doyen* Drill

Fig. 4
Nat. Size *Doyen* Burrs

the burr is dull at its distal end injury to the dura is avoided.

When fashioning a right-angled flap I am accustomed to make a drill opening at each of the corners, *i. e.*, four openings; when making oblong flaps, as in exposure of the middle lobe, six openings; and when small flaps are employed, only two openings are made; also only two openings are employed in situations where the contemplated base of the bone flap comprises thin bone, as the bone is readily sectioned under these circumstances, such as the temporal region and in exposure of the cerebellum. In these instances the base of the flap is directed downward. Neither the drilling nor the division of the bone requires an electric motor. The bone is effectually sectioned with a

Dahlgren Forceps

In order not to inflict injury upon the dura it must be separated from the lamina vitra between the drill holes. For this purpose I employ the *Braatz* sound (Fig. 5), which comes in three degrees of curvature. With this instrument the dura is separated, together with sinus walls, so that the bone section can be made with ease and deliberation. I have frequently thus been able to section the bone across the transverse, sigmoid and confluent sinuses without injury to their walls. Manipulations about the longitudinal sinus call for the exercise of special care.

Fig. 5
Rigid *Braatz* Sound

The separation is accomplished by gentle pressure upon the dura and brain. The pressure is exercised upon a small area of dura at a time, and only in the immediate vicinity of the burr openings. Should the rigid *Braatz* sound (Fig. 6) be used, as advance is

Fig. 6
Elastic *Braatz* Sound

made the pliable sound should be employed for farther separation of the dura. In a large number of observations I have never seen unfavorable brain compression arise as the outcome of this method of action. The necessity for preliminary separation of the dura mater from the inner skull surface is the only disadvantage in the use of the *Dahlgren* forceps.

If the bone is hard and thick the prolongation affixed to the cutting forceps (Fig. 7) is a valuable aid. The cutting surface of the forceps is firmly pressed against the bone with the left hand upon the lever, and the bone is divided with the pressure of the right hand. In cases where the bone is inordinately thick it may be necessary for an assistant to make pressure upon the lever, and the operator use both hands to divide the bone; this contingency, however, is extremely rare. In any event the *Dahlgren* forceps has sufficed for my work during the last ten years, and only in one instance, in which the skull was 22 mm. in thickness, was it necessary to chisel out a shallow furrow before dividing the bone with the forceps. During this time the instrument broke only once and, indeed, this occurred in the first instance I employed it. A fact which was a serious disappointment to me. I place this method first in describing the operation because it is, indeed, a very good one, is simple, may be used upon all portions of the skull, and does not require electric motor apparatus. Of course, its usefulness depends somewhat upon the technique of employment. In any event the writer is able to work very rapidly with the *Dahlgren* forceps. In addition, it is easily sterilized, a valuable quality in a field where only boiled apparatus should be employed, and takes up very little room. In this connection I have a strong objection to the presence of the electrically driven reach-rod, despite the fact that it is encased in a sterile protector. For this reason I have had my raspatorium and other instruments made as short as possible so

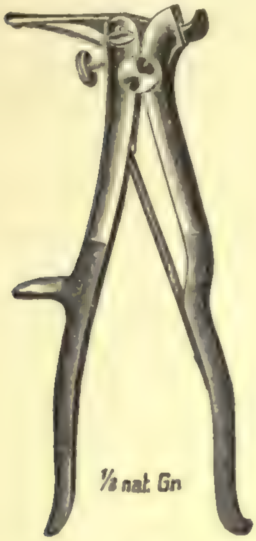


Fig. 7

Dahlgren **Cutting Forceps**
Krause **Model**

Fig. 8

Doyen **Chisel**

that the handles are enclosed by the hand to avoid extrinsic contact, which is likely to occur with the longer instruments.

Another advantage possessed by the *Dahlgren* forceps worthy of mention, and one not to be underestimated, is the fact that it is applicable to all thicknesses of cranium, a desirable quality when it is borne in mind how great the variations in this regard are even in restricted areas of the skull. Again, the instrument will section the cranium in either a straight or curved direction.

After the bone flap is sectioned it is lifted with wide levers, which are carefully inserted beneath the lamina vitra, seized with the *Langenbeck* forceps and turned down by fracturing it at its base. If the cranium is very thick or the base of the flap wide it is necessary to nick the contiguous drill holes with the chisel. Before doing this, however, the dura must be separated in this situation with the *Braatz* sounds in the same manner as described above. The nicking is best accomplished with the *Doyen* chisel (Fig. 8), which has a blunt probe pointed projection, rendering less likely injury to the dura. In this step of the operation, provided there be no severe hemorrhage from the meningeal arteries or veins of the dura, the *Gigli* wire saw is serviceable. In prying up a large bone flap it will be found that because of its elasticity the basal fracture is not readily produced. There is now, however, sufficient room to insert the *Gigli* saw, and slide it to the base of the flap. The levers lift the flap from the dura and protect it from injury while the base is divided from within outward by the saw. I have rarely found this step necessary. Indeed, I advise strongly against the use of the *Gigli* wire saw in opening the cranium. For in order to employ the wire it is necessary to place between the bone and the dura, from one drill opening to another, the *Braatz* sound, or similar instrument, to protect the latter from injury while sectioning the bone. This protection is absolutely essential, and is, as already stated, objectionable, for the presence of the sound or, as is preferred by some surgeons, the introduction of a clock spring causes undue pressure on the brain substance, which may be regarded as dangerous. The pressure may be minimized by making a number of drill openings at a distance of 2 cm. from each other; this, however, prolongs markedly the operation, an important consideration in trephining large areas. In these cases it is a fundamental principle to subject the dura and underlying brain to as little pressure as is possible. For this reason the gouge forceps, which are used to enlarge the opening in the bone, should accomplish the bending and breaking of bone fragments in an outward direction.

When the bone flap is turned down the periosteum is loosened from the edge of the opening for a distance of 1 cm. to facilitate its complete displacement. The incisions necessary to accomplish this should divert from the edge of the opening so as to give as wide as possible an avenue for the entrance of the circulating fluid. The loosening of the periosteum as described prevents the portion of periosteum covering the flap from being dislodged, which is exceedingly desirable, as the less disturbance of nutrition the flap is subjected to, the better. This contingency is prevented

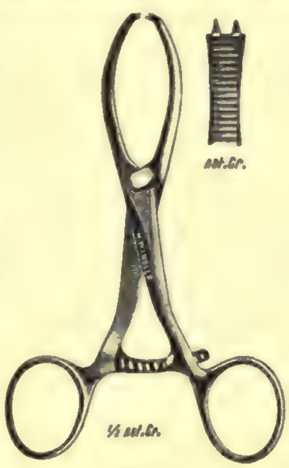


Fig. 9
Krause Claw Forceps

by the application to the bone flap of claw forceps (Fig. 9) in the middle and one at either side of its

Fig. 10.
Application of the Claw Forceps

base (Fig. 10), the latter being somewhat shorter than the former. This effectually prevents disturbance of the layers of the flap during the operation.

It is, however, not necessary to always direct the base of the flap downward. It will be seen by the illustration, and in the clinical histories, that for special reasons I have fashioned the base of the flap in various situations, including that of the sagittal suture, without causing any disturbance for this reason.

In many hospitals the

Electrically Driven Trephine Instruments

are largely employed. *Doyen* uses a circular saw protecting the dura from injury by means of a projecting shoe. He has applied the method to hemicraniectomy, denuding an entire cerebral hemisphere. The basal attachment of the flap is fashioned at the temporal region. This operation involves tremendous mutilation, one which can be but rarely justified. I have never seen a case of this sort. *E. v. Bergmann* used for the purpose a circular saw driven by an electric motor. In earlier years I, too, used this method very frequently, employing, however, a circular saw with an extended axle which permitted me to use both hands, so that I was able to hold the instrument very steadily despite the concussion transmitted from the motor. The circular saw must be very wide so as to enable the operator to scrutinize the groove in the bone as the saw is manipulated. It is my experience that the hemorrhage from bone and diploë is much more severe when the circular saw is used than obtains as the result of employment of the *Dahlgren* cutting forceps. This is no doubt due to the fact that the latter crushes the lamina externa and vitrea, which acts as a hemastatic. The great objection to the use of the circular saw is the likelihood of injuring the dura. In this regard the *Sudeck* spinal osteotome is much to be preferred, with which the sections are made, as the outcome of rapid rotations conveyed by the electric motor making rapid division of the bone feasible without danger of injury to the dura.

To obviate the objections to the circular saw *M. Borchardt*[1] submits a cylindrical burr (Plow burr) which is constructed to cut furrows in the bone of various depths, the latter being determined by the exploratory drill openings. The lamina externa and diploë only are divided. The instrument digs a groove from one drill hole to the other after the manner of a plow. The hemorrhage is slight, and as the instrument is pushed away from the operator the latter is not spattered with blood, as is the case when the circular saw is employed. The lamina vitra is ultimately divided with the chisel, or the *Sudeck* spiral osteotome may be used for the purpose.

Bleeding from the Emissaries and Diploe

The emissaries are the venous connections between the intracranial veins and the scalp.

In separating the periosteum from the bone it is possible to provoke sufficient bleeding from the emissaries to endanger life. This is most commonly observed in exposure of the posterior cranial fossa, and in the region of the mastoid process and the transverse sinus. More rarely does this obtain in

[1] *Zentralblatt für Chirurgie*, 1906, p. 1031.

areas situated over the convex surface of the cranium, though its occurrence is most likely in the region of the longitudinal sinus. From these openings, at times of the diameter of a goose quill, venous oozing occurs quite menacingly, or at times a brief spurt occurs which soon subsides into a steady flow. The venous bleeding from the divided diploë is rarely dangerous, and is readily controlled with gauze compresses. Occasionally the valveless veins of the diploë bleed severely.

For the control of bleeding we have several means at hand. Hemorrhage from the diploë is frequently arrested by a few blows with a *Passow* dull chisel (Fig. 11), of which I have three sizes on hand. The

Fig. 11
Passow Chisel

measure has the advantage that the operator is enabled to attack at once the same place and to arrest again the freshly provoked bleeding. More especially in working in spongy bone has the measure given satisfactory results in instances involving exacting operative procedure. The crushing of the lamina externa and interna with the cutting forceps has also effectually controlled bleeding from the diploë.

Fig. 12
Krause Bone Hooks for Arrest of Bleeding

In other situations I press the point of an elevator or introduce a bone hook (three sizes, Fig. 12) into the opening. These hooks were originally employed by the writer for the arrest of bleeding from the middle meningeal artery. The hook is introduced into the bleeding point and twisted back and forth several times. If the bone is of sufficient thickness and the lumen of the bleeding vessel not too large the hemorrhage is controlled by the measure. For the same purpose the driving in of ivory pegs is found effective. Several sizes of the pegs should be available. The peg is firmly driven into the bleeding opening and is cut off close to its margin and left *in situ*.

However, all of these measures may fail to accomplish the purpose if the cranial bones happen to be soft or thinned out as the result of prolonged increase of intracranial pressure. In these instances I plug the bleeding point with the corner of the selvage of a gauze bandage, and if this be not practicable I enlarge the opening with a *Doyen* drill or burr, push the gauze between the dura and bone, and tampon around and into the opening. Finger pressure maintained for several minutes will arrest the bleeding. Of course, if possible, the openings of the emissaries should be avoided in fashioning the flap.

The application of *Horsley's* wax to the bleeding bone after the periosteum has been removed, is stated to control the bleeding. The writer has had no experience with this preparation.

After it has once been an operator's experience to be confronted with disturbing bleeding from the emissaries, it is easy to understand how important avoidance of the openings is. In fact, it has on several occasions been possible to carefully separate the periosteum from the mastoid process and lift the emissaries from the bone, which permitted of ligature and peripheral division of the vessels. Also the emissaries may be avoided by making the incisions when feasible remote from the sinuses. When the bone flap is made it is permissible to still increase the size of the opening by removing an additional rim of bone, or to fashion a second smaller flap contiguous to the first. In all instances it is easier to deal with the bleeding when the dura is already exposed.

Temporary compression, or permanent ligature of both carotids, as is largely advised, especially by *Frazier*, I have never found necessary. The bleeding was controlled in all instances by the measures submitted.

Bleeding from the Dura

The **venous bleeding** resulting from separating the dura from the lamina vitra is in a general way of minor importance. It ceases spontaneously as soon as the *Braatz* sound is withdrawn and the dura and brain are permitted to come again in contact with the cranium. I have, however, several times met with profuse venous bleeding in performing the act in cases of brain tumor. If the occurrence accompany the first bone section there is nothing left to do other than to tampon the drill holes and one furrow with gauze to control immediately the bleeding and then to rapidly complete the other bone sections and leave the bleeding portion to the last. As soon as the bone flap is lifted tamponade or the encircling with ligatures of the bleeding points can be accomplished, and the bleeding arrested. In one of my cases the veins of the dura overlying the tumor were of the diameter of a lead pencil from which the hemorrhage was sufficiently profuse to endanger the life of the patient. The bleeding, however, was controlled in the manner stated (Observation III, 4) and the patient made a good ultimate recovery.

As these occurrences cannot be foreseen I make it a rule in opening the cranium after dividing the scalp and arrest of all bleeding, to make next the various drill openings. Bleeding from the drill holes is always controlled by the introduction of gauze packing. I then loosen the dura between the two drill holes corresponding to the flap base with the *Braatz* sound, and cut the bone at once in this situation with the *Dahlgren* forceps. Next, the same procedure is executed at either side of the flap, completing first one and then the other bone sections. That is, I never loosen more dura than is necessary for the imminent bone section. The sections in the neighborhood of a sinus, especially the longitudinal sinus, I generally execute last, as in this situation bleeding from the emissaries is likely to be profuse. At times the bleeding from torn Pacchionian bodies is a disturbing factor.

If the venous bleeding threatens the life of the patient, and is not controllable, the bone must be sacrificed. The skin and periosteum are rapidly denuded from the bone with the raspatorium, and the bone removed with the cutting forceps, beginning at the site of the drill holes. If the bleeding points are thus exposed the surgeon will be able to cope with the problem in accord with general surgical principles. In only one instance did I have to sacrifice the bone because of venous bleeding. The case was one of traumatic epilepsy in a man of thirty. Because of a localized point of tenderness and a bony depression at the point of union of the two central fissures as outlined by *Kroenlein*, it was necessary to fashion the bone flap over the longitudinal sinus. The attempt was accompanied by profuse bleeding from the anterior drill opening. A prolonged tamponade neither controlled nor lessened the bleeding. When the gauze was removed blood gushed forth in a portentous stream. For this reason the bone had to be sacrificed, revealing two holes in the longitudinal sinus corresponding to two emissaries. Gauze pressure arrested the bleeding, and the skin—periosteal flap was sewed back into place. At the end of four days the tampon was removed, and at the end of another six days the operation was completed. The patient made an uneventful recovery.

Arterial bleeding is, in my opinion, quite restricted to the areas supplied by the middle meningeal artery. This factor is most worthy of consideration in connection with exposure of the middle fossa of the cranium for extirpation of the ganglion of *Gasser*. I have frequently found the artery imbedded in a canal instead of a groove. As a general rule the bleeding from this vessel is without danger. On several occasions, however, in cases of arterial sclerosis, the bleeding was sufficiently alarming to warrant sacrifice of the bone flap in the way referred to above, in order to effect rapid encircling and ligature of the bleeding vessel.

It is a fortunate circumstance that I have not yet lost a case on the operating table from hemorrhage.

Trephining in Two Stages

The first act of the operation is completed with the fashioning of the cutaneo-osseous flap without opening of the dura. If the execution of the brain operation is to be enacted at a subsequent sitting the flap is replaced and retained *in situ* by means of deep sutures. Accurate apposition is essential in order to conserve asepsis and to prevent shrinkage of the flap. If bony union is to be avoided the bone sections must remove a rim of bone and periosteum at least 1 cm. in breadth, which is readily accomplished with either the *Dahlgren* forceps or the cutting bone forceps.

Brain operations are frequently extensive and dangerous to life. It is, therefore, wise to divide them into two stages, provided no unfavorable effect be the outcome. In abscess of the brain the operation is best completed at one sitting; however, in the majority of instances the best interests of the patient are conserved by an interval of from eight to ten days between the operation of approach and that of invasion of the brain substance.

In cases of epilepsy, in which relief is attempted years after the inception of the affliction, the operative attempt may with justice be divided into several stages. The establishment of generally applicable rules in this connection is not permissible. At times imminent collapse causes abandonment of the operative procedure after the trephining has been accomplished. It is in these instances a question of the judgment of the individual surgeon whether the operation should be continued or its completion postponed. On two occasions I have been influenced by the opinions of colleagues and completed the enucleation of brain tumors at one sitting (see Observation III, 3 and Observation III, 6) because the technique of approach had been accomplished with ease and with no apparent influence on the condition of the patient. In both cases a fatal outcome from collapse was the result.

During operations upon the brain I have frequently observed that the pulse and heart action were undisturbed, and suddenly the patient sank into profound collapse even though no considerable quantity of blood had been lost. In these cases a fatal outcome supervened despite the fact that the operative procedure was at once abandoned. The case related in Observation VI, 1, would most certainly have succumbed from collapse had the operation been completed at one sitting. Indeed, after achieving extirpation of the brain tumor at the second sitting the disturbance of the vital forces was so overwhelming, despite the fact that the enucleation of the brain tumor was rapidly accomplished, the life of the patient was for the day immediately succeeding the attempt, quite despaired of.

Division of the operation into two stages has also certain disadvantages. In one case (Observation

VII, 1) the cerebellar hemispheres were exposed in the first stage, and because of its great tension the dura was punctured over the right cerebellar hemisphere near the vermis, which resulted in discharge of 17 cm^3. of fluid. At the end of fourteen days the dura was opened. Puncture of the right hemisphere did not elicit any fluid; puncture of the left hemisphere resulted in discharge of about 3 cm^3. of fluid. Incision of the left hemisphere opened a cavity. Incision of the right hemisphere did not disclose the cyst punctured at the first sitting. Discharge of the contents of the cyst located in the right hemisphere undoubtedly obliterated the cavity demonstrated by the first puncture. The entire operation could undoubtedly have been completed at the first sitting had not an impending collapse prevented farther manipulations.

In a general way I have for years been a follower of *Victor Horsley*, and preferred the two-stage operation. However, I have in some instances extirpated brain tumors and exposed the cerebellar hemispheres —a grave procedure—at one sitting with favorable outcome.

It is to be noted that the simple opening of the cranial cavity does not so unfavorably influence the vital forces. In other portions of the body operations are performed which involve much graver mutilation and far greater loss of blood, without the occurrence of a similar degree of shock. In extensive opening of the cranial cavity the relationship of intracranial pressure is markedly disturbed, and this must result in modification of the function of the heart, respiration and blood pressure. It is only in this way that the sudden appearance of shock, which unfortunately is so frequently manifest during brain operations, can be accounted for.

V. Horsley irrigates constantly the operation field with a common salt solution at a temperature of 46° C., which he at times replaces with a solution of corrosive sublimate 1 in 10,000 at the same temperature with the view of controlling hemorrhage and obviating collapse. I am, however, too strong an advocate of dry asepsis to subscribe to this proposition.

If it has been necessary because of venous bleeding to tamponade the wound with gauze strips, these are removed no later than the fifth day, together with the sutures, so that a thoroughly aseptic field may be available for the second stage of the operation. For this reason all sutures are removed from wounds closed by sewing on the third or fourth day. The question as to how long a period of time should be allowed to elapse between the stages of the operation is not susceptible of a definite answer. Many factors are to be considered in arriving at a conclusion. Much depends upon the condition for the relief of which the trephining is undertaken and how well the first step of the operation has been borne by the patient. An interval of six days is as short a one as is in my opinion justifiable. If gentle wiping of the coagula from the edges of the bone sections provokes oozing, it is best to postpone the final stage of the operation. Under these circumstances it is best to wait from nine to fourteen days, for it will be found that even at the end of twenty-one days the old scar can be readily torn open with a dull instrument. At this time the wound cavity will be found filled with a firm clot adherent to the dura, which it may be necessary to remove with a sharp spoon.

On one occasion (see Observation IV, 1) I enucleated a tumor from the Island of *Reil* twenty-four hours after trephining, because of acute cerebral compression. The patient made a good recovery.

On the other hand, in the instances of two epileptic patients, both of whom were in feeble general condition, I allowed five-and-a-half and six weeks to elapse after the first trephining operation before invading the brain tissue. In the interval I sent the patients home to enable them to recover from the effects of the primary surgical manipulations. Under these conditions it is, of course, necessary to remove a strip of bone at the edges of the flap to prevent the occurrence of bony union. This prolonged interval is, however, not to be uniformly recommended. In the one case the scalp wound bled so profusely as to necessitate the introduction of the *Haidenhain* tension sutures. However, in both cases the lifting of the bone flap from the dura was easily accomplished without trauma to the latter. In the first case I found the lamina vitrea studded with small granulations, which also covered the dura, imparting to the latter a deep red hue; in marked contrast to the glistening white appearance of the normal membrane, found at the first operation. These torn granulations bled most profusely. In the other case no such phenomena presented, and the bone flap was raised without any bleeding whatever. In other regards the operations presented no especial difficulties.

Another disadvantage of the two-stage operation is the fact that the sinus walls are not as readily identified at the second sitting as obtains during the first. In order to avoid injury to the sinuses, during the second stage of the procedure, I mark the outline of the sinuses with a linen suture introduced into the dura at the first sitting. During the second operation separation of the layers of the flap is avoided by application of the claw forceps in the same manner as during the first stage.

Now follows

Opening of the Dura Mater

I have long ago abandoned crucial incision of the dura and formation of four flaps. This measure does not give sufficient room for inspection and manipulation of the brain. I incise the dura, fashioning a right-angled flap. Even in moderate compression of the brain it is impossible to pick up the dura with mouse-tooth thumb forceps, from the underlying brain. The membrane is carefully incised *in situ* with the knife, making an opening about 1 cm. in length, until the arachnoid is exposed and the flap incision is completed with a small scissors. The base of the dura flap is not necessarily directed downward, nor, indeed, is it always made to conform to the base of the bone flap. In working in the region of the longitudinal sinus it is best to direct the base of the dura flap toward the median line. It is then feasible to separate the flap quite to the edge of the sinus by careful stretching (see Observations III, 4 and VI, 1), thus avoiding injury to the sinus itself, and what is just as important, the many veins of the pia mater, which penetrate the dura in this situation, are avoided. A desirable attainment not accomplished when the dura is sectioned near the median line of the cranium.

Fashioning of the base of the dura flap in the direction opposite to that of the bone flap has additional advantages. If, as the result of profuse bleeding, the wound cannot be closed immediately after completion of the brain operation and provisional tamponade be necessary, hernia cerebri is very likely to occur. Especially is this liable to occur if the pia has been injured and the intracranial pressure be markedly increased. If the wound should be sufficiently clean to justify secondary suture the bone flap will be found of insufficient size to accomplish the purpose. The dura flap, extending, as it does, from the opposite direction, can well be utilized for the purpose despite the fact that this, too, will have undergone considerable shrinkage. (See Observation V, 1 and page 184.)

In operations within the area supplied by the middle meningeal artery this vessel should be encircled with a ligature passed with a round needle and deligated, to prevent unnecessary bleeding.

Injuries and Resection of Sinuses

At times the conditions require incision of the dura so close to a sinus that the operator should be prepared to cope with their injury. Especial care should be exercised in operating contiguous to the longitudinal sinus to avoid, if possible, trauma to the entering lacunæ, the walls of which are much thinner than that of the sinus itself, and which extend about 1 cm. to either side. Injury to the longitudinal sinus and its contiguous veins may be avoided by making the transverse dura section some distance from the sinus, and then to make two perpendicular short incisions toward the sinus, which permit of the raising of a secondary smaller flap, thus allowing of control of the bleeding as this is lifted from the brain.

A brief discussion of the two main sinuses is properly taken up at this time.

In most cases the **longitudinal sinus** deviates to the right of the median line, therefore the origin of the transverse sinus is atypical. At the sagittal suture the width of the longitudinal sinus, including its dural walls, averages between 6 mm. and 8 mm. At its central point, *i. e.*, midway between lambda (junction of sagittal and lambdoid sutures) and inion (external occipital protuberance), it becomes wider and immediately above the latter point is between 12 mm. and 15 mm. in width.

The course of the **transverse sinus** follows the linea semicircularis superior to its knee, the latter being located at the asterion, which corresponds to the junction of the parieto-mastoid and lambdoid sutures. It then continues as the sigmoid sinus to the middle third of the base of the mastoid process.

If the side of a sinus be injured, the solution of continuity is grasped with one or more *Pean* clamps and the opening closed with a continuous linen thread suture introduced by means of a round curved needle. This method may be satisfactorily employed in similar injuries to the larger veins of the dura, especially in the neighborhood of Pacchionian bodies and in situations where the larger veins of the pia open into the lumen of the sinuses.

Application of the method is illustrated as follows: The case, one of a ten-year-old girl (see Observation I, 12), was afflicted with *Jacksonian* epilepsy, which had its primary manifestation in the left foot. To reach the brain center animating the foot, it was necessary at the second stage of the operation to expose the upper edge of the cerebral hemisphere. In opening the dura the longitudinal sinus was torn. Immediate control of the bleeding was accomplished by forcible apposition of the edges of the superficial wound with the index finger and thumb. After exposing the operative field by sponging away the blood I applied a narrow *Pean* forceps. The tear in the sinus was a considerable one requiring longitudinal application of the clamp. No attempt was made to suture the hole in the sinus, indeed, I felt happy at the thought of having accomplished arrest of the bleeding in the manner stated. At the end of the operation the osteoplastic flap was replaced and sutured, except for the small area permitting of protrusion of the handles of the clamp. The clamp was left *in situ* for five days, at the expiration of which time the skin sutures were removed with the view of rapidly turning aside the flap in the event of return of the bleeding. The clamp was, however removed without recurrence of the bleeding, and the patient was discharged with the wound entirely healed at the end of thirty days.

Injury to the superior aspect of the longitudinal sinus is a common complication of depressed fracture of the skull in this situation. *Revenstorf*[1] advises in these cases the introduction through the dura upon either side of the rupture of sutures, which are tied together, encircling the wound like a purse string. If the sutures are carefully drawn together and the knot evenly tied the bleeding may be controlled without reducing materially the lumen of the sinus.

The extension of a pathological process, such as occurs with neoplasms, may call for

Resection of a Sinus.

If one of the larger sinuses (sigmoid, transverse, longitudinal and occipital) are to be divided, the bone must be removed so that the contour of the sinus is visible, and the sinus be easily approached on either side. It is, however, in my opinion, not at all times necessary to sacrifice the bone. As a rule it will be found feasible to lift the sinus, together with the dura, after an osteoplastic flap has been fashioned. I have frequently raised the sigmoid sinus from its bony bed in order to gain access to the posterior aspect of the petrous bone.

After exposing the sinus, the neighboring dura is divided in a perpendicular or transverse direction, according to its path, that is, to either side of the vessel. The introduction of the sound will determine the extent of the incision necessary. Catgut

[1] *Centralblatt für Chirurgie*, 1907, No. 38.

ligatures (linen thread or silk are too liable to cut through) are now introduced at the ends of the dura incision by means of an ordinary round or *Deschamp* needle and carried around the sinus. The ligatures include, with the longitudinal sinus, the falx cerebri, with the transverse sinus, the tentorium cerebelli and the falx cerebelli with the occipital sinus. (Fig. 14.) After introducing in a similar manner sutures several millimeters distal to the ones already placed, and firmly tying them, the sinus is divided between the ligatures.

After ligature of the transverse sinus a considerable portion of tentorium cerebelli may be removed posteriorly. However, the straight sinus must not be invaded. An analogous procedure may be applied to the falx cerebri. The longitudinal sinus presents especial difficulties in this connection, as the numerous veins of the pia covering the cerebral surface have to be deligated separately. In this way I have frequently excised portions of the enumerated processes of the dura on the living subject. The smaller sinuses, such as the spheno-parietal, which follows the course of the anterior branch of the middle meningeal artery parallel to the coronal suture on its way to the cavernous sinus and obtrudes into the operative field when opening the temporal region, double ligature and division is not difficult.

The

Opening of the Posterior Fossa of the Skull

deserves especial consideration.

As far as

Exposure of One Cerebellar Hemisphere

is concerned it makes an important difference whether the approach is made for cerebellar abscess or for enucleation of an accurately located tumor, or if the operation involve removal of a tumor at the junction of the pons and cerebellum. (Neuroma of the Acusticus.

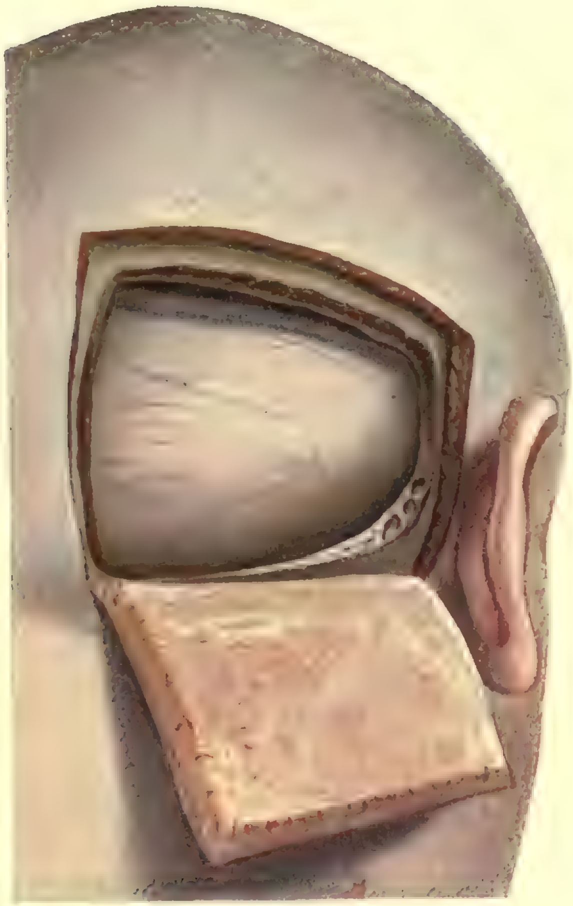
In the first instance a flap corresponding to the involved cerebellar hemisphere will suffice for the purpose. The upper incision is made along the superior linea semicircularis, from the external occipital protuberance to the posterior edge of the mastoid process. The two perpendicular incisions are made downward, one close to the external occipital ridge and the other begins slightly behind the mastoid process. The latter thus avoids the mastoid cells and the numerous emissaries which penetrate the bone. Only two drill openings are necessary, which are aimed directly at the transverse sinus or immediately above it, as the sinus most frequently is situated below the external occipital protuberance.

After completing the bone sections the osteoplastic flap is fractured at its base and turned downward. The line of fracture invariably occurs immediately above the foramen magnum, going through the thin plate of bone in this situation. The rim of bone attached to the thickened edge of the foramen is readily removed with the biting forceps. If necessary, the other edges of the bone should be enlarged until a comprehensive view of the transverse, sigmoid and occipital sinuses is obtained, the accomplishment of which I regard as essential. Frequently it has been necessary to invade the mastoid cells which are likely to extend far backward, and at times I have been compelled to remove some of them in order to obtain sufficient room for the purpose. Plate I shows the cells and the transverse and sigmoid sinuses. The dura is not yet opened. In this case (see Observation VII, 4) the bone has been removed. The dura is incised close to these blood channels, and is turned down in the form of a triangular flap with dependent base.

However, in order to

Expose the Posterior Surface of the Petrous Bone

as is necessary, for instance, for removal of a tumor of the acusticus, the opening in the bone must be of sufficient dimensions to permit of lateral displacement of the cerebellum without subjecting it to undue pressure. This requires inclusion in the flap of the crest of the occipital bone to permit of dislodgment of the falx cerebelli and occipital sinus, and exposure of the opposite cerebellar hemisphere to the extent of 1 to 2 cm. In decompression trephining this measure has the advantage of relieving to a considerable extent both of the hemispheres. Accordingly, the bone flap should extend for at least 1 cm. beyond the crista occipitalis, toward the healthy side. The upper horizontal bone section is made superior to the external occipital protuberance, avoiding the thick bone at this situation. Commonly



Rebman Company, New York.

two drill holes, more rarely three, are made immediately above the transverse sinus. The lateral incisions are carried deeply into the muscles of the neck, and the bone sections are made as far forward as possible. As division of the bone in the region of the mastoid process always provokes profuse bleeding, this section should be made last. The flap is then immediately turned down and the bleeding controlled. In practically all instances the posterior portion of the foramen magnum forms a part of the bone flap. (Fig. 13.)

I have on two occasions attempted to obviate the deep fracture of the bone by prolonging the median incision, by making a burr opening at the lower edge of the external occipital protuberance, and removed laterally in each direction sections of the bone with the *Dahlgren* forceps. With no avail, however, the fracture line extended in each instance into the foramen. It is true I have never seen any unfavorable outcome from this cause, as the fracture was always carefully executed to avoid disturbance of the medulla oblongata. The sinus marginalis which surrounds the posterior portion of the foramen I have never injured.

In order to accomplish complete turning downward of the flap it is necessary to loosen the periosteum to either side of the flap base and remove a small section of bone. The portion of the rim of the foramen magnum attached to the flap should also be removed. This latter step will contribute materially to the proper displacement of the flap. The perpendicular skin incisions are now extended downward, exposing thus the posterior surface of the atlas. Firm pressure on the subjacent soft parts will permit the operator to turn the osteoplastic flap well downward. To keep the flap well out of the way it may be fastened to the skin with a temporary suture.

Fig. 13
Arch of Atlas

(Plate III b.) The transverse sinus, together with the confluens, are visible above. To thoroughly expose the mastoid sinus the upper incision is extended, the periosteum and insertion of the sterno-mastoid muscle are loosened and the necessary portion of bone, to accomplish the purpose, removed with the biting forceps.

The dura of one cerebellar lobe and a portion of the dura of the other, together with the occipital sinus located between the hemispheres and the beginning of the spinal dura, are now visible. (Fig. 13.) If the procedure is now interrupted with the view of completing the operation at another sitting, the sinuses are marked with silk sutures. One is introduced immediately beneath the transverse sinus and another at the angle of junction of the transverse and mastoid sinuses. After ligature of visible blood-vessels the wound is closed with sutures deeply introduced into the muscles of the neck. After accurate approximation of the edges of the flap the *Kredel* plates and *Haidenhain* tension sutures are removed.

In completing the operation the dural flap is fashioned on the diseased side in the manner indicated above. The dural sections are made close to the three sinuses in order to gain as much space as possible. In most instances this method has sufficed to expose tumors of the acusticus. If, however, the cerebellum cannot be dislodged sufficiently, the dura is incised on the opposite side of the occipital sinus (Fig. 14). The curved *Braatz* sound is carefully passed around the falx cerebilli at a point about 1 cm. below the confluens, at the same time separating the hemispheres of the cerebellum from the falx with the middle and index fingers. A ligature is drawn in the opposite direction during removal of the sound which now encompasses the falx. The same step is repeated at a point 1 cm. lower down, the ligatures are firmly tied, and the occipital sinus, together with the falx, are cut between them. Several times I have had to deligate separately a small artery. The sinus

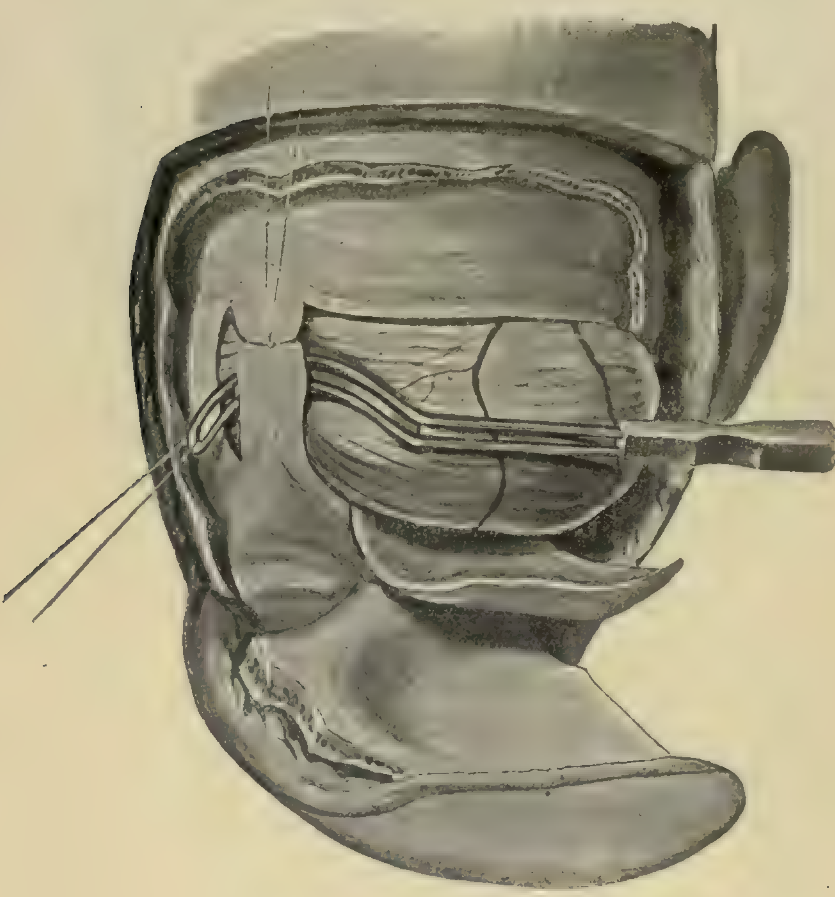


Fig. 14

has never bled after this procedure. Of all sinus ligaturing this is the easiest, as the sinus can, because of its narrow dimensions, be encircled with the blunt sound.

The severed sinus is drawn upward and downward by means of the ligatures (Plate III, Fig. b.), and no longer constitutes a disturbing factor. I find it expedient to fasten the upper portion of the divided dura to the skin with temporary sutures, and if necessary make two small perpendicular incisions which barely escape the transverse sinus, thus fashioning a small superior dural flap. (Plate III, Fig. a and Fig. 18.)

Exposure of both Cerebellar Hemispheres

In not a few cases it is quite impossible to be certain which cerebellar hemisphere is involved in the pathological process. It then becomes necessary to expose simultaneously both hemispheres, but the opening need not extend laterally to both mastoid processes. The opening may be made considerably smaller if the flap be fashioned as shown in Figs. 15 and 16. If the opening in the dura is found to be too small, the upper skin incision (Fig. 15) may be extended and sufficient bone removed for the purpose, or a smaller flap may be fashioned with its base directed laterally. Three drill holes are made above, the middle one of which involves the external occipital protuberance (Fig. 16). To separate this thick portion of the skull I use the largest burr. The bone puncture lies immediately above the confluens.

Of course, the exposure of both cerebellar hemispheres, especially that of the superior worm, require division of the falx and occipital sinus. The technique varies, however, inasmuch as the dura is incised immediately below the transverse sinus to either side of the occipital sinus as far as the lateral side of the flap, and two small incisions are made downward, skirting the occipital sinus. After completion of the technique of deligating the falx and sinus, as described on page 43, the dural covering

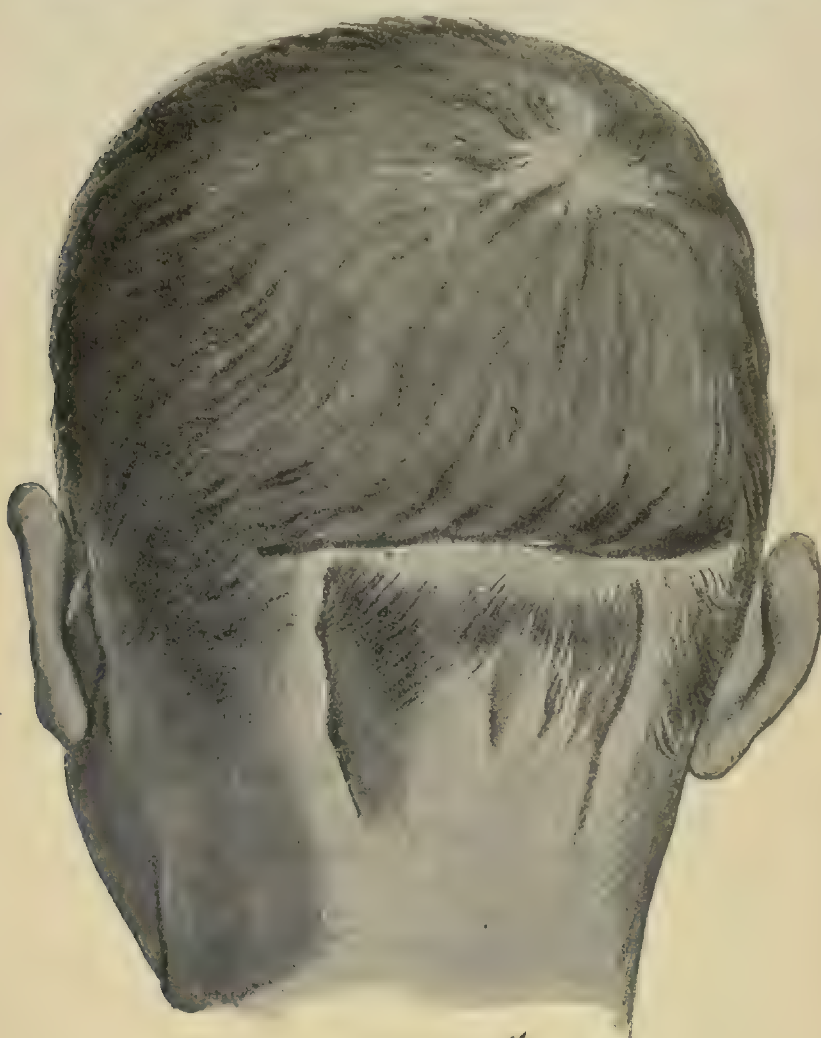


Fig. 15

of both hemispheres may be turned down as one flap, as soon as the lateral incisions near the sigmoid sinuses have been made.

When both cerebellar hemispheres are exposed it is unnecessary to tie and divide the transverse sinus and tentorium. In my opinion this step is unwarranted. Indeed, ligature of more than one transverse sinus would be followed by a fatal issue. It is much

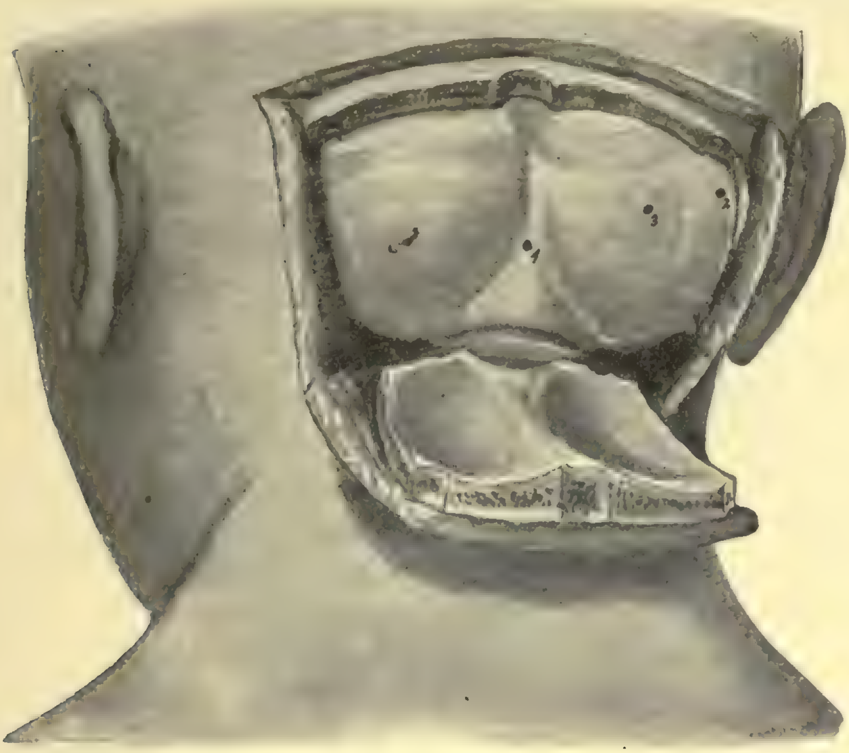


Fig. 16

more desirable to lift the intact tentorium with a brain spatula. The extent to which the deeper structures of the hemispheres are made accessible in this way is astonishing. During this step several veins which go from the superior worm to the rectus sinus and veins of *Galeni* are injured and bleed quite freely.

They are, however, readily deligated, or better still surrounded with a double ligature and divided.

Whether the exposure of both hemispheres is accomplished at one sitting or the final steps of the operation are postponed for three weeks, depends upon the condition of the patient and the indications for which the operation is undertaken. If the patient's condition will warrant it, the former procedure is the preferable one.

The

Upper Surface of the Cerebellum

is exposed for operative attack as the outcome of lifting the tentorium with the retractor. In cases where the neoplasm extends deeply along the superior surface of the cerebellum the hemispheres must be exposed in the manner just described, in order to achieve sufficient room for thorough inspection, and to employ measures of relief. (Fig. 17.)

A male patient, aged thirty-two, was sent to me by *H. Oppenheim* because of a suspected tumor of the cerebellum. The dominant symptoms of increasing cerebral pressure demanded immediate relief of intracranial pressure by means of drainage of the posterior horn of the lateral ventricle. (See **Subcutaneous Drainage of Cerebral Ventricles,** page 258), with the silver canula, together with decompression trephining over the cerebellum, without further investigation of the symptoms as to localization of the tumor.

The patient improved so rapidly after the employment of these measures that further attempts at relief were not made. Three weeks following the procedure related above, the patient collapsed suddenly while engaged in conversation with a visitor, and died in a few moments. Autopsy revealed a

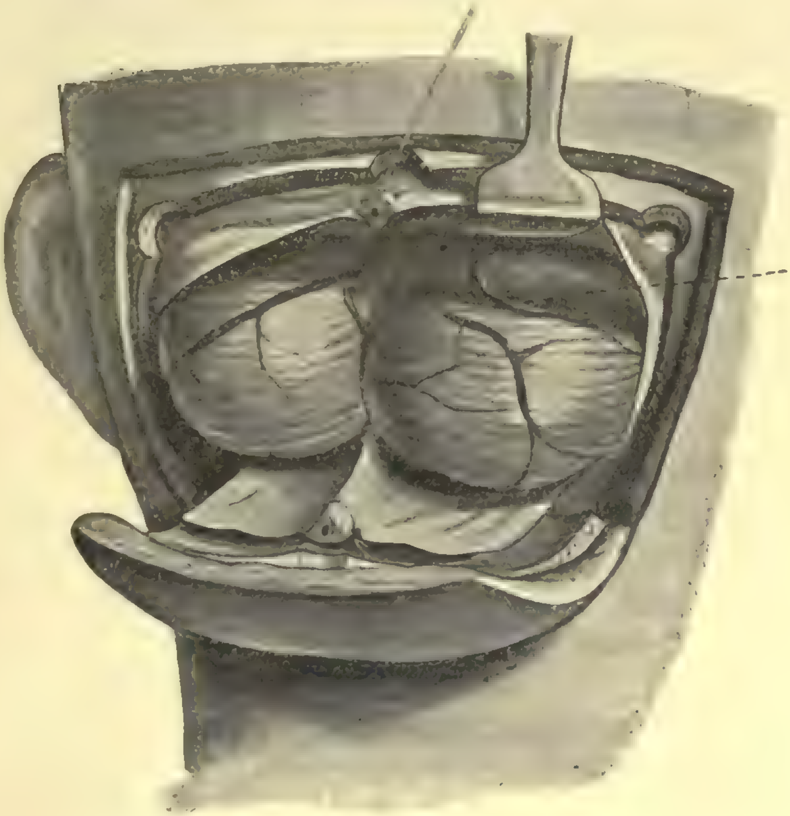


Fig. 17

tumor the size of a silver dollar situated at the upper surface of the right cerebellar hemisphere immediately below the tentorium. The tumor had raised the arachnoid about 1 cm. (Fig. 17), and would have been readily enucleated had the falx been divided. In consistence and color it resembled very closely the normal cerebellar tissue. However, the absence of striæ would have made its presence readily recognizable. Microscopical examination proved the tumor to be an endothelioma.

A portion of the upper surface of the cerebellum is made visible if, after exposure of one hemisphere, the cerebellum is drawn backward. This manipulation must, however, be carefully executed. In this way I have frequently exposed and inspected a surface of 45 mm. in width and 50 mm. deep, and, indeed, have been able to palpate the same area with the finger. (See **Inspection of all surfaces of the posterior cranial fossa and cerebellum,** page 130.)

Terrier[1] attempted to reach the cerebellar hemisphere by opening the temporal bone the size of a silver quarter of a dollar to reach the posterior edge of the occipital lobe, where it rests upon the tentorium cerebelli.

The intent was to lift the occipital lobe, expose thus the tentorium cerebelli, and after dividing it, reach the cerebellar hemisphere. The plan was analogous to that of *Volkmann*, who many years ago attacked the dome of the liver for echinococcus cyst by way of the healthy pleural cavity. *Volkmann* succeeded, *Terrier* did not, for when the dura of the occipital lobe was opened the cerebrum extruded from the opening and forestalled all further progress. A small opening destined to furnish approach to brain tumors is always ineffectual. The intra-

[1] V. Bergmann, "The Surgical Treatment of Cerebral Lesions." 3d edition, 1899, p. 368, et seq.

cranial pressure is of necessity much increased, and the protruding brain closes the opening and, indeed, not infrequently the cortex of the brain is torn on the edges of the opening in the dura and skull.

As the outcome of wide exposure of the posterior fossa of the skull, and by placing the patient in the sitting posture, the cerebellar hemispheres sink backward, so that the sides and, after raising of the organ, the inferior surfaces, together with the inferior vermis, are readily inspected. If the organ be slightly drawn outward the lobes are readily palpated, and exploratory section is easily accomplished, as will be extensively discussed in the chapter devoted to the Technique of Brain Surgery. (Page 149.)

General Considerations Regarding Brain Surgery

Leptomeningitis Chronica, Oedema of the Arachnoid

After the dural flap has been displaced the brain surface comes into view. The meshes of the arachnoid are in greater part removed with the dura, and, indeed, are not visible on the brain surface unless œdema or inflammatory exudate is present. Chronic leptomeningitis usually manifests itself in the form of several broad grayish stripes contiguous to the vessels. At times small white spots or thick yellow flakes are present, as shown in Plate II, Fig. a.

This illustration represents a case of *Jacksonian* epilepsy in a boy of twenty, and may be regarded as characteristic of œdema of the arachnoid. The cerebral cortex is barely visible, the vessels of the pia, especially the veins, shimmer dimly through the exudate as though obscured by a veil. However, the convolutions are still recognizable. If the exudate increases these, too, are obliterated as shown in Plate II, Fig. b. This case was one of *Jacksonian* epilepsy in a girl of twelve and a half years. (Observation I, 8.) The œdema of the arachnoid must be removed before the brain substance is invaded. This is accomplished by multiple puncture and if necessary scarification of the area with a sharp-pointed knife lightly introduced. The openings should be made at the most dependent part of the exposed sur-

Fig. a.

Fig. b.

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face, and the discharge of fluid may be enhanced by slight pressure with gauze. Presently the convolutions and fissures of the brain became defined. In making the punctures the blood vessels should be carefully avoided. Especially does this apply to the veins, for should one of them be opened a bloody infiltrate invades immediately the surrounding tissues, obscuring the field and rendering identification of the areas impossible. The operative field of the brain tissue is always covered by the pia mater. Separation of the latter from the underlying cortex is impracticable. The attempt to remove the pia always results in trauma to the cortex, and the interruption of the circulation gives rise to extensive disturbances of nutrition in the contiguous brain substance, a contingency which must be avoided.

In a considerable number of cases the dura will be found firmly adherent to the underlying tissues, and the incised dura will not permit of the formation of a flap. However, as in these instances the brain tissue underneath is always involved in the pathological process, this condition is taken up and discussed together with the technique of surgical manipulations of the brain itself.

Treatment of Cysts

Arachnoid Cysts

The treatment of arachnoid cysts is a simple matter. They are generally the outcome of **chronic inflammatory processes** or are the sequelæ of trauma. The former kind of cyst is shown in Plate

III, Fig. a, in a characteristic representation. The illustration depicts a patient twenty-five years of age. When the posterior cranial fossa, on the right side, was opened the dura was found to be much thickened as a result of chronic inflammation. (Observa-

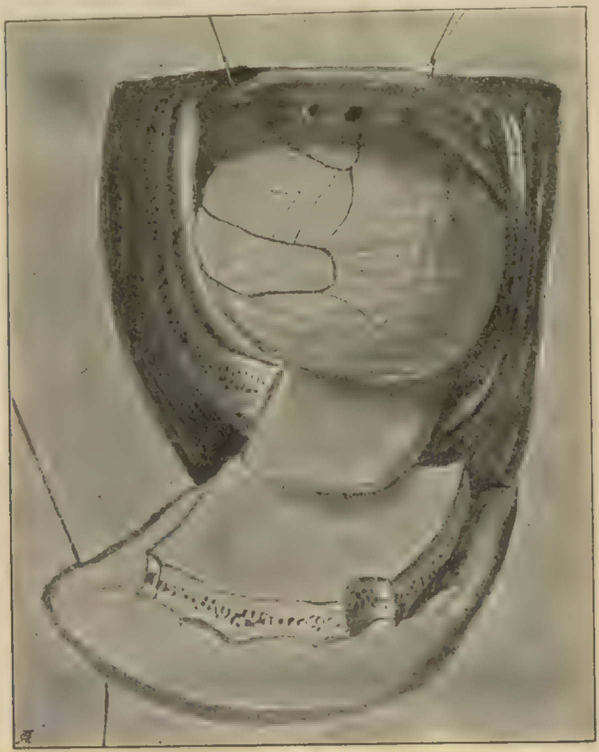

Fig. 18

tion VII, 2.) Turning down of the dura flap showed the thickening extending from the dura to the under surface of the tentorium (Fig. 18). The distended cyst did not become visible until the cerebellar hemisphere was displaced outward and was found to lie in contact with the inferior vermis. The cyst wall was quite thin and of a bluish violet color. The

Fig. a.

Fig. b.

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posterior wall of the cyst was incised and in greater part removed. The opening liberated a large quantity of clear fluid. The base of the space thus exposed was formed by the cerebellar hemisphere covered with pia mater. The latter was somewhat livid in appearance, but beyond this did not present any visible pathological alteration. The cyst wall was evidently formed by distended meshes of the arachnoid which had been agglutinated by a chronic inflammatory process, and become filled with fluid.

In this instance the wide opening of the cyst permitted of resection of its walls, thus obviating the probability of recurrence. The patient made a good immediate recovery, and examination at the end of a year and a half did not elicit any evidence of return of the affliction.

A similar form of inflammatory cyst is found at times in cases of epilepsy. In this disease a more or less extensive œdema of the arachnoid is not uncommon, and the accumulation of fluid may become sufficiently marked to constitute a cyst formation.

To escape repetition this condition is taken up in the chapter on epilepsy.

The **second form of arachnoid cyst** may be regarded as the outcome of **injury.** The elasticity of the cranium will permit of the causative trauma to the contents, and the skull immediately assume its normal outline without the occurrence of fracture, and, indeed, neither the X-ray nor an exploratory incision will demonstrate any lesion. The trauma may, however, contuse the membranes of the brain and the cortex, and give rise to hemorrhage, which ultimately develops into a cyst of the arachnoid.

A cyst of this kind was found while the writer was operating on a girl of twenty-five. The patient had been injured four years before by being struck on the right forehead by a wooden beam. The accident was the outcome of the explosion of a gas tank, and the force of impact sufficiently severe to render the patient unconscious for twenty-four hours. The evidence of cerebral concussion (headache, vomiting, loss of memory and vertigo) disappeared at the end of several months. However, at the end of three years the symptoms reappeared with the same severity. Examination revealed an exceedingly tender spot about 5 cm. above the supraorbital ridge. Neither a skiagram nor the operation revealed a fracture, nor was there any evidence of infarct demonstrable.

Trephining over the right frontal eminence showed the dura at a point corresponding to the superficial tenderness firmly adherent to the lamina vitra. Several yellowish deposits in the tissues of the dura were also to be seen. These evidently consisted of pigment from an old contusion. The dura did not pulsate, but was not markedly distended. Needle puncture released a considerable quantity of cerebrospinal fluid, the flow of which was readily arrested by gentle pressure. A dural flap was made and turned aside. Despite the fact that considerable fluid had been discharged, the arachnoid was still markedly œdematous over an area corresponding to the sight of the original trauma. The fluid had collected in the form of a cyst which originated from one of the fissures of the frontal lobe, in much the same manner as in the case just related. The treatment consisted in removal of the entire anterior arachnoid wall after the fluid had been removed, leaving the depression of the frontal lobe corresponding to the cyst area covered with pia mater.

To determine the possibility of the presence of brain cyst the needle was driven into the contiguous brain substance in several places to the depth of 4 cm. However, only normal brain substance was aspirated. The condition was undoubtedly the outcome of the injury of four years before, when the brain was no doubt contused. Had the process been located over the motor cortical zone a *Jacksonian* epilepsy would most probably have been the result; being, however, located over the frontal lobe only the general symptomatology stated above occurred. The dural flap was replaced and held in apposition with two sutures introduced at each corner, and amply covered the depression in the brain. The osteoplastic flap was accurately sutured and primary union of the wound obtained.

Ecchinococcus cysts occur also in the arachnoid. They are, however, extensively taken up in the next chapter.

Cysts of the Brain

Cysts involving the brain by extension or developing in the brain substance itself are of several kinds. The most important causative factors relate, as in the arachnoid, to trauma and chronic inflammatory processes. The products of encephalitis, if not absorbed, may exist to a sufficient extent to closely simulate neoplasma. Occasionally puncture and aspiration of a focus of this sort not alone clears up the diagnosis, but may cause absorption of the exudate and result in relief.

I have frequently found both cortical and subcortical meningo-cephalic cysts in cases of infantile paralysis while operating for co-existing epilepsy. As these conditions form an important etiological factor discussion of this form of cyst is taken up under a separate head. Neoplasms, especially sarcomata, have at times a tendency to undergo cystic degeneration, and occasionally form large solitary cysts. In some instances neoplasms are surrounded by cavities which are filled with a bloody fluid. More rarely parasitic cysts, such as the hydatid, are found in the brain, and again in a certain number of cases the origin of cysts is not discoverable.

The treatment of brain cysts depends upon the nature of the cyst wall and their etiology, and are therefore taken up under separate heads.

Brain Cysts with Connective Tissue Walls

In all forms of cysts healing eventuates if the contents be removed, and re-accumulation is prevented. This means, of course, that simple aspiration will not accomplish the purpose, as the walls of the cavity are much thickened as the outcome of prolonged distention with fluid, and do not collapse when the contents are withdrawn. The most certain method of treatment is to freely incise the cyst and to drain or tampon, thus provoking collapse of the walls and obliteration by granulation. The technique of the procedure is shown in the following case: On October 19th, 1907, I trephined for epilepsy a boy of seventeen (Observation II, 6), exposing the left sensomotor region. The brain did not present any alterations nor was there any indication of deep-seated lesion. January 16th, 1908, a sudden and rapidly increasing cerebral compression necessitated re-exposure of the left central region. Incision at the upper portion of the old flap exposed at once the brain substance, as the dura had retracted at this point; however, at the sides the dura was intact. The osteoplastic flap was raised from the dura with the finger and raspatorium without further injury to this membrane. The brain extruded from the incision at the upper edge of the exposed area to the extent of a thumb's breadth. The distended dura bulged about 1 cm. above the edges of the trephine opening. Beyond several yellowish spots, evidently hemorrhagic areas, the result of the first operation, the dura did not present any abnormality.

As the dura gave manifest evidence of fluctuation, the aspirator needle was introduced and a transparent amber-colored fluid made its appearance flowing in a rather forcible stream. The fluid was preserved for examination. With the needle left *in situ* as a guide I opened a cyst with an incision about 3 cm. in length, dividing longitudinally the cortex of the brain. The bleeding was inconsiderable and did not call for special measures of hemastasis. The cyst was of enormous size, and extended from the central region forward and inward to the depth of 72 mm. The first 100 cm.³ of the fluid remained clear, the remaining 100 cm.³ of fluid, which were removed with a spoon, was of cloudy serous appearance. The outer part of the cyst was lined with a thin membrane, which was removed by blunt dissection. Beneath this membrane the brain presented yellowish spots which looked as though they were areas of old hemorrhagic infiltration.

Parasitic origin of the cyst was excluded on the ground that single ecchinococcus cyst never attains the dimensions manifest in this case, and microscopical examination did not reveal the characteristic hooklets. In this case complete excision of the cyst wall was impossible. The microscopical and chemical examinations substantiated the conclusion arrived at, at the operation, that the cyst was a simple one, the walls of which consisted of connective tissue. The inner walls presented a velvety surface and were brownish red in color. After careful drying of the cavity with gauze it was loosely filled with vioform gauze (5 cm. wide) of which 5 m. were required for the purpose despite the fact that the cyst wall had considerably shrunken as the outcome of release of the fluid contents.

To make smaller the cyst opening and to facilitate after treatment I fastened the edge of the incision in the cavity to the skin at the anterior portion of the superficial wound and removed a corresponding area of bone with the biting forceps of the size of a silver quarter of a dollar. The rest of the flap was held in place with approximation sutures in the usual manner. The vioform gauze tampon was led out of this opening, and an additional smaller gauze drain inserted.

On January 20th the gauze tampon was removed and replaced by a drain, the length of the index finger. No secretion was discharged at this time. At subsequent dressings, made every four or five days, a small quantity of yellowish white discharge occurred which had accumulated to the level of the drain. At each dressing the drains were shortened about 1 cm. The shorter one was removed on February 1st, the longer one on February 18th. Four days later the wound closed, and the following day the patient left the bed.

All cysts the walls of which consist of connective tissue or altered brain substance should be treated in the manner just described. However, drainage is not always easily accomplished, as the cyst may be deeply located in the brain, especially when present in the cerebrum. However, in all instances, the cyst should be punctured and an effort made to keep it empty, so that collapse and healing by granulation may take place. Frequently, the manifestation of dangerous symptoms force an effort in this direction. An example of what may be attained under exceedingly unfavorable anatomic conditions is as follows. (Observation IV, 2.) A five-year-old girl gave a history of previous discharge of pus from the right ear. The drum showed evidence of old disease. The right side of the skull and especially the regions over the squamous plate and mastoid process of the temporal bone were exceedingly tender. Exposure of the mastoid cells showed them to be healthy.

The skull was opened above the mastoid process with the biting forceps and chisel, sacrificing the bone. The dura was distended and did not pulsate. The first three punctures into the temporal and occipital lobes were negative of result. The fourth directed forward and upward after reaching the depth of 65 mm. resulted in the discharge of 10 cm.³ of reddish yellow fluid. The fluid coagulated in a few moments, showing it to be the contents of a cyst and not from the ventricle. The deep location of the cyst permitted only of drainage by passing the knife along the puncture needle into the cavity. The canal was held open with two small retractors and a drainage tube inserted. The rest of the wound was tamponed with vioform gauze. The drain was gradually shortened and entirely removed at the end of fourteen days. At first a considerable discharge of fluid was maintained, but this ceased entirely at the end of six weeks. Four months later the entire wound was scarred over. The severe symptoms which had existed for two years (see clinical history) gradually subsided and the child made a complete recovery.

Traumatic Brain Cysts

Cysts caused by trauma result from infiltration of blood and disintegrated brain substance, or a combination of both of these factors. In either instance absorption has not taken place. Hemorrhage is much more frequent in the cerebrum than in the cerebellum, and consequently cysts are more rarely developed in the latter.

The method of operative technique is illustrated in the following case, which, however, possess value for other reasons. The patient, a girl of twenty-three (Observation VII, 1), had developed two cerebellar cysts, one in either hemisphere. As the process could not be located definitely in one lobe I exposed both posterior fossæ on January 15th, 1907. The dura bulged over both lobes, slightly more on the right side than on the left, and did not pulsate. The two occipital lobes, palpable immediately above the transverse sinus, were manifestly softer to the touch than the cerebellar lobes. The dura was punctured in several places. The first at the point of greatest indentation between the two hemispheres and the medulla oblongata. (Fig. 19, 1.) When the point of the needle reached a depth of 13 mm. (the center of the lumen exactly 9 mm.) a clear yellowish fluid appeared of which 17 $cm.^3$ was aspirated. Fluid continued to flow from the puncture hole after the needle was withdrawn. The fluid coagulated as soon as it cooled. The chemical examination (*Doctor Eichler*) showed that the fluid contained a large quantity of albumin and a considerable amount of nucleoalbumin. Ventricular fluid contains very little albumin and does not give the nucleoalbumin reaction. No sugar was found in the fluid while the chloride reaction was marked. This justified the conclusion that the fluid came from a cyst. Punctures 2 and 3 (Fig. 19), did not bring forth any fluid.

After emptying of the cyst the dura over the right lobe showed pulsation and collapsed so markedly as to become wrinkled. With each respiration it flapped like a loose sail in the wind. The dura over the left lobe, however, pulsated but feebly and remained quite tense. At this time the patient's pulse became

Fig. 19
Arch of Atlas

alarmingly feeble and the operation was halted. The osteoplastic flap was sutured back into place.

The symptoms did not improve after the collapse from the operation had been overcome, as the outcome of the puncture, indeed they increased in severity. Fourteen days later, on January 29th, both cerebellar hemispheres were exposed together with division of the occipital sinus, as described on page 43 *et seq.* (Plate III, Fig. C.) Puncture to the depth of 2 cm. of the left lobe of the cerebellum withdrew the same kin l of clear yellowish fluid previously obtained from the right lobe. Puncture of the right lobe made at this sitting gave a negative result. The fluid coagulated at once. With the needle left *in situ* a transverse incision several centimeters in length and 2½ cm. in depth was made, opening a cavity the walls of which gave no evidence of pathological changes to the naked eye. No connective tissue nor cyst sac was present. The cavity was filled with vioform gauze (page 164.)

The right cerebellar lobe showed at its lower median aspect, between the puncture sights of the first operation, a whitish thickening of the arachnoid. After double ligature and division of a large vein an incision 3 cm. in depth was made between puncture holes 1 and 3. The latter were readily recognized by the presence of small adherent clots corresponding to the places of the original puncture holes. The incision exposed a cyst cavity which was quite empty as the result of the first aspiration, and the walls of which were similar to those of the cyst on the left side.

The wound was closed by suturing except for the two lower angles where the gauze tampons and an additional drain emerged. Two days later a portion of the tampon was withdrawn, at which time a moderate amount of clear fluid was discharged. Three days later all drains, tampons and sutures were removed. No fluid appeared at this sitting.

On the eleventh day bleeding from the cyst cavity in the left cerebellar lobe made it necessary to reopen the wound. The subject of secondary hemorrhage is taken up in the chapter devoted especially to this occurrence. The patient recovered without further unfavorable manifestations.

Parasitic Cysts

Parasitic cysts are best treated by removal of the cyst wall, and this should be accomplished if at all possible. The technique is illustrated by the following case. A laborer, thirty-one years of age, came under observation for a tumor which had been diagnosticated as situated in the right central region. An acute cerebral compression had suddenly developed and was sufficiently severe to render the patient quite comatose. Indeed, the coma was so profound as to make the use of only a small quantity of chloroform necessary.

The region of the fissure of *Rolando* was exposed by osteoplastic resection of the skull. The dura was tense and did not pulsate. It was intended to open the dura with a crucial incision. The first perpendicular incision of the dura punctured a cyst cavity which promptly collapsed as the contents were discharged. The dura pulsated at once after the fluid had escaped, which occurred in a rather forcible stream. A second incision into the dura, made crosswise, formed four flaps which were reflected, and the cyst wall was now incised in a perpendicular direction, enlarging the puncture made while incising the dura in the first instance. The cyst cavity was about the size of a plum, and was situated in the anterior central convolution, in the hand center. The cortex was at the thinnest portion covering the cyst about 1½ to 2 mm. in diameter. The cyst was lined with a thin whitish gray membrane, which was enucleated in toto without difficulty.

The distal portion of the cyst wall seemed to consist of normal brain tissue which bulged into the cavity made vacant by enucleation of the cyst. This was punctured with the result that fluid of the same character as was discharged at the first puncture squirted forth. Perpendicular incision of this wall disclosed the presence of a second larger cyst, which was lined with a smooth membrane and extended about 6 cm. forward, downward and inward. Judging from its direction it might have been regarded as a distended lateral ventricle; however, the lining membrane proved it to be a parasitic cyst. The membrane was removed in two sections. A drain was inserted into the deeper cavity and both cavities loosely packed with gauze. The brain collapsed to a considerable extent after the cysts were opened, permitting of apposition of the dura. The space between the osteoplastic flap and the dura was about the size of a child's fist. This was also loosely packed with iodoform gauze. The patient withstood very well the operation, which required an hour and a half.

The microscopical examination showed the cyst to be a multiple hydatid. Indeed, the patient ultimately died from the occurrence of multiple hydatid cyst in the basal ganglia of the brain (Observation II, 7).

Hydatid cysts rarely reach the size found in this case and can, therefore, usually be removed provided they be located in an accessible portion of the brain. However, with ecchinococcus cyst, even when situated in the convex portion of the cerebrum, the involve-

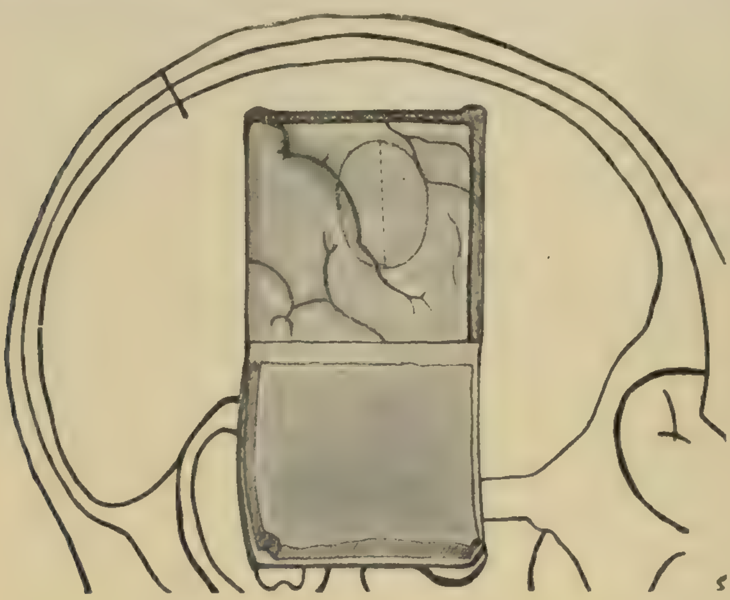

Fig. 20

Cysticeruscyst of the Anterior Central Convolution, opened by Vertical Incision

Details in text

The Dural flaps formed by the cross incisions are not shown to enhance clearness. (Half schematic)

ment of brain tissue may be so extensive as to preclude removal. In these instances it is only possible to incise and tampon the cavity. The incision in the cyst should be made as in the case described on page 59, so as to isolate its cavity from the rest of the wound, thus permitting of subsequent irrigation with largely diluted *Lugol* solution.

Fig. a.

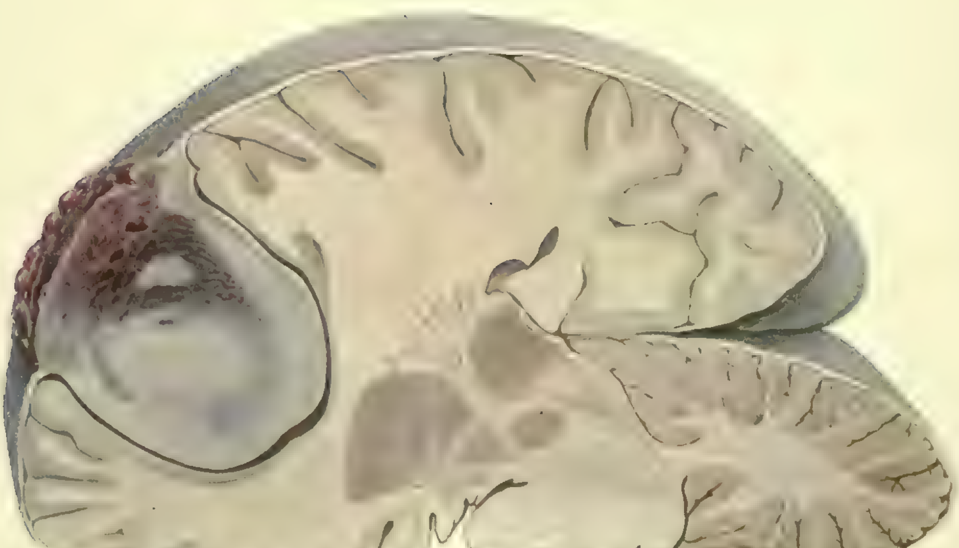

Fig. b.

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Cysts with Tumors

In a subsequent chapter discussion will be entered into of the enucleation of a subcortical gliosarcoma situated in the white matter beneath the motor area which was complicated by the presence of a hemorrhagic cyst. This kind of cysts, which are the outcome of bleeding and cerebral softening, rarely reach great size and may be regarded as incidental to the tumor formation and of secondary importance.

On the other hand cystic degeneration of solitary neoplasms of the cerebellum are not uncommon, and the observer would be apt to regard the process as simple serous cysts did not the microscope demonstrate this conclusion as fallacious. *Williamson*[1] first called attention to this fact, and the possibility of error in this regard is to be especially borne in mind when making exploratory puncture.

In many instances nodules composed of new tissue have been found in the walls of the cysts and on other occasions cystic degeneration has been located in the interior of neoplasms. The preparation depicted on Plate IV., Fig. a, taken from a seven-year-old girl, shows how a sarcoma or glioma may undergo extensive cystic degeneration. In this instance the process is multilocular in character.

In all cases in which neoplasms have undergone cystic degeneration the entire new formation, together with the contiguous brain tissue, must be removed. A more comprehensive discussion of this problem follows in subsequent sections of this work.

[1] Serous Cysts in the Cerebellum. *The International Journal of Medical Sciences*, 1892.

Mention is here made of cysts of the cerebellum which are the outcome of dilatation of the fourth ventricle. In these cases a communication exists between the ventricle and the sacculated cavity representing the cyst. The sacculation is at first only slight, increases, however, gradually until the dilatation extends from the vermis into the lateral lobes. *Virchow* reports a case of this sort in his "Pathological Growths," 1863, and *Clarus* reports another in his "Inaugural Dissertation on Cysts of the Cerebellum," Würzburg, 1874. Dermoid cysts have occasionally been observed in the cerebellum.

To summarize the treatment of cysts, if they be not the outcome of degenerative process in neoplasms, the cyst wall should be excised, if possible, when dealing with parasitic cysts. If this be impossible the cavity should be opened sufficiently wide to permit of loose tamponade, and eventually irrigated with iodine solution. The same procedure is advised with regard to cysts with connective tissue walls, while in the case of simple cysts without a sac a short tamponade and drainage will be all that is necessary to achieve obliteration.

Tumors

Those Emanating from the Brain Membranes and Involving the Brain Substance by Extension

In presenting the subject it seems to me most desirable that the various steps of the procedure be described in the sequence as the contingencies occur upon the operating table. Of course, lesions which are associated with each other cannot be separately considered if they are the outcome of complications dependent upon the same cause, though they may be situated in different parts or at different levels of the brain substance.

However, this chapter cannot be restricted to the simple technique of operative procedure. Frequently the method of operating is determined by the pathological findings disclosed during the operation, and for this reason I will *per force* enter into a consideration of the problem from this view-point. I will also take up a few afflictions which do not originate in the brain, but involve it by extension, yet are not of sufficient surgical import to warrant consideration in a separate chapter, as for instance, tuberculosis of cranial bones which is taken up in this chapter.

Tumors which originate from the inner table of the cranium, the dura mater, arachnoid and pia mater are, as a general rule, benign in character, and are most frequently fibromata or fibrosarcomata.

However, they do grow into the central organ and at times give rise to all the symptoms of intracranial pressure. They push the brain before them and form a cavity or depression, the floor of which consists of a much thinned out layer of cortical substance, while the tumor itself is, in the vast majority of instances, covered by a distinct capsule. At times, a narrow interval exists between the invading tumor and the brain, as clearly shown in Plate IV, Fig. b. This specimen was taken from a bartender, aged forty-one. (Observation II, 3.)

The outer layer of the dura may, as the result of the increasing growth of the tumor (which in most instances takes place toward the brain), be involved as the outcome of chronic inflammation due to irritation from the tumor. This was shown in the case just mentioned at the autopsy. The extent of the process manifesting itself, before the dura was opened, by the wart-like elevation of the membrane and its dark color. (Plate IV, b.)

As the dura is really the inner periosteum of the cranium it is easy to understand how chronic inflammation of this membrane gives rise to the growth of new bone. For this reason the same patient shows the bone immediately overlying the tumor thickened to the diameter of 21 mm. (Fig. 21.) In addition, the patient presented an elevation above the frontal eminence corresponding to the tumor, the size of a goose egg, which was covered with normal skin save that the latter was considerably thinned out over the dome of the mass. This case is one of a rare instance in which a brain tumor enclosed in a proper capsule made its appearance externally. (Fig. 22.)

It is to be regretted that the patient did not come

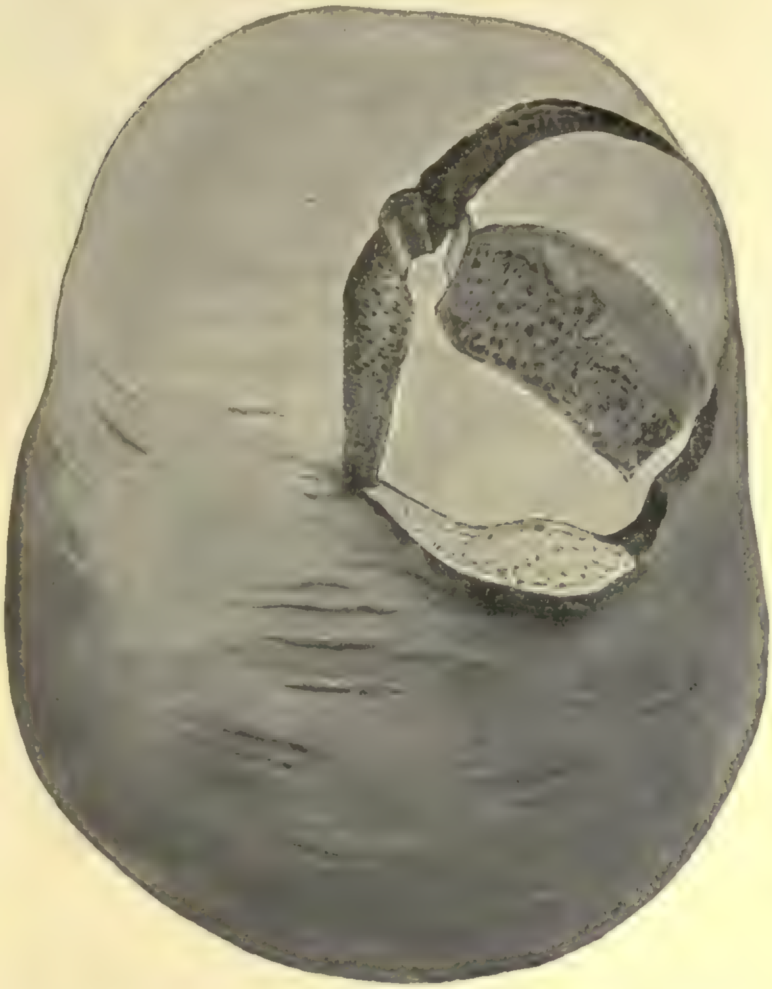

Fig. 21

under observation at an earlier stage of the disease. He had been seriously ill for five years and died of double pneumonia four days after being operated upon. At the autopsy the dura was incised and turned over the brain in the usual manner. The tumor, which was the size of a mandarin (6.6.5 cm.) was so firmly adherent to the dura that it was lifted from its bed in the right frontal lobe without further effort. It was not adherent to the brain,

Fig. 22

and could just as readily have been removed during life. The remaining cavity was as smooth as the acetabulum and lined with pia mater and a thin layer of cortical brain substance. (Plate IV, b.) Besides the displacement of the cortex the white substance was pushed downward, not sufficiently, how-

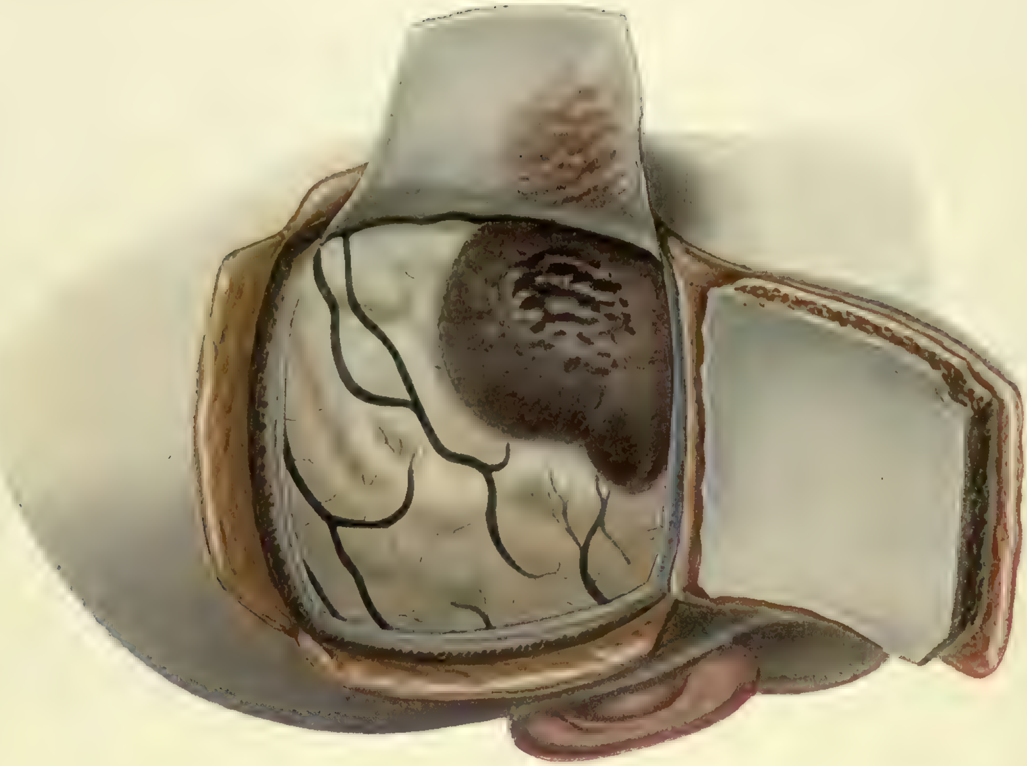

Fig. b.

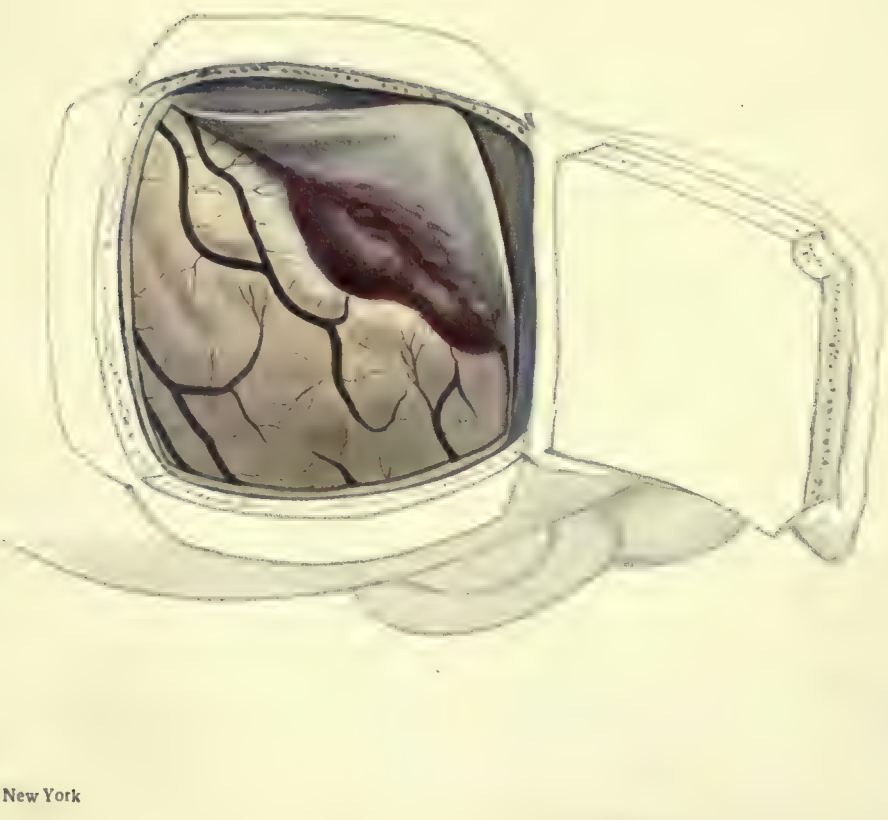

Fig. a.

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ever, to cause any deformation of the anterior horn of the lateral ventricle.

Visible alteration of the dura does not frequently occur in this class of cases. After exposing the dura palpation will demonstrate the presence of hardening, as shown in a case subsequently to be related. This may, of course, not be particularly marked, being dependent upon whether the growth has a broad base or is attached to the dura by a narrow pedicle.

Only in rare instances may tumors be removed with simple traction upon the dura, as obtained in the case just quoted. They are always firmly adherent to the dura. However, the formation of a dural flap will not permit of immediate delivery of the tumor from its bed. In order to obtain a view of the extent of the process and the surface of the brain, the mass should be enucleated together with the dura with the knife, scissors or by blunt dissection. Fragments of the tumor are very apt to be left behind in this way. The method is readily understood by a study of Plate V, which illustrates how much more advantageous it is to make a single flap than to open the dura by a crucial incision and the formation of four smaller flaps. In the case of a merchant (thirty-five years of age; Observation VI, 1), the usual symptoms of cerebral compression were accompanied by pain in the posterior portion of the head and neck, right hemianopsia, hyperæsthesia, ataxia and partial paralysis of the right side of the body. *H. Oppenheim* diagnosticated a neoplasm in the left occipital lobe.

On June 9th, 1906, I exposed the brain by means of an osteoplastic flap, making the dural flap with its base toward the longitudinal sinus (as I anticipated working in this region) in order to avoid the large veins of the pia, which are located in the immediate vicinity of the sinus. The dura was incised, beginning at the left upper angle of the wound, and the incision carried horizontally to the longitudinal sinus. A similar horizontal incision was made at the lower aspect of the opening in the skull and these two joined near the transverse sinus by a perpendicular incision. The dural flap was then turned up over the median line exposing the normal occipital lobe, and at the same time bringing the tumor into view. The neoplasm was readily differentiated from the surrounding brain tissue by its flesh-colored appearance. The dura was separated from the tumor by blunt dissection with the finger.

Cortical, encapsulated tumors may be removed with the finger in this manner in certain portions of the brain when the increased intracranial pressure and trauma consequent to the manipulation is not too great. However, the enucleation must be accomplished in all portions of the brain with great care, and progress is to be made under the guidance of preliminary palpation. This was done in our case. After detaching the dural flap I found that the tumor not only reached the median line but also extended inward toward the cuneus and downward in the brain substance. To find the extent of involvement in this direction I drew the falx cerebri carefully toward the right side with a flat tractor; however, the tumor extended beyond the area thus exposed. As

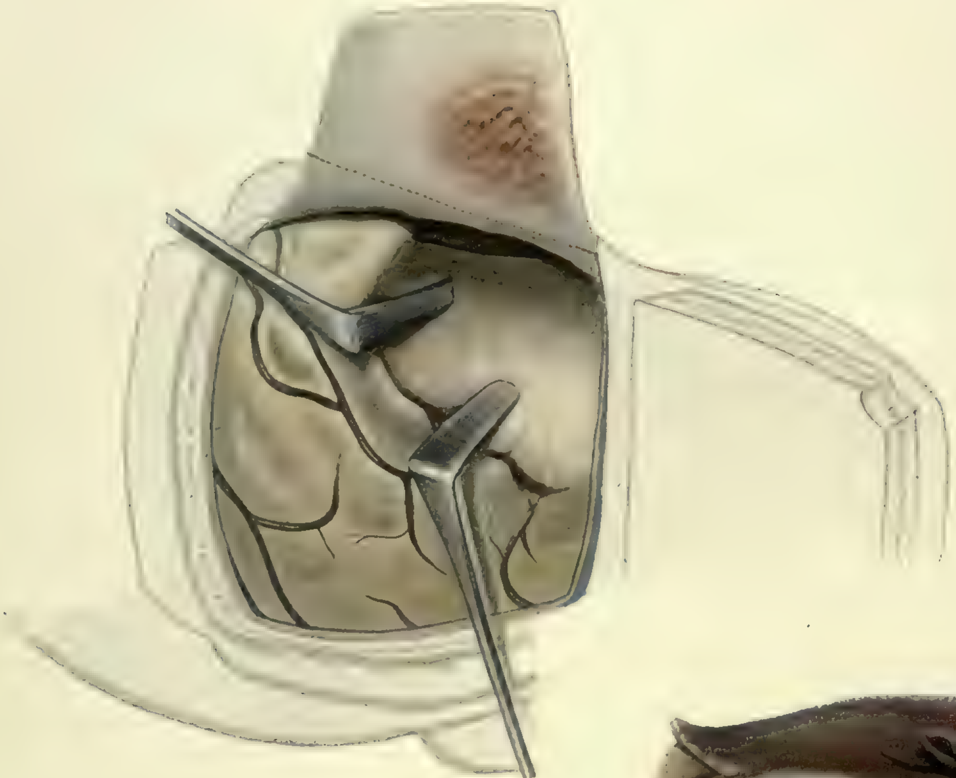

Fig. c.

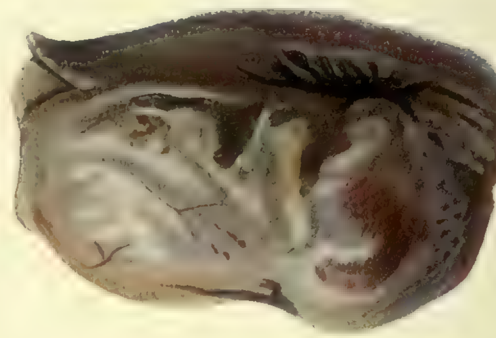

Fig. b (1/1).

Fig. a.

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the tumor was manifestly harder in consistence than the surrounding brain tissue I pushed the bare finger (the only reliable instrument available in difficult cases) along the middle surface of the left hemisphere until the clearly defined limit of the mass was reached. (Plate VI, Fig. a.) It was necessary to bury the index finger to beyond the base of the middle interphalangeal joint to accomplish the purpose. With the tip of the finger I could feel the tumor loosen as I made slight traction, and so I was able to lift its sharply defined border and accomplish the enucleation, by blunt dissection, without provoking much hemorrhage. The removal of the tumor left a deep cavity in the brain. This was held open by retractors to permit of search for fragments of the growth which may have been left behind. As none was discovered the sides of the cavity were released and came together spontaneously while still under observation of the eye. (Plate VI, Fig. c).

The portion of dural flap which had been adherent to the tumor showed at the site of adhesion fragments of the neoplasm which were excised (Plate VI, Fig. c, dotted line). The remaining portion of the dural flap was laid over the site of the cavity from which the tumor had been removed, covering the same from the right side. As the tumor had invaded the brain to the left and downward a layer of normal cortical brain substance remained, and this was also replaced over the cavity. The osteoplastic flap was then sutured into place. The tumor measured 32, 55 by 58 mm. and was egg-shaped in outline. Fig. b, Plate VI, shows the tumor in natural size. Histologically the neoplasm proved to be a spindle-celled sarcoma. After its removal the exposed occipital lobe showed marked pulsation. The recovery at the end of two years is still complete and the hemianopsia has entirely disappeared.

While in the case just described the tumor formed a wide attachment to the dura and was for this reason easily recognized, the conditions are not so favorable in this regard when the growth is attached to the inner surface of the dura by a narrow pedicle. The development of the growth invades in the latter instance more rapidly, the brain substance displacing it as it grows. This obtains most certainly if the neoplasm grows into a fissure of the brain which happens to lie immediately beneath the point of origin of the tumor. I have seen this occur in the anterior portion of the brain in an instance in which the fissure of *Sylvius* was invaded by a tumor the size of an apple, which originated from a pedicle attached to the inner surface of the dura not wider than a pea. The nature of the growth, however, left no doubt as to its dural origin. This tumor extended to the island of *Reil*, and was successfully enucleated from the distended fissure of *Sylvius*. The patient, a woman, aged thirty-seven (Observation IV, 1), was referred to me for operation by *H. Oppenheim* with a diagnosis of tumor in the left cerebral hemisphere, probably located in the region of the temporosphenoidal lobe.

On November 8th, 1907, I made a temporal osteoplastic resection. The opening in the skull measured symmetrically 8 cm. on all sides. The dura was tense and did not pulsate but was normal in appearance. Palpation developed a hard area of the dura the size of the finger nail. Corresponding to the site of localization of the fissure of *Sylvius*, previously marked out on the scalp with nitrate of silver, the dura presented a shallow depression, several centimeters in length, and the area of hardness was palpable at a point corresponding closely to the beginning of the fissure of *Sylvius*. Rapidly increasing intracranial pressure made it imperative to open the dura and remove the tumor at the end of twenty-four hours after trephining, though it had been the original intent to permit of a longer lapse of time. The patient at this time was in so profound a state of coma as to render chloroform narcosis unnecessary.

The tension of the dura had increased and pulsasion was absent. In turning down the dural flap it was found adherent over a small area the size of a pea which extended into the brain substance. The dura was separated from the area in order to expose the entire surface of the opening. The pea-sized area (Fig. 23 a and Fig. 24 a) was located at the anterior portion of the fissure of *Sylvius* and extended distally from the flattened surrounding convolutions which latter were dry and hard. Its location corresponded to the hard area palpated on the dura, but was slightly lower down, toward the base of the skull, than the point of tenderness of the scalp. The pedicle was considerably harder than the surrounding brain tissue and extended inward in the form of a large tumor, which was covered above by the operculum and below by the first temporo-sphenoidal convolution. It had presumably displaced the island of *Reil* toward the median line. The somewhat thickly encapsulated tumor was lifted from the fossa *Sylvii* with the index finger without difficulty and delivered from the brain. The cavity left behind measured 50 by 50 mm. As soon as the tumor was removed from the brain tissue a rather

Fig. 23

sharp arterial hemorrhage occurred which spurted rhythmically with the pulse beat. The bleeding was not sufficiently severe, however, to cause alarm, and was regarded as coming from one of the branches of artery of the fossa of *Sylvius*. The soft brain tissue did not permit of clamping and tying of the vessel, though the bleeding was readily controlled by tamponade and slight pressure.

The delivered tumor was still adherent by several penetrating arachnoidal vessels which, after deligation and division, permitted of removal of the growth.

Fig. 24

The small area of attachment of the neoplasm to the dura was widely excised. The now rapidly obliterating residual cavity was lightly packed with gauze to control the oozing, the end of the tampon being led to the surface, through the lower forward angle of the superficial wound. A smaller drain was inserted at the same place. At the end of the operation the brain did not pulsate and protruded, evidently as the result of œdema, rather forcibly through the opening in the bone so that the osteoplastic flap was replaced and sutured under considerable tension.

The origin of the tumor corresponded to a point located in the center of the antero-posterior diameter and at the junction of the middle and lower thirds of the area exposed by the osteoplastic flap. The diameters of the tumor were as follows: Sagittal 60, vertical 56, and horizontal 43 mm. Placed in the base of the skull of a cadaver the neoplasm (Fig. 24) quite filled the entire middle fossa. The patient recovered.

The procedure just described is, of course, only feasible when the neoplasm is distinctly differentiated from the brain tissue by its consistency. In the case just cited this difference was exceedingly well marked, more especially as the surrounding brain tissue had undergone considerable softening.

Serviceable as enucleation with the finger may be, it is not applicable in manipulations requiring removal of tumors which are deeply situated, as obtains in invading the cerebello-pontian angle (Tumors of the Acusticus). The liability of making dangerous and fatal pressure upon contiguous parts, such as the origin of important nerves in the floor of the fourth ventricle, precludes employment of the cumbersome finger for this purpose. Tumors located in this situation may frequently be readily enucleated; the technique of which procedure is, however, taken up in a separate chapter. (Page 134.)

The residual cavity in the brain, left after removal of a neoplasm, rapidly obliterates, as has already been shown, and ultimately leaves only a small depression corresponding to its original site. If the bleeding has been arrested by sponge compression or ligature, shallow brain depressions may be disregarded, and the osteoplastic flap may be replaced and sutured. I have found it serviceable to make slight pressure upon the flap, if it has been possible to preserve its integrity, in order to facilitate repair. This indulgence is still more useful if the trephining has been done for removal of cerebral tumors, (see page 91), as in this class of cases the dura is not usually involved in the process. To avoid unnecessary repetition this is mentioned in this connection.

If the defect in the brain is deep I tampon the space between the collapsed dura and the lamina vitra with gauze and lead a portion of it out through the angle of the osteoplastic flap. This is by far better than tamponing the cavity in the brain itself, as all foreign bodies exercise a deleterious effect upon the brain, inasmuch as they cause pressure, œdema and softening; which problem will, however, be more extensively taken up later. (Page 170.)

Invasion of the Brain Substance

Excision of the Cortex

The technique of removal of sections of the cerebral cortex for *Jacksonian* epilepsy, where there is no alteration in the brain tissue, presents the least difficulty of all of the measures directed to the relief of brain lesions. After the "primary spasm" area has been located by electric stimulation, the center corresponding to the part thus affected is excised together with the contiguous brain substance, to the depth of 8 to 10 mm. In order to obviate obscuring hemorrhage I deligate all vessels encroaching upon the area to be excised, and introduce additional ligatures toward the center of the area, which I use to lift the focus to be removed, and cut between the ligatures, leaving the latter long while the former are cut short. The procedure is quite clearly demonstrated in the illustration, Plate VII, a, which belongs to Observation I, 4, and Fig. b, which belongs to Observation I, 10, where details may be obtained.

Though this deligation of vessels is essential it may not properly be considered as devoid of objections, with respect to the surrounding brain substance. Fig. c, Plate VII, shows at the site of excision considerable hemorrhagic invasion of brain substance though the excision was limited to a very small area. Death occurred on the fifth day following an immediate aseptic result. The autopsy made

Fig. a.

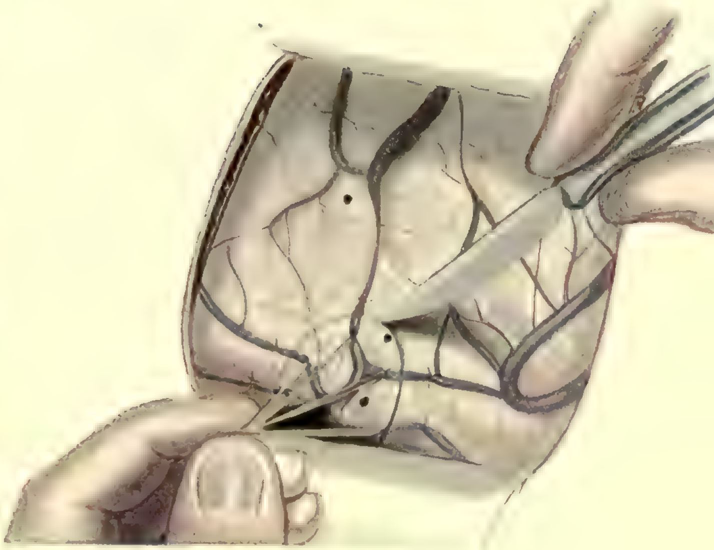

Fig. b.

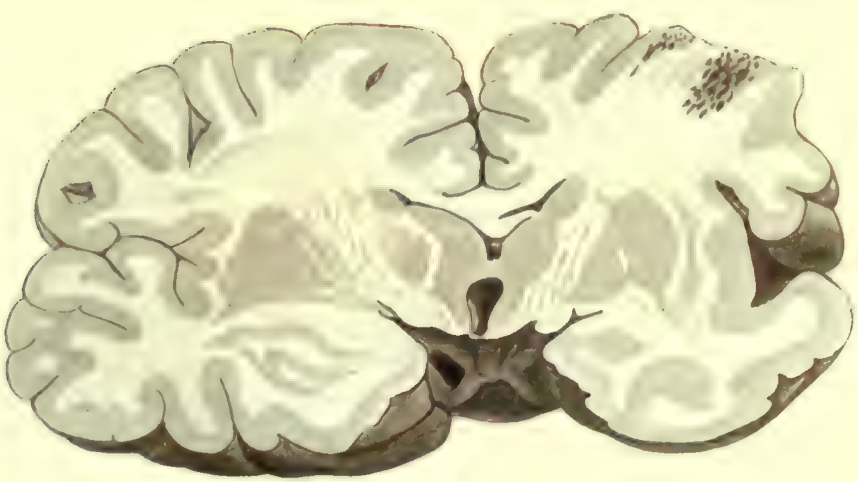

Fig. c.

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by *Professor Oestreich* did not demonstrate the cause of death and did not show any cause for the hemorrhage other than the operation. (Observation I, 4.)

This observation stimulates the writer to call attention to the danger of ligating blood vessels in the brain, especially arteries, which may result in serious nutritive disturbances in this situation. Before extirpating a neoplasm of the brain all afferent vessels should be ligatured. However, this measure should be restricted as far as is feasible to the smaller branches of the vessels, and the main trunks are to be carefully avoided. In this way dangerous cerebral softening may be prevented. An especial warning is offered against ligature of the internal or common carotid, as invariably cerebral œdema follows. *Horsley* has shown that the arteries run from below upward, and it is therefore advised that the excision begin below and terminate above toward the median line. My experience teaches that the flow of the circulating fluid does not follow any definite course in the veins. In a general way the current flows from the longitudinal sinus.

Jacksonian epilepsy is frequently attended with distinct pathological changes in the meninges and brain substance, and, indeed, these changes exist quite frequently as the causative factor in infantile paralysis. Of the various changes which cause *Jacksonian* epilepsy, those which are the outcome of chronic inflammatory processes and agglutinate the arachnoid, pia and cerebral cortex are the only ones properly considered in this connection. If this sort of lesion is to be excised, hemorrhage need not be an important factor, as scar tissue is quite devoid of blood vessels, and but rarely measures directed to its control are required.

In the case of a girl of nineteen I found a tense scar which had contracted into horizontal folds and was located at the edge of cerebral hemisphere just where the convex portion meets the inner surface. The scar measured 40 mm. in length and was 13 mm. in width. Access was only obtained by depressing the cerebral hemisphere with gauze, although the trephine opening had been carried beyond the median line. In this way two large veins, which led from the longitudinal sinus to the edge of the hemisphere, were exposed and divided between two ligatures. This made visible the entire scar together with a large portion of the median surface of the brain and the falx cerebri. The scar was grasped with a tenaculum forceps and excised together with a portion of normal brain substance (3 mm.) with the scissors. The scar consisted of white fibrous tissue, which had replaced the normal cortical substance as the outcome of an inflammatory process. The venous hemorrhage during the excision was slight and readily controlled by pressure.

Extirpation of Tumors of the Brain

The tumors lying on the surface of the brain known as

Angioma of the Pia Mater

occupy, as far as the technique required for removal is concerned, a position between the method of procedure necessary for cortical excision and that applied to the enucleation of neoplasms which originate in the brain substance itself. The formation of the dural flap may provoke severe hemorrhage, if during this step of the operation a blood vessel should happen to be invaded which extends from the angioma to the dura, and indeed this may be the case without there being any visible evidence to this effect. Observation III, 2, illustrates very well the possibilities in this regard.

A male patient, aged forty-six, came under observation for *Jacksonian* epilepsy. A rather extensive osteoplastic resection was made in the central region of the skull. The first incision into the dura was attended by a violent hemorrhage which was forcibly projected from the wound but was immediately controlled by digital pressure. Formation of the dural flap was at once completed, and as it was carefully raised, two large-sized veins came into view which were doubly deligated and divided. Complete displacement of the dural flap exposed a plexus of veins dilated to the size of the little finger, which were intimately intertwined upon the surface of the brain. The primary dural incision had opened the branch connecting the two veins which had been deligated. The main branch leading to the dura was tied above and below.

None of the dilated blood vessels gave evidence of pulsation, justifying the conclusion that the serpentine vessels were veins of the pia mater. In the center of the operative field a number of smaller veins were distinctly visible (about 2 mm. in diameter) which effectually obscured inspection of the cerebral cortex. (Plate VIII.)

The posterior border of the denuded area left exposed an interval of normal brain tissue between the edge of the tumor and that of the trephine opening, about a finger's breadth in width. Above, the longitudinal sinus with a number of veins lying closely side by side was visible. However, the formation of new blood vessels extended well beyond the surface exposed by removal of the dural flap.

This necessitated extension of the skin incision and removal of 2 cm. of bone which reached quite to the base of the skull. The dural flap was enlarged to an extent corresponding to the enlargement of the superficial wound. However, normal brain tissue was not brought to view until the hemisphere was carefully raised into the trephine opening. This manipulation was not reproduced by the artist on the ground that an attempt in this direction would interfere with an accurate representation of the actual conditions presented by the neoplasm. At the lower portion of the exposed area the fissure of *Sylvius* was visible. Behind the anterior edge of the wound the main vein leading to the tumor was located at the first temporo-sphenoidal convolution. This main trunk divided into two branches 1 cm. in diameter and a smaller central branch.

These three vessels were encircled with a "full curved" needle ½ mm. in diameter and 36 mm. in length, passed rather wide of their walls including the contiguous brain tissue, and deligated. Nevertheless considerable bleeding emanated from the

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punctures made by the needle, which was controlled only after rather prolonged pressure. While the pressure was being made I deligated all vessels leading to the tumor at the anterior and posterior aspects of the wound in the same manner, so that no time would be wasted and pressure upon the subsequent needle punctures would cause no delay. I then deligated the veins leading from the longitudinal sinus and ultimately, as a precautionary measure, introduced around the main trunk below, a deep ligature which entered in front the fissure of *Sylvius* and emerged behind the first temporo-sphenoidal convolution. Care was taken to avoid the artery of the fissure of *Sylvius*. However, it was not necessary to go quite so deep to accomplish the purpose.

After deligating the numerous veins with linen thread they appeared like a number of over-distended sausages from which it was not possible to force the contained blood by pressure.

The method of treatment just described is no doubt the only one possible in this class of cases, because of the danger of hemorrhage, where the angioma is spread over a considerable area of brain. Extirpation of the tumor, if situated in the motor cortical zone or other part of the brain concerned in important functions, would involve too much trauma and require the sacrifice of too much brain tissue.

After introduction of the multiple ligatures I observed that the blood no longer circulated in the dilated vessels. This justified the assumption that the flat venous angioma may be more readily isolated in this way than obtains in dilatation of arteries, as is illustrated on the face, where multiple ligature does not achieve the purpose despite the fact that thorough ligaturing has been employed.

The operation was a prolonged one and much blood was lost, requiring haste toward the end. For this reason I did not split longitudinally the distended vessels with the view of promoting cicatrization. In order to cause additional irritation I tamponed the entire operative field with vioform gauze, bringing the end of the strip out of the posterior superior angle of the wound and closed the rest of the area of approach with sutures. The tampon was partially removed three days later, and the rest withdrawn after the lapse of an additional four days. The gauze was quite firmly adherent and required considerable force to remove. A little oozing occurred at this time. Healing followed without interruption.

The nature of the process may be designated as an *Angioma Venosum Racemosum*. The Angioma Arteriale Racemosum of *Virchow*, with its thickened dilated and elongated blood vessels, may properly be offered as resembling in character the process in this case. The affected veins were symmetrically enlarged and in places presented varicose dilatation. The elongation caused the abnormal convolutions of the veins which were, however, not thickened. The fine plexus of vessels situated at the center of the growth were dilated to the size of the normal veins of the pia or perhaps a little larger, and were a trifle lighter in color than the surrounding larger vessels. As to the condition of the neighboring artery of the fissure of *Sylvius* we cannot give any information, as it was not exposed during the operation. There was no abnormal pulsation visible at any time.

In a second case, that of a boy of ten, I operated for a much smaller venous angioma (Observation III, 1). In this instance I doubly ligated all approaching veins of the pia and divided them between the ligatures. I then split the tumor area to the depth of 1 cm. and the length of 2½ cm. and tamponed with gauze. This case was operated upon September 19th, 1903, and recovered. The recovery is maintained at the present writing. I have not encountered any other form of angioma.

Tumors of the Brain Substance

The procedure in extirpation of tumors of the brain substance itself varies with the character of growth and with the location, whether in the portions concerned in the functions necessary to life or if developed in parts of lesser importance. It is also a factor of considerable magnitude whether they extend inward from the cortex or grow toward the periphery from a deep seat of origin. Important as these considerations are with regard to the symptomatology and the diagnosis as to the character of the neoplasm, the essential influence upon the technique of enucleation is whether the growth is recognized when the dura is opened or whether they must be searched for in the deeper portions of the brain.

Tumors Located in the Cortex of the Brain

may be recognized by the absence of pulsation of the dura, by the fact that at times their color shimmers faintly through this membrane, and occasionally by a slight elevation at the site of their location. Only rarely and in cases of tumors of very hard consistence will palpation elicit helpful information, as the distended dura obliterates fine distinctions in this regard. After deflecting the dura they are in most instances readily recognized by their color; however, in infiltrating glioma this distinction may not obtain. It has been my experience not to find the dura intimately associated with brain tumors, and I have not had to remove the former for this reason.

If the problem involve removal of

Encapsulated Tumors

the procedure is a simple one, as these growths simply need be peeled out in the same manner as obtains in the case of dural tumors of dural origin.

In this connection I wish to report the technique employed in a case for the reason that this involved especial measures. The case was one of a man (aged forty-five) who had been sent to me with the diagnosis of a tumor involving the arm region of the motor zone. The motor area was exposed by means of an osteoplastic flap, and six days later enucleation of the neoplasm was made. The base of the dural flap was located below, and in order to avoid the veins immediately contiguous to the longitudinal sinus the upper transverse section of the membrane was made about 2 cm. below this vessel. The portion of dura remaining above was seized with clamps and two small vertical incisions were made at either side of the trephine opening. This short flap could now be raised without endangering the longitudinal sinus, and exposure of the upper portion of the central convolution was accomplished.

The inner side of the dura did not exhibit any pathological changes and was not adherent to the tumor. The latter presented a flat spot the size of the thumb nail, was brownish red in color and situated between two convolutions which were assumed to be the anterior and posterior central convolutions. We will see in the chapter on epilepsy that exact localization of motor areas in the central region of the brain, through the pia, is quite impossible, and that the seat of the anterior central convolution is only demonstrated with certainty as the outcome of electrical stimulation. However, electric stimulation of the brain should not be employed except for imperative reasons, as it is in the human animal attended with not inconsiderable damage. In this case the tumor was located beneath a distended dura which pulsated but feebly, and judging from the high position the neoplasm occupied in the motor zone, involved the arm area. In consistence the tumor was manifestly harder than the contiguous brain tissue.

The two convolutions were next displaced laterally from the tumor with gauze wipes exposing a club-shaped area. I now pressed forward with the finger from above and gradually and carefully enucleated the mass. The tumor, which was about the size of a small apple, presented its widest part toward the periphery. From the edge of the anterior convolution I removed a small portion corresponding to the site of contact with the tumor. The latter was studded with minute yellowish spots, and excision was made to be on the safe side. This was probably an area of hemorrhagic softening which is not infrequently found in the neighborhood of tumors in this situation. The bleeding was entirely venous and readily controlled by pressure except for rather persistent oozing from one larger vein which we did not succeed in ligating. This necessitated leaving a small vioform gauze *in situ* for three days. The tumor bed collapsed rapidly, thus permitting of approximation of the osteoplastic flap, except, of course, where the gauze strip protruded. Repair of the wound occurred promptly; however, on the eighteenth day following the operation the patient died as the result of a pneumonia superimposed upon an old bronchitis. The tumor proved upon histological examination to be a glioma.

I have upon another occasion been able to enucleate a solitary tubercle, which had undergone central softening, from the white substance of the parietal lobe with the closed scissors.

Far more unfavorable conditions attend removal of

Non-Encapsulated Tumors of the Brain

In these cases no other course is available than to deligate all approaching vessels and to extirpate with scissors and knife. If the tumor differs markedly in consistence from the brain tissue, as frequently obtains with sarcoma and glioma, the extirpation resembles the technique of enucleation by shelling out,

Fig. a.

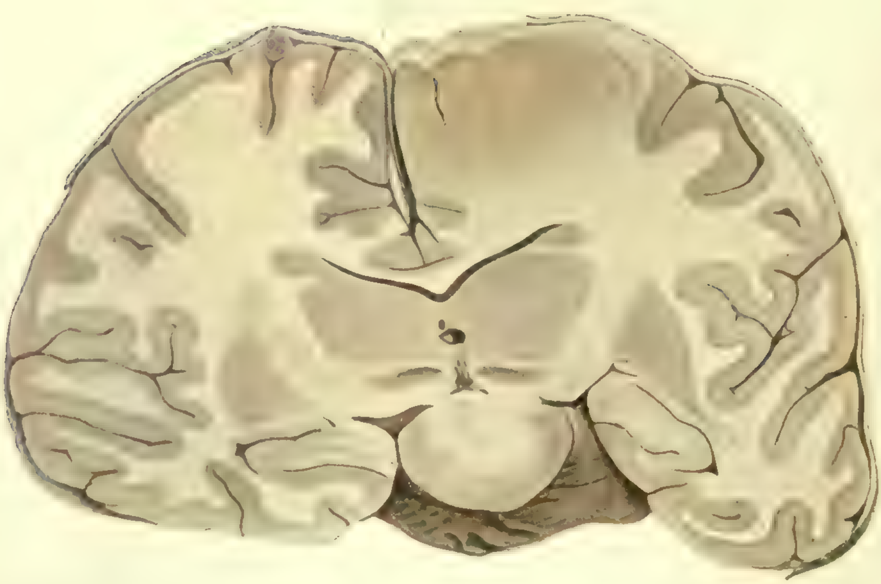

Fig. b.

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and we may expect to accomplish complete removal, especially if the contiguous brain tissue has undergone more or less softening.

Most unfavorable conditions are undoubtedly presented in cases of infiltrating glioma, for their limitations are not always recognizable even upon section of the brain tissue, and their removal becomes of doubtful expediency. The mass is to be removed widely with the scalpel and spoon and the normal brain tissue quite invaded and removed. However, even then it is a matter of doubt whether or not portions of the growth may not have been left behind.

A case of this sort is depicted on Plate IX. The patient, a man of fifty-three, whose clinical history is given in Observation III, 3, was afflicted with a non-encapsulated glioma which had been diagnosticated by *H. Oppenheim* as located in the upper third of the motor cortical zone. Exposure showed the tumor to extend 4½ cm. downward and measured 5 cm. laterally. Excision left a cavity 5 by 6 by 2½ cm. Death from collapse ensued and autopsy showed that despite the considerable area of excision the tumor had not been entirely extirpated. While the discoloration of the cortex made recognition of its limits possible in this situation, the neoplasm had extended still more widely in the deeper portion of the brain, where the contrast in color did not obtain (Fig. b). In addition to this the absence of modification in consistence as contrasted to the normal brain substance made a radical extirpation impossible. In operating upon cases of this sort the technique in this regard is a matter of chance.

Subcortical Tumors of the Brain

The difficulties just discussed are still greater in the removal of tumors located in the white matter of the brain. After displacement of the dura it is fair to assume that the symptoms previously presented are the outcome of encroachment upon the cranial cavity if the convolutions are flattened, the sulci obliterated, and the cortex present a dry lusterless appearance. Recognition of the deeply located site is not determinable by palpation, and for this purpose needle puncture (akidopeirastic) probe puncture and aspiration of tissue portions are indispensable.

Probe puncture with the hollow needle and aspiration of cylindrical sections of tissue for microscopical examination are extensively discussed in the chapter on **The Neisser-Pollack Brain Puncture** and the section entitled **"Personal Experiences,"** to which the reader is referred (page 237). In operating upon the brain all possible contingencies should be prepared for and a trained assistant capable of making immediate microscopical examinations should be available. It is worthy of note that the cylindrical brain sections permit of more accurate examination after thorough hardening.

At times the fluid aspirated will furnish a guide as to further procedure. In the case of a woman of forty-nine, who presented the symptoms of tumor in the right motor region (Observation III, 6), exposure of the brain revealed a yellowish elevated area. Puncture in the center of the area (Plate X) provoked discharge of 5 cm^3. of sero-sanguinous fluid tinged with yellow when the depth of 2 cm. was reached. I

Fig. a.

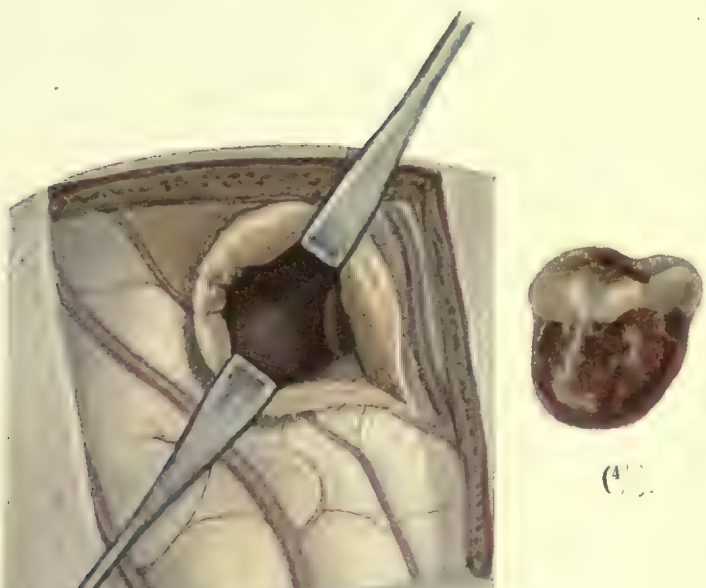

Fig. b.

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then made an incision 4 cm. in length through the dome of the elevation, causing the discharge of an additional 5 cm^3. of similar fluid. The finger was then inserted, revealing the presence of a round tumor the size of a walnut which was located forward and inward from the site of incision (Fig. b). The tumor was readily enucleated with scissors, as the surrounding brain tissue had undergone considerable softening. The tumor—which upon microscopical examination proved to be a glio-sarcoma—had produced hemorrhagic softening and caused the development of the cyst in which the neoplasm was contained.

Akidopeirastic was introduced by *von Middeldorp* in 1856, and is of considerable value in certain instances, as shown by the following experience. The history of the operation is related at length, as it furnishes an example of the method of procedure employed by the writer, in enucleating subcortical neoplasms. The patient, a male (aged thirty-four), had already been subjected to the trephining operation in the right temporal region three years previously. Aside from the fact that the dura had not been opened at the first operation the opening had been made too far forward. *H. Oppenheim* sent the case to me with the diagnosis of a neoplasm in the lower portion of the right central convolution. The patient presented choked disk, cortical epilepsy, monoparesis facio-brachialis sinistra and sensory disturbances in left upper extremity. On April 23d, 1907, an extensive osteoplastic flap was made which measured 80 mm. in its sagittal and 60 mm. in vertical diameter, exposing the motor zone and at the same time the dura was opened with the base of the flap directed downward.

The exposed brain area gave no evidence of change except that the convolutions were flattened and pulsation appeared diminished. However, the exploratory needle met with a certain added resistance when the depth of 20 mm. was reached, in the anterior central convolution. This phenomenon was verified by repeated punctures, and after deligating the contiguous blood vessels I made a horizontal incision 55 mm. in length through the cortex of the brain into the white substance beneath, exposing at a depth of 26 mm. a non-encapsulated tumor (Plate XI, Fig. a). At this time the patient's general condition became alarming, and extirpation was not deemed advisable; however, a small section of the tumor was removed for microscopical examination. The wound was closed and primary union followed. An intercurrent croupous pneumonia made it necessary to postpone the second stage of the operation until May 16th.

During this interval the skin over the field of operation began to bulge. A puncture made at the dome of the protuberance on May 3d withdrew 1 cm^3. of fluid slightly tinged with yellow. The enlargement, which pulsated slightly, was believed to be caused by œdematous brain and tumor mass. By the 10th of May an area of ulceration the size of a silver quarter of a dollar had formed, at the site of the scar of the operation of three years before. By the 27th of May the entire operation field had elevated above the normal level of the skull to the dimensions of an adult male fist. The ulcerated skin area had developed into a granulating brain prolapse the size of a child's closed hand. The latter was excised to conserve asepsis during the radical operation which was undertaken on June 1st. The portion of the protuberance

Fig. 25

(Fig. 25) covered by skin had now reached the size of two adult fists. The ulcerating area had grown again, and attained the size of a potato. Removal of the latter exposed a grayish green, partially cystic tumor mass. The skin and bone were divided in the line of the old scar and the flap turned down, exposing at once the tumor. The neoplasm was not encapsulated, and was carefully enucleated from the brain tissue with a flat, soft metal spatula and the index finger (Fig. 26). A prolongation of the tumor the size of the index finger, extending forward and downward, was removed together with a portion of surrounding, apparently normal brain tissue

Fig. 26

with the spatula. In excising the latter portion of the mass a slit-like cavity was opened, which probably was a part of the lateral ventricle. (Anterior horn?) A quite active arterial hemorrhage bubbled up from the deep wound which was, however, readily controlled by gauze tamponade. Macroscopically there was no evidence of remaining neoplasm. The tampon strip was led from the anterior inferior angle of the wound, the rest of which was closed by suturing.

During and immediately following removal of the tumor the pulse became irregular and ceased to be perceptible for one to three minutes on several occasions. These intermissions were followed by exacerbation of rate up to 140 beats per minute. Later the pulse became slower and stronger. Tamponade was followed by epileptiform convulsions which were preceded by nystagmus, also contraction of pupils and short intervals of clonic spasm of all the extremities.

The extirpated tumor—an infiltrating glioma—was about the size of a grape fruit (over 8 cm. long), was œdematous and infiltrated with hemorrhagic areas of greater magnitude than the surrounding brain tissue. The œdema, however, was no more marked than was presented by the brain tissue. Besides its grayish-green color the tumor differed from the surrounding brain substance inasmuch as it was much less vascular than the latter. Beyond this the tumor was the seat of numerous flat, slit-like cystic cavities.

In comparison to the conditions at the first operation, when the excision was abandoned, the tumor was located much nearer the surface, this being no doubt the outcome of the decompressing effect of the preliminary osteoplastic resection. Beyond this the tissue surrounding the mass was more markedly softened, making more readily discernible the line of demarcation. The first operation may be regarded as having had a favorable influence to this extent.

The tampon was removed on the fifth of June and its wound of egress closed with two small sutures. The wound healed rapidly and without complicating occurrences. On the tenth of June the effects of the operation were overcome, the patient was mentally clear and the appetite good. This condition was maintained until well into the month of July. At this time the patient began to show evidence of depressed vitality and mental derangement, and died on the 20th of August from a gradually increasing asthenia.

It would be exceedingly desirable if the **direction of dividing the cerebral cortex** were susceptible of certain well-grounded laws, when approach to subcortical neoplasms and deeply located abscesses is made. All trauma to the brain destroys a large number of important nerve elements and results frequently in paralysis. For this reason incision into the cortex and subsequent invasion of the deeper structures of the brain is to be executed with care, and only as the outcome of clearly defined indications. Exact guidance in this connection is not available at present. It is to be hoped, however, that the future will give more accurate information with respect to the direction of the fibers, and thus make possible certain methods of procedure in incisions in this situation. As few blood vessels as is possible should be deligated or divided for the reason already stated, that cerebral softening is likely to happen as the result.

Occasionally it has been feasible to remove subcortical tumors without destruction of nerve tissue when the neoplasm has been situated in a fissure as at times obtains in the fissures of *Rolando* and *Sylvius*. Under these circumstances it is only necessary to separate the meshes of the arachnoid, tie the contiguous blood vessels and enucleate the tumor after separating the convolutions adjoining the seat of the growth. The technique of this procedure is shown with regard to the fissure of *Sylvius* on page 79, and the central fissure on page 92.

The brain substance is held aside by dull right-angled retractors which should be available in various sizes. These tractors are employed in holding open the incision or the adjacent convolutions during removal of the tumor. I find it of service to cover the smooth metal blades of the tractors with a layer of gauze which causes the brain substance to adhere to its surface, and the brain tissue is held asunder with less pressure than obtains if this be not done. As to the treatment of the tumor bed after enucleation see page 82.

Opening Brain Abscess

The opening of brain abscess always requires division of the cerebral cortex, and for this reason the brief remarks submitted with regard to the general subject of brain abscess belong here, immediately following discussion of the technique of removal of subcortical neoplasms, especially as I have quite abandoned exploratory puncture through the dura in cases of suspected abscess. Puncture of the brain for pus must be done with a large needle, as the exudate is likely to be very tenacious, and if the puncture be made through the intact dura, pus is apt to gain access to the arachnoid spaces and spread the infection. As a rule I fashion at once the dural flap with a dependent base, obtaining thus ample space for inspection, and any oozing of pus from puncture openings made at this time can be removed with gauze wipes. In operating for epilepsy or tumor the field is aseptic, while in attacking brain abscess it is necessary to avoid contact of the arachnoid with the infectious exudate, a precaution which should be taken in both septic and tuberculous abscesses. The safest procedure is to make preliminary

Protective Tamponade of the Subdural Space

This is accomplished by inserting between the dura mater and the arachnoid space sterile vioform or iodoform gauze strips (Plate XI, Fig. b). In these cases the incisions forming the dural flap should be located a little farther from the edge of the bone, *i. e.*, about 1 cm. The marginal dura is now incised in an oblique direction at the corners of the exposed brain area, forming three small flaps which are located to either side and at the upper border of the wound, and these may be held aside with clamps, exposing quite efficiently the subdural space. The large dural flap is now drawn tensely toward the base of the space and the interval between it, and the brain tamponed with great care, for here, of course, because of its dependent location, infection is most likely to occur.

Not until thorough isolation of the area by tamponade has been accomplished do I make exploratory puncture or incision into an abscess. Incision may be done at once if the

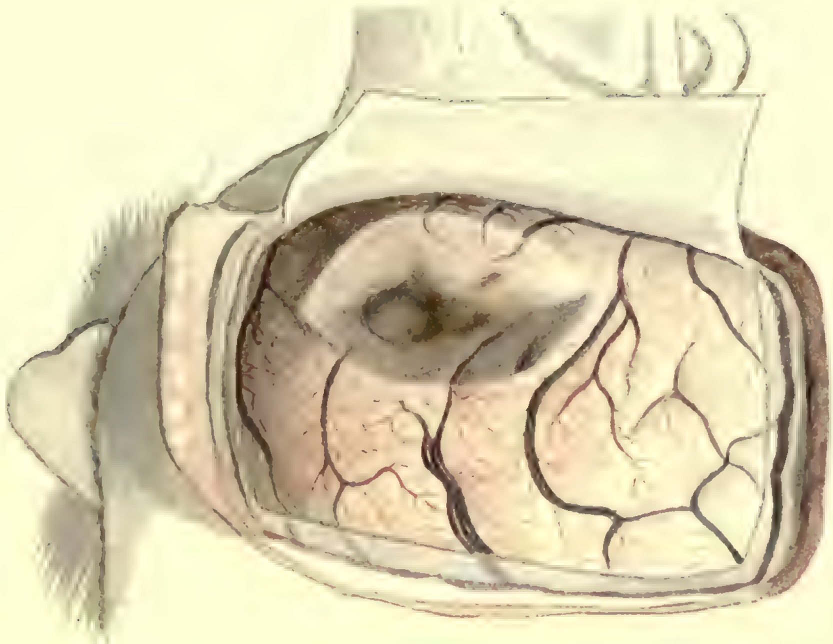

Fig. a.

Fig. b.

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Abscess be Located Superficially

and is recognized when the dura is opened. The incision in cases of this sort is made through tissue already destroyed, and no additional damage is done. Conditions of this kind are shown in Plate XI, Fig. b, which illustrates the case described under Observation V, 1.

When, however,

Abscess in the Deeper White Substance

is invaded the problem presents a quite different aspect as regards localization of the pus focus. I first puncture the brain with the needle alone, employing one of wide diameter, *i. e.*, about 2 mm. If the pus is under pressure it will ooze out through the needle, if its consistence be not too tenacious. If no pus appears I make suction, at the same time slowly withdrawing the needle. If the result be negative this procedure is repeated at several various situations, altering each time the direction of the puncture. The pus may be sufficiently tenacious to resist aspiration. In these instances incision with the knife is indicated if sufficient justification be created by the clinical picture, for, of course, liberation of the pus is absolutely essential to the maintenance of life in these cases.

When the abscess is located the canula is left in place and used as a guide. The knife is then carried along the needle and the abscess cavity opened to the extent consistent with the size of the abscess cavity, or the closed forceps is introduced into the cavity, guided by the needle, and opened when the cavity is reached, thus crowding aside the brain tissue. The usual precautions employed in dividing brain tissue are shown proper consideration in the execution of this step of the procedure. The port of entrance to the pus cavity is held open with the blunt right-angled retractors already described, and after careful wiping away of the pus the space is inspected. It is not unusual to find pus emerging from contiguous smaller abscess cavities, the existence of which are determined with the sound. It is best to introduce the little finger into these smaller cavities under guidance of the sound, and carefully break down its walls. Sufficient of the isolating wall should be destroyed to convert the entire area of infection into a single cavity, thus conserving rapid healing. It is to be borne in mind that a multilocular arrangement of cerebral abscesses is not uncommon.

If the abscess be of acute septic origin its walls should not be curetted, as this would be liable to cause extension of the infection. If the abscess be chronic and have a distinct membrane, as is frequently the case in this kind and in tuberculous abscesses, the membrane should be removed. I am in the habit of inserting into these cavities several good sized drains and then tampon the rest of the space with vioform or iodoform gauze. Fig. a, on Plate XII, depicts this measure employed in the case of a male of eighteen. The protective tamponade is not shown in this illustration for reasons of clearness. The case was one of metastatic abscess located at the faciobrachial center (left), which had occurred secondarily to a pleural empyema.

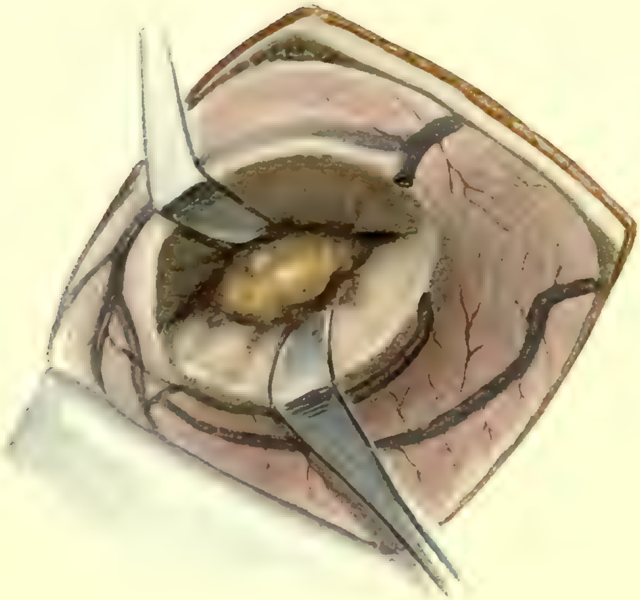

Fig. a.

Fig. b.

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Dural and Extradural Processes Involving the Brain

A number of conditions originate in the cranial bones and dura which extend to the brain and require invasion of the latter for relief. Strictly speaking the neoplasms which spring from the dura belong to this class but have been considered under a separate head (page 71) as they present essentially the clinical picture of brain tumors and practically require the technique of brain surgery for removal.

Brain Puncture with Extradural Abscess

Injuries of the skull are frequently complicated by involvement of the brain itself, although special consideration of the treatment of the brain trauma need not be taken up in this chapter. This applies also to traumatic brain abscess and those suppurative processes in the brain occurring as the outcome of inflammations of the scalp and cranial bones. However, I enter in this connection, to a certain extent, into discussion of the extradural abscesses which so frequently complicate middle ear disease. Removal or temporary resection of the contiguous bone and careful loosening of the dura, which forms the inner periosteum of the cranial bones is all that is necessary under these circumstances. Especially in children, because of the thinness of the dura, care in its manipulation is especially required. However, in cases of extradural abscesses and in suppurative middle ear disease **serous meningitis** is liable to occur and simulate very closely abscess of the brain. The exposed dura is tense and devoid of pulsation, and the question comes up as to the advisability of making exploratory puncture of the brain.

From the standpoint of asepsis puncture of the dura and invasion of the underlying parts through a suppurating area is an exceedingly offensive proposition. Indeed, I have already stated that puncture of a diagnosticated brain abscess should only be made after the dura has been opened and the surrounding parts carefully isolated by tamponade. If the symptoms are reasonably accounted for by the suppuration outside the dura, the puncture should not be made. The entire exposed area may be packed with iodoform gauze, and if the symptoms, after a day or two, should still point to cerebral involvement the technique employed has at least contributed somewhat to lessening the extradural sepsis. If, however, the clinical picture be a grave one and indicate cerebral involvement and call for immediate invasion of the brain tissue, the exploratory puncture should be made at a site remote from the extradural abscess and the puncture point be previously wiped with a one per cent. sublimate solution. I have frequently proceeded in this way and have had no deep infection occur; however, a verbal communication from an excellent ear specialist informs me that he has frequently seen it occur. If the case be one of serous meningitis, clear fluid will be discharged from the puncture hole in considerable quantity as the outcome of the increased pressure. If the fluid discharged be pus the method of procedure is that stated on page 104.

What has here been stated with regard to the

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brain complications of suppurative middle ear disease, also applies to pus in other situations in the cranial cavity as for instance in

Tuberculosis of Cranial Bones.

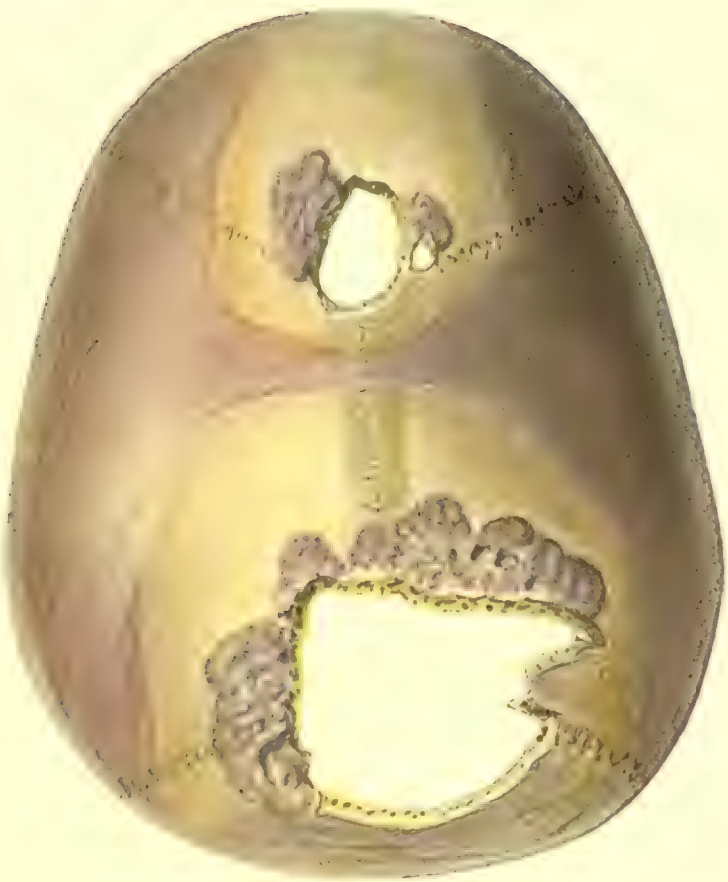
In the majority of cases tuberculosis of the flat cranial bones perforates, whether it be of the character of a cheesy sequestrum or—as is less often the case—tuberculous granulations which gradually invade the bone and ultimately reach the dura. The outer surface of the dura is not infrequently covered with tuberculous granulations, and these must be removed at the time of the operation, a step usually efficiently accomplished with the curette.

Fig. b, Plate XII shows a perforating tuberculosis of cranial bones. The illustration is made from the inner surface of the cranial dome after the dura mater and the brain have been pushed to the left side. The parietal bone is perforated with an irregular opening, surrounded with cheesy deposits which also stud the outer surface of the dura.

At times the cheesy granulations extend over a wide surface of the dura, so that even an extensive trephining does not permit of complete exposure and removal of the involvement. Although the area of disease may be extensive, it usually ceases in the dura and does not go on to invasion of the brain itself. Characteristic examples of the process are depicted on Plates XIII and XIV. Plate XIII shows the outer and Plate XIV the inner surface of the dome of the cranium. In the latter instance the dura is peeled back from the bone. The patient, a male, aged eighteen, had been afflicted with tuberculosis for years, and ultimately died of amyloid degeneration of the abdominal organs. The process had perforated the cranium, involved the dura and quite destroyed the entire frontal bones. The repair tissue replacing the destroyed bone had cicatricised into a hard tense membrane which was intimately adherent to the dura and could not be separated from it. This is shown in Plate XIV as a translucent area. Despite the extensive disease the brain remained intact, and the normal convolutions are shown in Plate XIII through an incision made in the scar area.

However, the brain may become involved in two ways as the result of tuberculosis of the cranial bones. Most frequently the formation of **abscess in the brain tissue** occurs. The operative treatment under these circumstances does not differ in technique from that which obtains in the class of cases just discussed, except, perhaps, that entire removal of the membrance lining the abscess cavity is imperative. As I do not take up this subject again, an example of the process is depicted on Plate XV.

The illustration shows a specimen from a female patient aged thirty. Three years before coming under my observation she had been subjected to operation for relief of a tuberculous focus in the trochanter major of the right femur. Two and a half years later the corresponding hip joint was resected for the same affliction. The latter was followed by recovery with a sinus. She was admitted to my service suffering from a cold abscess of the skull in the region of the



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anterior fontanelle. Incision revealed the presence of a tuberculous sequestrum the size of a pea. This was removed, the neighboring bone scraped and the tuberculous granulations lying on the subjacent dura were removed. The dura pulsated in a normal manner. The wound was packed with iodoform gauze. Repair without sinus resulted.

Two months later another abscess formed over the posterior fontanelle. At the same time the patient complained of headache and vertigo, the latter persisting when the patient was in the recumbent position. Beyond these no cerebral symptoms were present. Opening of the abscess disclosed cheesy bone, which, despite extensive resection, did not permit of entire removal. The dura was thickly covered with tuberculous granulations and did not pulsate; it was also markedly tense. Incision of the dura disclosed a pus area the size of an apple immediately beneath the cortex of the brain. The abscess cavity was lined by a characteristic membrane which could be readily removed with the semi-sharp spoon. Iodoform tamponade achieved considerable reduction in size of the cavity and the brain symptoms disappeared. However, a sinus remained. The patient's general condition did not improve; in a few weeks albuminuria developed, which was followed very soon by amyloid degeneration of the abdominal organs, and six months and a half later death supervened.

Autopsy revealed a much more widely distributed process than had been made manifest by the clinical symptoms. The case was evidently one of **progressive infiltrating tuberculosis** of the cranial bones. Extensive areas of the bone were of a pale yellow color consisting of cheesy infiltration. Normal bone appeared only in narrow strips. Beneath the diseased bone the dura was covered with tuberculous granulations which at the site of the trephine openings had accumulated to a still greater extent.

Only in rare instances is the **Brain Surface infected** by extension of tuberculous processes from the bones. A case of this sort is shown on Plate XVI, which represents the conditions found in a young man of seventeen, who had been burdened with a tuberculous heritage from the father's side. The patient had noticed a gradually increasing swelling on the left side of the skull, which developed within a period of several months. When he came under observation he presented evidence of cerebral pressure, (bilateral choked disk, vertigo, staggering gait, headache and vomiting), also aphasia, and paresis of the middle and lower divisions of the right facial nerve. A cold nonpulsating abscess was palpable, situated 7 cm. above and 1 cm. in front of the right auricle. The location corresponded to the lower portion of the central fissure (Plate XVI, Fig. a, brown line). Exposure of the bone revealed a sequestrum the size of a lentil which was so firmly imbedded as to require removal with the chisel.

This step brought the dura into view, which proved to be tense, devoid of pulsation and covered with tuberculous granulations. Bone to the extent of 5.6 cm. was removed before the diseased area was entirely exposed. When the dura was opened the

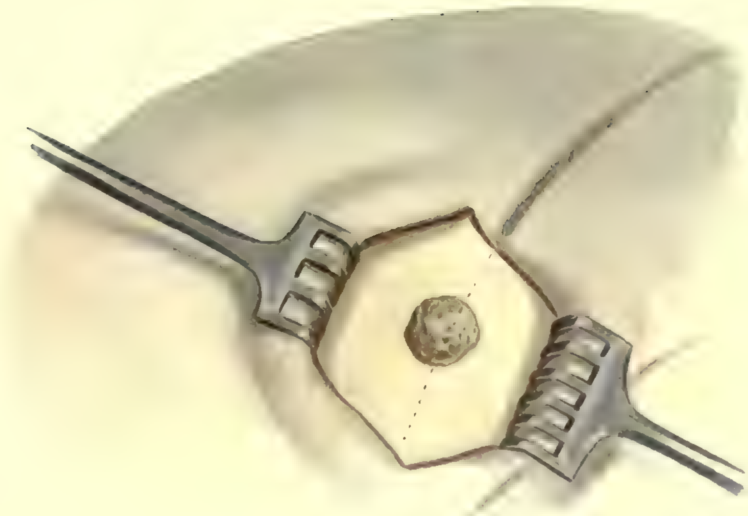

Fig. a.

Fig. b.

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brain prolapsed sharply and was found to be infiltrated with tuberculous granulations which involved the cortex (Plate XVI, Fig. b) and extended into the medullary tissue, requiring considerable invasion of the latter in order to accomplish removal. The defect was filled with iodoform gauze. After the operation the right side of the patient was paralyzed. However, this cleared up almost entirely during the subsequent three weeks. The brain continued to prolapse through the trephine opening and ultimately attained the size of an apple. Twenty-four days after the operation the patient died in convulsions. Autopsy showed the lungs and spleen infiltrated with tuberculous areas and the right cerebral hemisphere was the seat of a conglomerate tuberculous focus the size of a walnut (Page 148). The seat of the operation was free from tuberculous disease.

Gumma

Syphilis of the cranial bones and dura is much more likely to invade the brain than tuberculosis in these situations. It is a well-known fact that old syphilitic processes are not always amenable to medication. Gumma of the skin, bones, tongue, etc., which have for years resisted antisyphilitic medication, have healed after thorough excision. It would seem rational to employ a similar method of procedure in cases of pachymeningitis syphilitica which provoke cerebral disturbances and do not yield to any other method of treatment. Indeed, in some instances, it is best to attack the disease surgically before the cerebral cortex and medullary substances become invaded, and important functions be permanently impaired or destroyed. Early interference is especially indicated in instances where the process is located in the region of the centers concerned in functions essential to the maintenance of useful life. Experience in other portions of the body teaches that the antisyphilitic medication becomes again effectual after removal of an obstinate focus.

In order to complete the subject, mention should be made that **Actinomycosis** may extend to the brain and form areas of infection within its substance.

Perforating Sarcoma has a tendency to extend outward causing ulceration and destruction of the bone, and appears upon the surface of the skull in the form of an artheromatous mass in the scalp. Occasionally, however, the growth takes place toward the brain. A separate chapter is devoted to consideration of dural sarcoma.

In the class of cases just discussed, in which the brain is secondarily involved by extension of the process, the treatment involves a combination of trephining, dural section and brain resection. As these steps are given detailed consideration in other portions of this work they need not be taken up here.

Operations at the Base of the Brain

In order to gain access to the base of the brain for the purpose of attacking tumors in this situation, it is necessary to lift the brain with broad, flat retractors. I employ for the purpose the form of instrument used for exposure of the ganglion of *Gasser* (Fig. 27) and the spatulæ shown in Fig. 28. The

Fig. 27

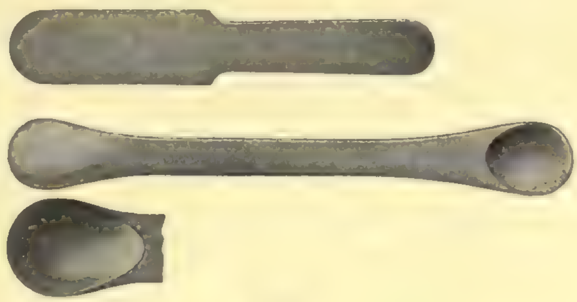

Fig. 28

one shown in Fig. 27 is slightly curved at the handle end. An important consideration is, whether the approach is made after the dura has been widely opened or the dura be displaced with the fingers, dull periosteal elevator, or by means of small gauze wipes attached to slender sponge-holders. A certain degree of pressure upon the brain obtains in either instance. When the dura is left intact the retractor pressure is disseminated by the hard resisting dura, and pressure at a restricted area is avoided.

However, pressure upon the unopened dura raises the entire cerebral pressure by displacement of cerebro-spinal fluid as the outcome of compression. For instance, raising of the frontal lobe forces the cerebro-spinal fluid from the lateral ventricle toward the medulla oblongata and may give rise to disturbances of respiration and heart's action, which are at times of menacing import. To, in a measure, obviate this contingency the dura may be opened to a slight extent, and discharge of the cerebro-spinal fluid permitted. Beyond this, lifting of the brain is carefully executed, and the pulse and respiration subjected to persistent espionage during the procedure. To obviate venous bleeding from the dura and bone at the base of the skull, the wound beneath the tractor is loosely packed with gauze and the tractor firmly pressed downward. When the brain is permitted to reassume a more normal position, the bleeding from the dura stops. During these intervals the pressure on the brain is released.

The greatest difficulties are confronted as the outcome of insufficient illumination, this, of course, becoming more manifest as the depth of the wound is increased. Many surgeons employ electric forehead lamps or similar apparatus. The writer has been able to succeed so far with daylight alone; however, side illumination from a high window is exceedingly desirable. The best artificial illumination apparatus is that manufactured by *Zeiss* at the instigation of *v. Eiselsberg*.

Operations upon the brain itself, of course, cannot be, like removal of the ganglion of *Gasser* and tumors connected with it (see chapter on this subject), accomplished without opening the dura. However, the first portion of these operations may be performed without section of this membrane, and thus the brain tissue be spared unnecessary manipulation. In this connection I submit a description of

Exposure of the Pituitary Body

based on the history of the following case. A technician, twenty years of age, as the outcome of an unsatisfactory love affair, fired a large-sized bullet (7 mm.) into his right temple. The immediate symptoms were severe but cleared up rapidly, and at the end of a month the patient was discharged cured. The Roentgengram showed the bullet located in the anterior cranial fossa resting upon the right orbital plate of the frontal bone (Fig. 29). At the end of several additional weeks he came again under observation suffering from severe cephalalgia, intermittent unconsciousness and disturbed mental operation. Removal of the bullet was regarded as indicated. An osteoplastic flap, 6 cm. wide and 3½ cm. in height, was fashioned at the right forehead lateral to the frontal sinus and the dura laid aside to a corresponding extent. When the dura was raised from the base of the skull the bone was found studded with small pigmented areas, evidently the result of the old injury. The bullet was found near the inner side of the orbital plate, close to the entrance of the optic nerve into the orbit. It was encased in a rather thick layer of periosteal tissue. After removal of the bullet the flap was replaced and sutured. The patient was operated upon in January, 1900, and recovered. Examination made near the end of 1907 found him entirely free from symptoms.

As I had succeeded in reaching the optic foramen

Fig. 29.
Revolver Bullet in Anterior Cranial Fossa, Lying on Posterior Part of Orbital Plate. Drawn from Radiogram.

from in front, in order to extract the bullet, it seemed feasible to approach the pituitary body in the same way.

As shown on Plate XVII, the technique is as follows: A right-angled osteoplastic flap, 5½ cm. wide

Fig. a.

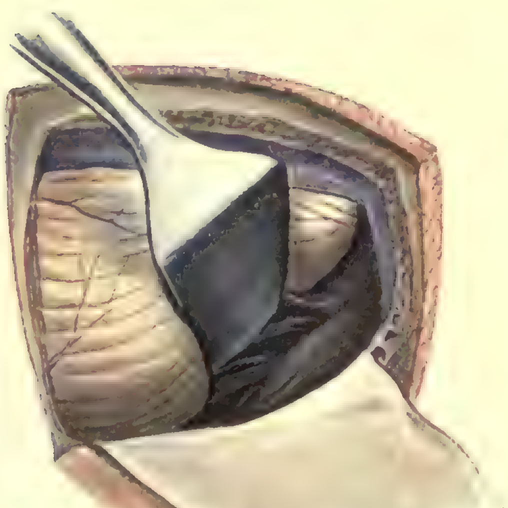

Fig. b.

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and 5 cm. in height, is made, the base of which is downward. To avoid the longitudinal sinus the median section is made 1½ to 2 cm. lateral from the median line. This oblique avenue of approach is better than the more direct route. The dura of the frontal lobe is now in view. At first the manipulations are made extradurally, since, as has been already stated, less disturbance attends the lifting of the frontal lobe when the brain is protected by the dura in this manner. The dura is loosened from the upper surface of the orbital plate as far back as the lesser wing of the sphenoid bone. Here the dura is opened in a vertical direction on a line with the lower median angle of the wound at a depth of 5 cm. (better a half cm. farther forward), measured from the anterior surface of the frontal bone. If the incision in the dura be made at a deeper point there is danger of injury to the optic nerve which is covered by the dura in this situation. Laterally the dura is opened parallel with the posterior border of the lesser wing of the sphenoid bone about ½ cm. in front of it, to avoid the sinus which lies immediately in contact with the edge of the bone. That is, the incision is made on the upper roof of the orbit. This exposes the optic nerve, coming from the chiasm and to the side the cerebral carotid. The pituitary body is located beneath the anterior edge of the chiasm. It is to be noted that the peduncle of the pituitary body arises from the brain behind the chiasm, but that the hypophysis itself lies in front of the chiasm. I have convinced myself of this relationship by observations upon the cadaver, which I have also verified upon the living, justifying the illustration showing this arrangement. The wound is somewhat deeper than is required for removal of the ganglion of *Gasser*, measuring from the anterior edge of the bone 6½ to 7 cm. in depth, according to whether the approach is made from the median line or to one side. The diaphragm of the Sella Turcica is now carefully incised with a small hook-shaped scalpel and the hypophysis is readily removed.

The method has not yet been employed for removal of tumors of the pituitary body, but has been used in the instance of enucleation of a large

Tumor at the Base of the Skull

which was located exactly at this situation. The patient, a woman, aged thirty-four, had been under observation since the end of 1904, in *Schloesser's* Polyclinic, for disturbances of vision. *H. Oppenheim* diagnosticated "a tumor at the base on the left side in the region of the chiasm in the middle portion of the middle fossa of the skull. It is not," he proceeds to state in his report, "possible to state whether the growth has its origin in the base of the skull or in the brain itself. The early occurrence of characteristic eye symptoms (ultimately left amaurosis, right temporal hemianopsia) argues for the base of the skull, so also does the late appearance of hemiparietic manifestations on the right side." The Roentgengram showed an unusual shadow in the region of the Sella Turcica. In addition to this,despite the fact that the patient suffered great discomfort, the body weight had increased thirty pounds (from 115 to 145) as the outcome of adipose deposit and the skin had become markedly dry.

The first step of the operation was performed as follows: After preliminary control of bleeding by the *Haidenhain* method, in which manner I isolated a spherical triangle, the base of which corresponded to immediately below the supraorbital ridge. This space measured 12 cm. at its base, beginning at the median line, and ended 2 cm. in front of the external auditory meatus. At the median line the space measured 13 cm. and at the side of the skull 15 cm. in length. In this case I directed the base of the osteoplastic flap upward, so that in case it became necessary to remove the orbital plate of the frontal bone and the lesser wing of the sphenoid, the tongue of soft parts delivering nourishment to the flap would not be interfered with; also, because turning the flap down over the face would not have conserved asepsis. The bone was sectioned at a distance of 22 mm. lateral from the median line, and the flap measured 66 mm. in all directions. The lower outer drill hole perforated the greater wing of the sphenoid bone. The incisions through the soft parts were made unusually large, and were carried through the fibers of the temporal muscle, as enucleation of the tumor was regarded as of doubtful expediency, and if the operation were to be restricted to simple decompression exposure in this manner was necessary.

Consequently, after fracture of the base of the flap and its displacement, the three upper trephine openings were enlarged an additional centimeter, so that the exposed area reached to 2 cm. behind the lesser wing of the sphenoid bone. At this time the anterior branch of the middle meningeal artery was injured and deligated with a ligature passed round it with a needle. At the lower edge of the wound the dura was torn to the extent of a centimeter, and the brain forced its way through the tense dura. The protruding brain was supported with a gauze wipe while the lower edge of bone, *i. e.*, the upper edge of the orbit, together with a portion of the orbital plate, was removed with chisel and biting forceps to sufficient an extent to expose the base of the skull corresponding to about what is necessary for removal of the ganglion of *Gasser*. The frontal sinus and the longitudinal sinus were not invaded during enlargement of the inner portion of the gap in the bone. The total area exposed by resection measured 80 mm. in front, 75 mm. behind, 82 mm. below, and 72 mm. above. The osteoplastic flap was replaced and sutured without drainage.

Three weeks later extirpation of the tumor was undertaken. The osteoplastic flap was strongly elevated, and at the edges in the line of the skin incisions soft pseudo-fluctuating masses could be quite distinctly palpated. When the scars were opened a considerable quantity of degenerated brain substance welled out. Displacement of the osteoplastic flap revealed that the prolapsing brain tissue had been forced through the tear in the dura, which occurred at the first operation, as the outcome of the increased intracranial pressure. The macerated brain tissue was wiped away and without regard for the tear, the dura was separated from the upper surface of the

Fig. b.

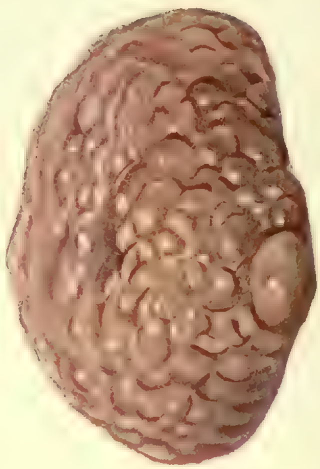

Fig. c ($^1/_1$).

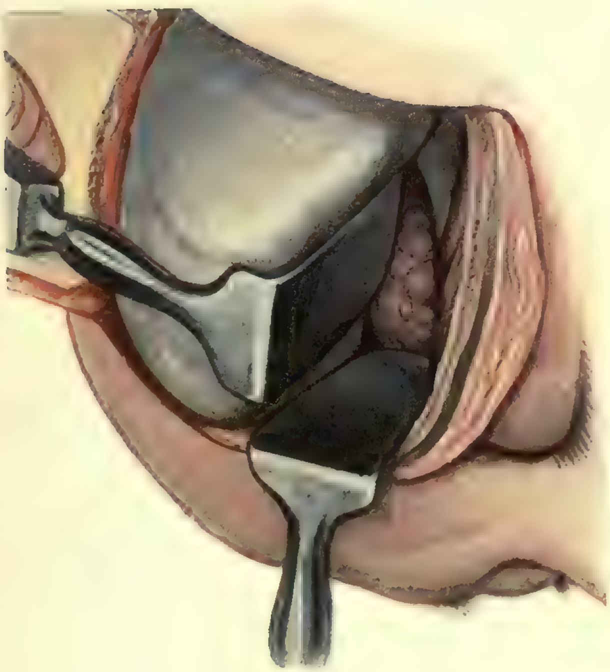

Fig. a.

orbital plate of the frontal bone with wipes until the posterior border of the lesser wing of the sphenoid was reached. This measure was readily accomplished. The longitudinal sinus became visible at the median side of the opening, but was not injured. The distended frontal lobe, still covered by dura, was now lifted with two spatulæ. The cerebral pressure proved to be enormous. My assistant made forcible traction with the spatula with both hands, using his entire strength, yet managed to gain only a finger's breadth of additional space. The brain felt like a strongly blown up rubber ball. However, as the bleeding was slight it was feasible to go beyond the lesser wing of the sphenoid into the middle cranial fossa and expose the beginning of the temporal lobe with its dural covering. This is shown in the illustration as a dark triangular area of dura.

Additional traction on the dura caused it to tear close to the free edge of the lesser wing of the sphenoid bone, accomplishing thus the intent as previously described. It was now possible to obtain sufficient room between the bulging brain and the upper surface of the orbital plate by traction with the spatula, to gain access to the space farther back and inward toward the region of the chiasm, exposing in this way a reddish corrugated tumor the size of the distal phalynx of the thumb (Plate XVIII, Fig. a). In order to determine the size and extent of the process I passed my left index finger into the wound, keeping close to the neoplasm. As its consistence was hard and resisting, I was able to separate it from the surrounding brain tissue. However, I was unable to reach its distal portion, and was forced to regard enucleation in this manner as impracticable.

I now loosened the still intact dura from the posterior aspect of lesser wing of the sphenoid and drew the anterior angle of the temporal lobe backward, together with its encasing dura. This permitted of a view of the left opticus which appeared as a grayish yellow band. I was able to demonstrate this to those present—including *H. Oppenheim.* At the same time an artery several millimeters in diameter came into view. Judging from its location this probably was the cerebral carotid or one of its terminal branches. I could not approach the tumor by the side of these parts, but succeeded in displacing them downward without doing any damage. I was now able to reach the distal portion of the new growth and loosen a portion the size of a walnut. By patient manipulations with the finger the tumor was divided into four pieces, which were enucleated. As the last piece was removed a rather sharp venous and moderate arterial bleeding occurred, which, however, was controlled by tamponade.

The tampon was removed in a few minutes and the extensive residual cavity inspected (Plate XVIII, Fig. b). On the right side the cavity was bounded by the anterior portion of the temporal lobe which now encroached toward the median line (in the illustration this appears as the two lower convolutions). At the bottom of the space the Sella Turcica was visible, which admitted the end of the index finger, leaving it fair to assume that it was not enlarged. The depth of the wound was from the skin in front to the extreme posterior surface 10 cm., reaching backward to the clivus *Blumenbachii, i. e.*, to the anterior edge of the pons. There was no evidence of remaining fragments of the growth. The tumor was quite globular though the surface was lobulated. When the fragments had been apposed it presented the appearance shown on Plate XVIII, c. which depicts the neoplasm in natural size. It measured 58 by 48 by 18 mm. The wound was closed by suture.

The operation was an exceedingly extensive one. However, the patient recovered sufficiently later in the day to demonstrate the absence of paralysis. The pulse rate, unfortunately, was 120 per minute at this time, and respiration quite labored. The latter became so hampered that frequently the lower jaw had to be pushed forward and the tongue held. Thirteen hours after the operation death, apparently from paralysis of respiration, occurred.

Autopsy made by *Professor Oestreich* showed the operation area to contain about a tablespoonful of blood, together with a small portion of macerated brain tissue. When the brain was removed a second intradural tumor was discovered in the left middle cranial fossa. It was located in the center of the fossa and was adherent to the lower portion of the falx cerebri and the lateral portion of the Sella Turcica. The bone had been invaded by the growth to a moderate extent. The tumor was about the size of a plum, hard, lobular and quite vascular. It had formed a depression in the left temporal lobe and caused an area of cerebral softening in its immediate contiguity. The Sella Turcica did not show any evidence of change. The bone was sawn across in the region of the hypophysis, disclosing that the tumor had involved about 2 cm. of the diaphragm of the Sella Turcica on the left side. Whether the pituitary body itself was involved was not discoverable. The cerebral carotid which had been exposed during the operation was clearly visible.

The right optic nerve was quite normal in appearance, white in color and round in outline; the left, thin, flat and reddish gray in color. The chiasm was displaced to the right and occupied an oblique position. The left motor oculi communis was flat, thin and gray-white in color. The other cranial nerves presented no macroscopical evidence of alteration. The arteries at the base of the brain did not show any degeneration. The longitudinal and transverse sinuses contained soft clot and some fluid blood. The entire arachnoid was flimsy and transparent. The convolutions of the cortex were flat and the sulci quite obliterated, the surface of the brain moderately wet. The left frontal lobe gave evidence of bruising.

The brain was not incised to permit of hardening in toto. The anatomical diagnosis of fibrosarcoma (region of Sella Turcica) was confirmed by the subsequent microscopical findings.

Caton and *Paul*[1] describe a

Temporal Approach

to the pituitary body. The formation of the osteoplastic flap is similar to that employed in resection

[1] *British Medical Journal*, 1893. II, p. 1421.

of the ganglion of *Gasser*. *Horsley* has made several operations of this sort, approaching the hypophysis by lifting the temporal lobe with a spatula after opening the dura. The S-shaped portion of the cerebral carotid is in the way when the approach is made in this manner, and should be carefully avoided.

My student, *W. Braun*[1], has demonstrated on the cadaver that extra dural approach of the Sella Turcica may be made by the temporal route by going beneath the cavernous sinus. However, the area exposed in this way is quite small.

Friedmann and *Mass*[2], in experiments upon cats, were able to remove the hypophysis by splitting the soft palate and drilling the body of the sphenoid in the median line. *Fritz Koenig* was able to do the same on adult cadavers. The danger of this method on the living is sepsis, and the fact that the field is very small. Also, it must be remembered that the pituitary body is completely surrounded by large vascular channels.

The Nasal Route

has been successfully employed by *Schloffer*[3] by daylight and without the aid of artificial illumination or reflectors.

The patient, aged thirty, was subjected to the following procedure. The entire nose was turned to the right in the manner described by *Bruns*. The

[1] For Exposure of the Central Portion of the Middle Cranial Fossa, Gasserian Ganglion and Cavernous Sinus, and the Hypophysis. *Deutsche Zeitschrift fuer Chirurgie*, Bd. 87, 1907, p. 157, ff.

[2] *Berlin Klin. Wochenschrift*, 1900, No. 52.

[3] *Wiener Klin. Wochenschrift*, XX, No. 21, 1907.

turbinated bones and septum, together with the inner wall of the left orbital cavity back to the optic foramen, the inner wall of the left antrum of *Highmore*, and a portion of the nasal process of the superior maxilla were excised. The ethmoid cells were then opened and removed, and last the cavity of the sphenoid was opened. Fifty-three millimeters back from the root of the nose a thin, transverse bony wall was opened with forceps, exposing a round pulsating tumor. The opening in the bony wall was enlarged, making a window 15 mm. wide and 10 mm. high and the dura incised and opened. The latter manipulation was followed by the protrusion through the window in the bone of a bluish mass. This was in greater part removed, piecemeal, with a blunt pliable tin spatula, and a small portion was left behind in the region of the hypophysis. The manipulations provoked very little bleeding. *Schloffer* was able to determine the size and form of the Sella Turcica with the probe. The larger cavity (in the Sella Turcica) was filled with balsam of Peru gauze, and a smaller tampon of the same material placed against the adjacent skull base, both of which were led out through the nose. The wound in the soft parts was sutured. The smaller tampon was removed on the sixth day, the larger from the Sella Turcica on the ninth. Histological examination showed the tumor to be an adenoma. The patient died suddenly two and a half months after the operation.[1] *Schloffer* does not regard the operation as

[1] *H. Schloffer*, Further Report of Case Operated upon for Tumor of the Hypophysis. *Wiener Klin. Wochenschrift*, XX, No. 36, 1907.

more difficult than removal of the ganglion of *Gasser*. Autopsy showed the wound firmly healed and the cavity filled with connective tissue. The size of the tumor had been underestimated. A large process of the growth had extended into the brain from the base of the skull and encroached upon the frontal lobe. *Schloffer* had estimated the portion of neoplasm left behind as one-fifth the size it actually was. It proved to be considerably larger than the portion removed.

Judging from the drawing accompanying *Schloffer's* last report, the main tumor mass would have been encountered, had my frontal method been employed, as it would have presented when the frontal lobe was lifted. *Per contra* it would not, perhaps, have been feasible to so readily invade the region of the Sella Turcica.

v. Eiselsberg[1] has employed a method quite similar to that of *Schloffer*. The nose was turned to the right side after the soft parts had been divided at its root. The septum was divided and the upper turbinated bones removed. Next the frontal sinus was exposed and its anterior wall resected with the chisel, the vomer excised piecemeal up to its origin, the periosteum pushed aside as far as the sphenoid and the anterior wall of the sphenoid cavity exposed. Now, *v. Eiselsberg* carefully gouged into the cavity, laying bare a glistening white membrane of the dimensions of a hazel nut. When this was incised in the median line a tablespoonful of sanguinous fluid escaped. A cyst occupied the space where the hypophysis is located.

[1] *V. Frankl-Hochwart* and *v. Eiselsberg*, on the Operative Treatment of Tumors of the Hypophysis. Verhandlungen der Gesellschaft deutscher Nervenaertzte und Neurolog. *Zentralblatt*, 1907, No. 21.

The incised wound pulsated clearly. As much tissue as could be removed from either side of the incision without damaging the chiasm and carotid was cut away with the curved scissors. Under the microscope the excised fragments of tissue appeared to be carcinomatous. The superficial wound healed in twelve days. The flattened glabella resulting from removal of the anterior wall of the frontal sinus gave the patient an exceedingly disagreeable appearance. Of course, the achievement cannot be regarded as a radical removal of the affliction.

Hochenegg reported a case of successful extirpation of the pituitary body, at the Surgical Congress at Berlin, 1908. The printing of this book had, however, progressed too far to permit of my taking the case up in this connection.

If it be necessary to approach other areas at the base of the skull and render them subject to inspection and palpation, the respective portions of the brain covering the parts to be invaded must be lifted in the same manner as obtains with the temporal and frontal lobes. The accurate observation of all the surfaces of the cerebellum is of signal importance, and for this reason the technique will be taken up at this time.

Inspection of all Surfaces of the Posterior Cranial Fossa and the Cerebellum

For this purpose the procedure I have used since 1898 will be found serviceable[1]. Above all the pia

[1] For Exposure of the Posterior Surface of the Petrous Bone and Cerebellum. *v. Bruns, Beitraege zur Klinischen Chirurgie*, Bd. 37, Heft 3, Seite 728.

mater covering the cerebellum, together with the ventral arachnoid, must not be injured. Despite its thinness it gives a certain amount of support to the cerebellum, while each trauma to it, especially if there be great cerebral pressure, is attended with protrusion of cerebellar tissue which interferes seriously with observation, and in some instances defeats entirely the object of the operation. If the patient be placed in the sitting posture it is feasible to approach wide areas of the posterior surface of the petrous bone by tilting the head to the healthy side, provided the cranial pressure be not great. The exposed cerebellar hemisphere sags to the dependent side without additional assistance. In this way the bone surface is sufficiently exposed to make visible a vein which usually enters the cerebellum from the superior petrosal sinus, and permit of its ligature. (Fig. 30.) If necessary, the cerebellum is displaced with a pliable spatula which can be adjusted to the outline of the several surfaces of the cerebellum (Fig. 28), or my own retractor used in approach to the *Gasserian* ganglion may be employed (Fig. 27). All displacements of the cerebellum are to be carefully and slowly executed, as in this way the increased intracranial pressure is gradually compensated for. Also in this manner dangerous disturbances of the respiratory and cardiac centers may be avoided, as I have been taught by experience.

The displacing of the cerebellum is accomplished in the following sequence:

1. Toward the median line (Fig. 30). This exposes the upper portion of the posterior surface of

the petrous bone, and the entrance of the acusticus and facial nerve into the internal auditory meatus. Additional median displacement of the cerebellum exposes these nerves backward to the pons.

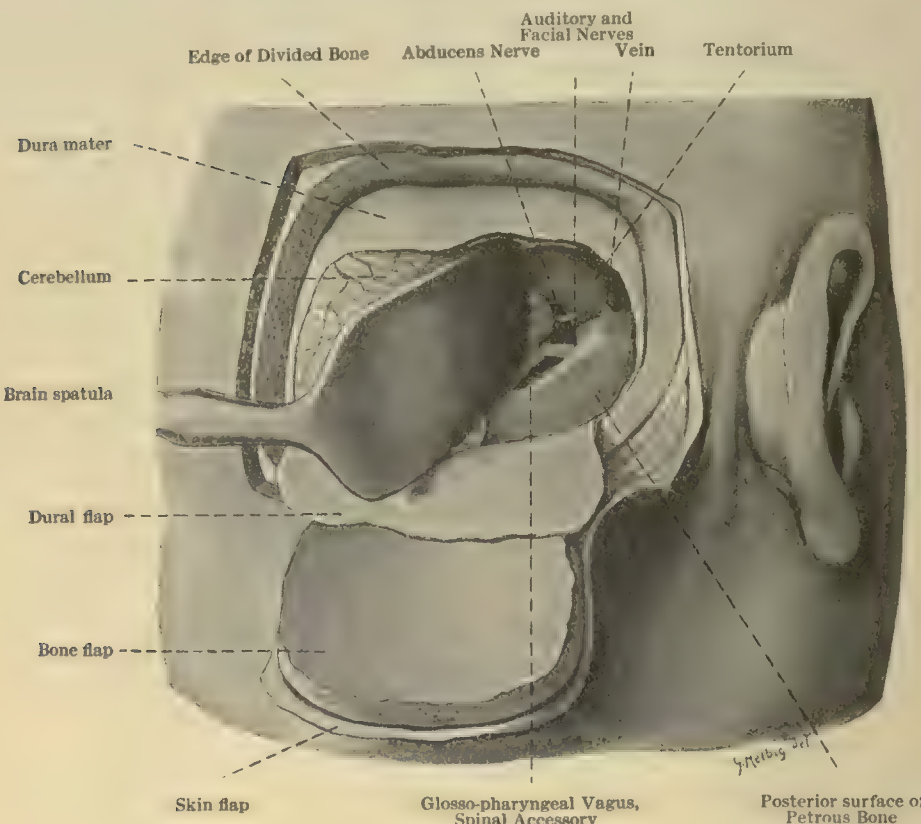

Fig. 30

Intradural Exposure of Posterior Surface of Petrous Bone

2. Obliquely backward and inward (Plate XVII, Fig. b.) exposes clearly the glossopharyngeal vagus and spinal accessory.

3. Directly upward—exposes still more the three nerves mentioned together with the posterior cranial

fossa. The spinal accessory, as it rises from the spinal canal and the side of the medulla oblongata, are clearly definable in this way.

4. Downward—exposing the upper surface of the cerebellar hemispheres. (See page 48.) These displacements do not give an obscure picture, but, on the contrary, the operator obtains a view of the more remote areas and can convince himself of the presence of neoplasms in the posterior cranial fossa or the neighborhood of the cerebellum. Especially in cases in which the intracranial pressure is not great, all surfaces of the cerebellum and the contiguous bones are readily inspected. If the intracranial pressure be markedly increased, as happens when solid tumors are present, the problem is much more difficult. The manipulations in these instances must be exceedingly carefully executed, and injury to the cerebellum assiduously avoided. Not until inspection and palpation of all surfaces are completed may incision or excision of the cerebellar tissue be undertaken for purposes of diagnosis. I make it an absolute rule to observe these precautions in all instances.

Consideration is to be shown the veins which ascend from the upper surface of the cerebellum to the tentorium cerebelli and enter the transverse sinus through its inferior wall. If they interfere with the procedure they should be doubly ligated and divided. Unintentional injury to these vessels may result in considerable bleeding coming from the sinus. However, in those instances in which bleeding has occurred from this source as the outcome of failure to recognize the sinus until obscuring hemorrhage occurs, the bleeding has been controlled by tamponade with gauze wipes.

Extirpation of Tumors at the Cerebello-Pontian Angle (Tumors of the Acusticus)

A separate chapter is devoted to extirpation of tumors located at the junction of the cerebellum, pons and posterior surface of the petrous bone. How they are approached has just been described. They are removed with ease when they originate from a nerve trunk, for instance, the acusticus, are isolated from the surrounding tissues and are encapsulated.

Plate XIX, Fig. a, depicts a specimen taken from a male patient, aged forty-eight, who developed pneumonia five days after the operation, and died four days later. The trephine wound was found quite healed at the autopsy. The tumor lost its connections with the surrounding brain when the arachnoid was removed from its surface and the neighboring parts of the pons, the medulla and cerebellum. A single white, soft strand, 2-3 mm. in thickness, maintained the connection. This had its attachment at the point of origin of the acusticus-facial bundle between the pons and olivary body. There was no clear line of demarcation between the tumor and the right half of the pons which, together with the contiguous medulla (especially olive) and the peduncles of the cerebellum, had been displaced and rendered impracticable of differentiation.

At times tumors of this sort fall into the space made by the displacement of the cerebellum with the spat-

Fig. a.

Fig. b.

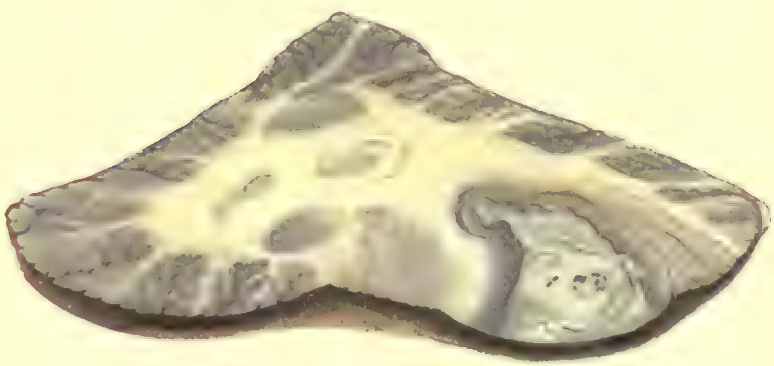

Fig. c.

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ula, and are easily removed when a few fibers of membrane are severed.

The surgical problem is, however, more difficult even when the tumor is differentiated by its color and consistence from the surrounding brain tissue if it be incorporated in the brain tissue itself. Then extirpation must be carefully accomplished. A case of this sort is shown on Plate XIX, Fig. b. The patient had been under the observation of *Geheimrat Ziehen.* The extirpation was done at one sitting, and as the general condition of the patient was menacing I sacrificed the bone in order to conserve speed.

As the right cerebellar hemisphere was displaced upward and inward with the spatula, the dark grayish red tumor appeared in the space between this hemisphere and the posterior surface of the petrous bone, being situated 5½ centimeters from the surface of the skull. The tumor was covered with a layer of connective tissue which I tore apart with a dull tenaculum, and attempted to deliver it with a sharp hook inserted into it. This maneuver did not succeed, as the hook tore out. I now introduced behind the tumor a large metal spoon, such as is used for the removal of gall stones, and lifted it out. The neoplasm was about the size of the distal phalanx of the thumb. It measured 18 mm. in breadth and 25 mm. in length and proved to be an encapsulated fibrosarcoma. The patient was discharged from the hospital cured. The clinical history will be found under Observation VII, 4. Fig. 31 shows the tumor drawn into its original location by the artist. The picture is arranged to show the base of the skull from above and the contour of the cerebellum, the pons and medulla oblongata are outlined on the bone corresponding to their normal relationship. The tumor was deeply located between these parts.

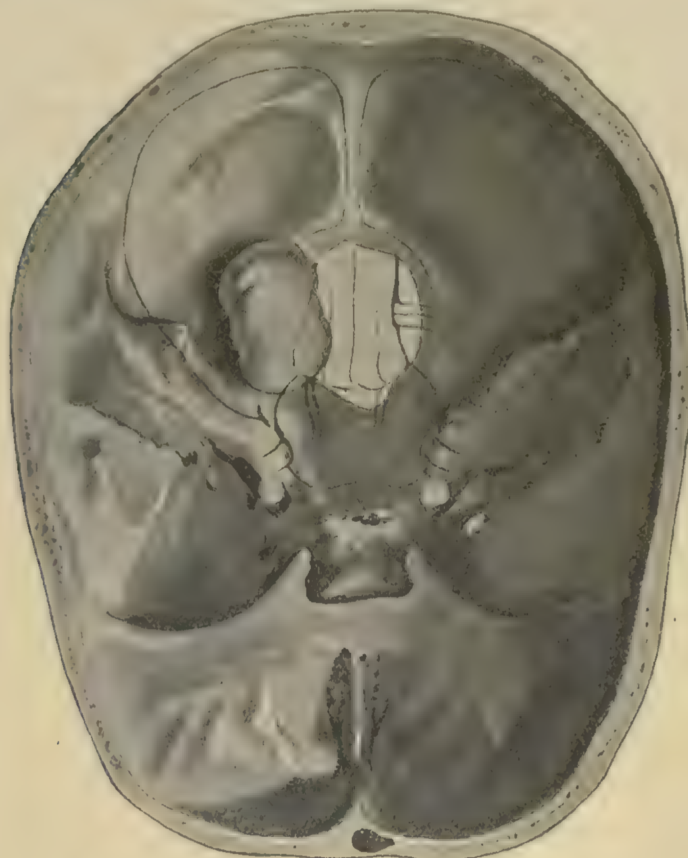

Fig. 31

Differentiation in color and consistence in this class of cases is not always as clearly marked as obtained in the case quoted. At times the color of the neoplasm is not different from that of the cerebral tissue, and what slight difference there might be, in this respect, is obliterated by the arachnoid which covers the tumor and the cerebellum. Identification of the growth is rendered still more difficult because the blood vessels cross the tumor without change in appearance from that presented over the normal brain tissue. As the outcome of intimate association the tumor may be displaced, together with the cerebellum, and thus escape recognition. In these instances the capsule overlying the region of the cerebello-pontian angle must be carefully torn apart with wipes—which suffice for the purpose, as the membranes are exceedingly thin in this situation—in order to find the line of cleavage between the normal cerebellum and the neoplasm.

The consistence of these tumors varies considerably and may be the cause of difficulties in extirpation. When they are very hard they can readily be enucleated by blunt dissection. It is best to employ for the purpose small wipes affixed to slender holders which may be used alternately with the pliable spatula or spoon. The most reliable instrument—the tactile finger—is not available in this situation, as it occupies too much room and may produce dangerous pressure disturbances upon the medulla oblongata. All manipulations should be slowly executed so as to permit of accommodation to the abnormal pressure on part of the brain tissue. The posterior surface of the petrous bone may be subjected to harsher measures, provided, however, these do not extend to the facial and auditory nerves. I have succeeded in removing the tumor, which had made pressure on both of these nerve trunks, from the patient last reported (page 135), without injuring them. Before the operation the otoscopic findings indicated complete loss of hearing; however, at the end of eight months, following extirpation of the tumor, the patient was able to hear whispered words with the previously afflicted auditory apparatus.

After the tumor has been loosened from the cerebellum and the posterior surface of the petrous bone, the last retaining connection at the pons is separated with the spoon or pliable spatula.

As an example of the method of extirpation employed in this class of cases the following history is submitted. The patient, a male adult, aged forty-four (Observation VII, 6), was sent to me by *Professor Seiffer* with the diagnosis of a tumor at the angle of junction of the cerebellum and pons. On November 25th, 1907, the first stage of the operation was performed, and on December 4th extirpation accomplished. At the second operation only light chloroform narcosis was necessary, and only 5 g. of this agent sufficed for opening the wound and incising the dural flap. The rest of the operation was completed without narcosis, owing to the unfavorable general condition of the patient. This, however, did not give rise to any pain. The incisions through the dura were made immediately contiguous to the three sinuses. The first incision into the dura was attended by a forcible discharge of cerebro-spinal fluid which subsided into a less vehement flow as the other incisions were made. Division of the falx cerebelli was not necessary, and although the tumor was a large one, weighing 50 g., the field of exposure was ample for the purpose. When the cerebellum was displaced toward the median line the tumor came into view, being recognized by a slight elevation from the surrounding tissues (Fig. 32, see below). Its

Fig. 32

color was the same as that of the cerebellum, and its surface presented blood vessels which were symmetrically continuous with those of the surrounding brain. The arachnoid covered the tumor in the same way as obtained upon the normal tissues. The thin capsule of the neoplasm was now opened with small wipes held in slender forceps; at the site of junction of the cerebellum with the mass and at the same time the blood vessels were torn across. This step began at the lateral side of the cerebellum, and the tumor was gradually loosened from its attachments by gently continuing the blunt separation over the greater part of its surface. This was accomplished without damage to its substance as its consistence was somewhat firmer than that of the brain tissue itself. At one point—at its upper surface—it was necessary to tear some nerve fibers with which it was quite firmly associated. (Facial and Auditory?)

Not until the tumor had been separated to beyond its equator did I advance farther, carefully inserting a thin pliable brain spatula (Fig. 33). With this instrument the tumor was now detached from the posterior surface of the petrous bone and the contiguous basal ganglia—at the same time watching carefully pulse and respiration—and delivered in toto. The residual cavity measured 9 cm. in depth and presented on its inner surface a marked indentation in the pons and medulla oblongata. A rather brisk arterial hemorrhage continued to well up from the inferior surface of the cavity, which was controlled by gauze tamponade and slight pressure. The end of the tampon was led out of the wound at its lateral lower angle. The osteoplastic flap was held *in situ* with sutures. The tumor measured—from before backward, 55 mm.; from right to left, 46 mm., and 45 mm. from above downward. The patient tolerated remarkably well the operation despite the fact that during the few days immediately preceding the extirpation, his general condition had become menacing. Pulse and respiration remained good until suddenly, at the end of five hours after the operation, respiration ceased, and this was followed by cardiac paralysis. The autopsy did not disclose any hemorrhage. The gauze tampon filled lightly the cavity and was moderately soaked with bloody serum. The opening in the bone reached quite to the foramen

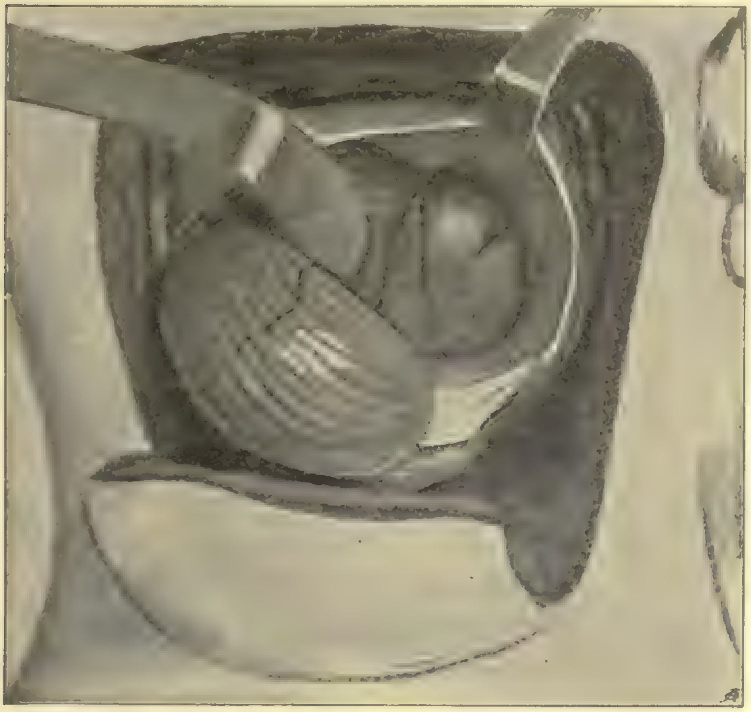

Fig. 33

magnum, being separated from it by a narrow rim of bone. To the left the breach extended considerably beyond the median line.

Only when—as in this case—the tumor is removed *en masse* can the operator be certain that the entire growth has been extirpated. Still the parts contiguous to the residual cavity should be carefully scrutinized for portions which may have been left behind, especially if the consistence of the neoplasm does not differ palpably from that of the brain. The conditions are markedly less favorable when, for any reason, the tumor needs be removed piecemeal. In these instances complete extirpation is always an uncertainty. This may be illustrated by relating the history of a patient (a woman of fifty-five) sent to me by *H. Oppenheim*, with a diagnosis of tumor of the right acusticus. The neoplasm was quickly exposed, being located beside the cerebellum; however, despite all precautions it tore repeatedly as the outcome of its friable (not soft) character, though at no time was traction made nor the tenaculum inserted. The mass was removed in five pieces which comprised a total size equal to that of a plum. The immediate subsequent behavior of the case was excellent, the wound healed by primary intention and the patient was regarded as out of danger. On the eighteenth day following the operation the pulse suddenly increased and respiration became labored. A light pneumonic infiltration did not seem to account for the disturbance, and three days later the patient succumbed. Autopsy showed the brain membranes to be normal, but only half the tumor had been extirpated. The remaining portion reached 1 cm. beyond the anterior edge of the pons. This, of course, made the tumor inoperable.

Sarcoma of the Arachnoid in the Posterior Cranial Fossa

In the rare instances in which sarcomata, which

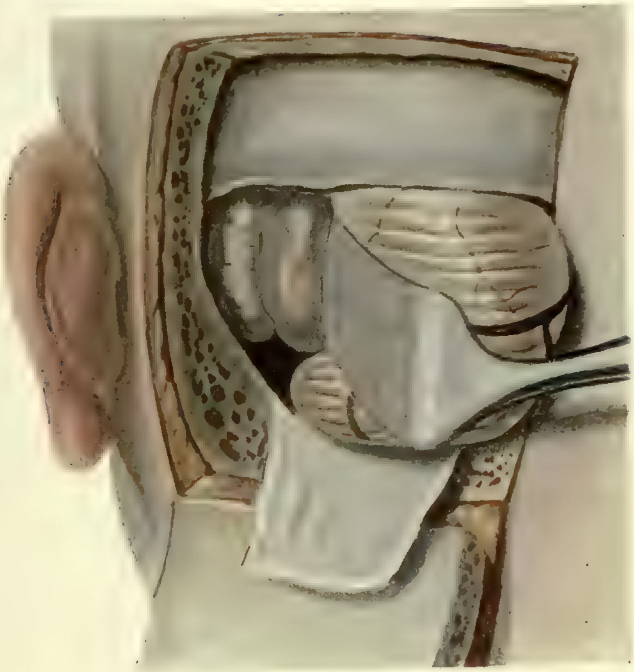

Fig. a.

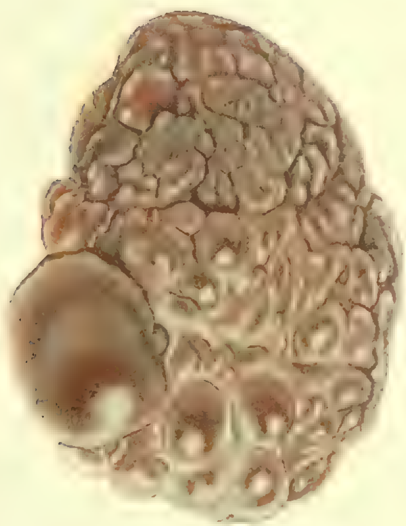

Fig. b (1/1).

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have their origin in the arachnoid, are situated between the cerebellum and the posterior surface of the petrous bone, extirpation is accomplished in the same manner as obtains with tumors of the acusticus. An example of this sort is submitted in Observation VII, 5, which relates the history of the most extensive new growth I have as yet encountered in this situation.

Extirpation of the tumor was accomplished in two stages, the first being performed on May 2d, and the second May 14, 1906, in the case of a boy of sixteen. Median displacement of the cerebellar hemisphere with the spatula exposed at the depth of 3 cm. a bluish, opalescent, smooth, slightly fluctuating tumor, which presented a diaphragmatic constriction (Plate XX). The tumor was about the size of the cerebellar hemisphere, and because of its smooth surface I was able to encompass it with my little finger; it was, however, slightly adherent to the posterior surface of the petrous bone, and evidently extended downward into the occipital foramen. I now passed a large blunt spoon along the median aspect of the growth and attempted to lift it from its bed *in toto*. The thin capsule tore; however, the greater part of the mass was delivered (48x40x28 mm.). The rest was removed in a similar manner. The neoplasm measured as a whole 8 cm. in length, 5 cm. in breadth, and 3 cm. in thickness (Plate XX, Fig. b). A slight arterial hemorrhage occurred which was readily controlled by tamponade of the residual cavity. The latter was 7 cm. in depth.

Up to the time of introduction of the blunt spoon pulse and respiration were undisturbed. The moment the tumor was enucleated respiration suddenly ceased, which was resumed, however, after several minutes of artificial efforts directed to this end. The osteoplastic flap was held in place with sutures. Four hours later death occurred suddenly. The pulse had until this time been rapid but of good volume.

Section of the brain after formalin hardening showed that the tumor had grown into the contiguous brain tissue, causing deep indentures and displacement of fibers in the pons and medulla, together with atrophy of the fibers of both these organs. It was not possible to determine whether the neoplasm had caused any changes in the contiguous cerebellar hemisphere, as this was the seat of hemorrhagic infiltration, the outcome of the arterial bleeding which occurred during the operation, and the normal appearance of the organ was effectually obliterated. Microscopical examination did not give additional information in this regard as the glia of the cerebellar hemisphere appeared as irregular fibers lying in a mass of coagulated blood.

The hemorrhage was probably not alone the result of the bleeding at the time of the operation, but was the outcome of analogous conditions that occur in the arteries of the mesentery after removal of large neoplasms from the abdominal cavity. In our case the capillaries of the pia mater, arachnoid, the pons and cerebellar substance were suddenly relieved from the pressure caused by the growth, and the consequent influx of blood caused the hemorrhages. In this way I accounted for the hemorrhage which extended into the olivary body, the cerebellum and the left cerebral peduncle.

The microscope showed the tumor to be an œdematous spindle-celled sarcoma in which a few islands of fiber detritus and glia cells were present. To the naked eye the surface of the tumor presented more nearly the conditions seen in tumors of the spinal arachnoid than obtains with neoplasms situated at the cerebello-pontian angle, chiefly, however, because it lost its bluish color and was much reduced in size after removal.

The autopsy also revealed an unusually marked hydrocephalus of the entire four ventricles of the brain.

Tumors of the Cerebellum

Extirpation of tumors of the cerebellum may be accomplished together with sacrifice of considerable cerebellar tissue. The technique is readily performed even though only one half the cerebellum is exposed. If carefully executed one third and even one half a cerebellar hemisphere may be removed without—in my experience—grave consequences. I have not met with important bleeding. If further invasion becomes necessary, section of the falx cerebelli and opening of the adjacent posterior cranial cavity becomes necessary. The more room the operator obtains toward the healthy side, the more readily is the one involved approachable.

At an autopsy made five months after the operation the entire cerebellar hemisphere was absent. The patient had been constantly under observation in the hospital from the operation until death occurred, and at no time did symptoms present which could in any way be traced to this fact. The case was one of a girl (nineteen years of age) who had received an injury of the head when fifteen years of age. This was followed by cephalalgia, chiefly at the back of the head, vertigo, vomiting, tachycardia, dysphagia, left-sided tinitus aurium, and general convulsions. The vision became reduced, double-choked disk appeared, and locomotion became uncertain with a tendency to stagger toward the left. After prolonged observation *Geheimrat Ziehen* diagnosticated a tumor of the left cerebellar hemisphere and sent the case to the Augusta Hospital. (For further details see Observation VIII, 3.)

On June 27th, 1904, I exposed the left posterior cranial fossa, sacrificing the bone. The dura was tense and did not pulsate. As the dural flap was turned aside a moderate quantity of clear fluid escaped. The exposed cerebellum pulsated, and beyond a small thickened area of the encasing pia did not present any abnormality. The thickened roughly granular portion of the pia, together with the subjacent cortex, was removed for microscopical examination. Careful inspection and palpation of the contiguous surface gave negative results. Exploratory incision into the cerebellar tissue was also negative of result. The wound was closed by suture.

The immediate outcome was favorable, the symptoms disappeared, the violent headache disappeared from the day of the operation, in fact the entire general condition of the patient improved. The patient left the bed on the 28th of July. The wound was healed except for a surface the size of a silver dollar, corresponding to the lateral incision, at the site of which a white mass of brain tissue protruded. This was cut off with the scissors. It became necessary to repeatedly remove in this manner protrusions of brain tissue which varied in size from that of a hazel nut to that of a walnut. In each instance the removal was accompanied by discharge of large quantities of clear fluid. From the end of August the patient went about during the day, and by September 10th had gained 12 kilos in weight. At this time the general condition was not so favorable—the outcome of retained fluid. Removal of a prolapse the size of a silver quarter of a dollar liberated a large quantity of fluid, and the unfavorable symptoms disappeared. A drain was now introduced. After the beginning of October the patient lost ground and the release of fluid no longer afforded relief. Death from heart failure occurred November 12th, by which time the patient had become reduced to almost a skeleton.

Autopsy showed marked hydrocephalus internus, especially of the fourth ventricle, and an almost entire absence of the left cerebellar hemisphere (Fig. 34). The improvement had been due to relief of the compression, the outcome of the trephining. The loss of substance of the left cerebellar hemisphere did, of course, not occur at one time, but was the outcome of the frequent removal of the prolapsed tissues. No symptoms referable to the loss of cerebellar tissue were present at any time.

From the view-point of this case it seems fair to assume that extirpation of neoplasms of the cerebellum may be accomplished at the expense of loss of considerable cerebellar tissue if it be necessary to widely excise them. So one would, in a case of conglomerate tubercle (Plate XIX, Fig. c), not be content with simple removal of the involved area, but

Fig. 34

would widely excise the surrounding healthy tissue.

The illustration shows a case of a young man, aged seventeen, who was afflicted with a tuberculous focus in the region of the central fissure (page 112). Autopsy revealed an additional tuberculous invasion of the right cerebellar hemisphere the size of a walnut, which originated at the under side (lobulus semilunaris inferior) and diffusely infiltrated the cerebellar substance. The center of the tubercle was devoid of blood vessels. The fissures of the cortex did not extend to the surface of the mass. Horizontal section showed a central area of softening outlined with a yellowish fatty zone, which extended from the cortex in a circle into the cerebellar tissue over an area the size of a silver half dollar. The edge of the tumor was entirely surrounded by displaced gray and white fibers.

I am firmly convinced of the necessity for thorough removal of diseased brain areas, together with the contiguous healthy tissue. I am, however, opposed to the sacrifice of normal cerebellar substance with the view of making more readily accessible the posterior surface of the petrous bone in order to remove tumors of the acusticus. I regard the displacement of the cerebellum in various directions as described on page 131 as meeting thoroughly the indications. *Per contra* I regard

Exploratory Section of the Cerebellum

for diagnostic purposes as not alone justifiable but as positively indicated under certain circumstances. Subsequent to liberal exposure of the posterior cranial fossa and delivery of the suspected cerebellar hemisphere, the exploratory section is easily made, and I have never experienced unfavorable manifestations as the outcome of the measure. The most complete exposure is obtained when the section is horizontally made, beginning at the lateral aspect of the hemisphere, and is carried to the median line to a depth of four centimeters. The cut surfaces are held apart with flat right-angled retractors. In one case, a boy of eleven (Observation VIII, 1), in which I sectioned both hemispheres in the manner stated, autopsy three years later did not reveal even a scar at the site of the original incisions.

Exploratory incision is important on the ground that deeply located tumors are not recognized as the outcome of either inspection, palpation or puncture. In this connection the reader is referred to the case of *Terrier* (page 48). *Terrier* attempted to reach the cerebellum by splitting the occipital lobe and division of the tentorium, and thus enucleate the tumor, but did not succeed. The patient died four months later, at which time the wound had entirely healed. Autopsy revealed a conglomerate tubercle the size of a mandarin located in the left cerebellar hemisphere. Exploratory incision would have disclosed the tumor and permitted of its removal.

In the case of a male nineteen years of age, after all other manipulations had failed to reveal a lesion in the exposed right cerebellar hemisphere, I made an incision into the part (4 cm. in depth), opening a cavity the size of a large cherry, situated in the white substance. The walls of the cavity were smooth, grayish red in color and moist, but no fluid was present. As the hemisphere had been liberally delivered from its bony fossa the cavity, together with the contiguous cerebellar tissue, was excised. The patient died two days later of heart failure. Autopsy revealed a similar cavity in the left unexposed cerebellar hemisphere, also an enormous dilatation of all the ventricles of the brain. The left posterior horn was the size of a plum and the fourth ventricle dilated to the size of the distal phalanx of the index finger.

Care of the Wounds of the Brain

Primary Suture

Every surgical attack upon the brain should be followed by complete arrest of all hemorrhage. Spurting arteries and the larger veins should be deligated. To arrest oozing I make temporary gentle pressure with gauze wipes. After this is accomplished the ideal conditions are to replace the dural flap, which I do not as a rule hold in place by suture, and to fix the osteoplastic flap by sewing without drainage in cases where an antiseptic outcome is to be expected. A small opening may be left in the superficial wound to permit of discharge of the slight amount of blood collection, which occurs for the first few hours immediately following the operation. Even after the removal of large tumors of the brain the technique spoken of may be employed, for it is astonishing how soon extensive cavities will obliterate as the outcome of the invasion of contiguous portions of the brain into the residual space. This is illustrated in the instances shown on Plate VI, Fig. c, and Fig. 26 (page 100).

Tamponade for Bleeding

Unfortunately, the method just indicated is not always feasible. At times the operation must be rapidly completed because of threatening general manifestations, and again it is not always possible to locate and ligate all the bleeding points, and at times, though more rarely, the venous bleeding is so great and diffused that it cannot be at once arrested. In all these instances it is necessary to introduce strips of plain or vioform gauze into the wound. However, this contingency represents rather an indulgence of emergency than the measure which should be the rule. The tampon is to be regarded as applicable to venous bleeding rather than effectual in arterial hemorrhage. Beyond this the tampon is likely to produce softening and, indeed, may, if applied in the region of the medulla oblongata, cause disturbance which menace the life of the patient. I always make tamponade with several wide strips of gauze which have woven edges, introducing them carefully into the cavity and close the wound with sutures, except for the space requisite to permit of egress of the gauze, and in addition introduce a narrow gauze drain into the area of operation close to the lamina vitra. The tampon causes some reaction, and if the portion of gauze lying on the skin becomes dry, and the exit of secretions and cerebro-spinal fluid is prevented, pressure occurs, which is obviated by the presence of the smaller drain. The gauze strips and drain are removed—depending upon the extent of bleeding—on the fourth to sixth day.

Tamponade in Cerebral Abscess and Tubercle

The treatment of the brain abscess wound is different. The entire cavity must be kept open to permit of healing from the bottom and to prevent retention of secretion. For the purpose I use iodoform gauze with the view of obtaining antisepsis. Of course, the osteoplastic flap is simply laid over the cavity and perhaps held in place by a few sutures. The dressing is soon saturated with cerebro-spinal fluid and the outer portions must be changed daily. The iodoform gauze tampon is not disturbed until the third to the fifth day.

I regard it advisable to tampon the residual cavity after removal of conglomerate tubercle for several days with iodoform gauze. Even though the merging of the foci have not taken place the excision of contiguous healthy tissue may not have effectually removed all the disease, and recurrence may appear. The technique is essentially similar to that I employ in tuberculosis elsewhere in the body. At the end of five days the wound may be closed by suture if no indication to the contrary appear. In the event of the latter contingency tamponade must be maintained until all evidence of infection has disappeared. In this connection the reader is referred to the case reported on Page 181.

Preparation—Dressing, Time of Repair

Posture of the Patient

During all operations upon the brain care must be exercised to avoid undue pressure upon the thorax and abdomen which might interfere with respiration. The top of the table should be arranged to allow of change of position on its transverse axis, so as to make it feasible to raise the head of the patient if venous bleeding be excessive (*v. Bergmann*), or to lower the same in the event of syncope.

The operating room should be warm (24–28° C.). Beyond this I lay the patient upon warm pads at the temperature of the body, and wrap the entire body in woolen blankets.

For **operations on the cerebrum** the patient is postured with the shoulders and thorax raised to a little less then an angle of 45 degrees. If the posterior portion of the head rests on the pad, *i. e.*, when the anterior portion of the skull is being invaded—the portion of the table upon which the pelvis rests is lowered a little while the upper body is caused to rise obliquely. This position is very secure. In operating on the side or posterior aspect of the head it is best to posture the patient on his side and allow the head to extend beyond the edge of the table. In all instances an assistant holds the head firmly with the fingers apposed to the jaw and cheeks.

When **opening the posterior cranial fossa** the patient may be placed on the sound side in such a manner as to bring the shoulder on a level with the edge of the table, a posture which makes readily approachable the area of operation. The head is held by an assistant, or, better still, may rest on the head supporter (see this chapter), as is employed by the writer during operations upon the spinal cord. In the case of fat persons or those who have short necks, this posture does not give sufficient room, and I employ it, as a rule, only for the first step of the trephining, although I have removed tumors of the acusticus on two occasions with the patient in this position.

As a rule the operator finds it convenient to be seated when invading the cerebellum. The head of the table is lowered slightly, head and shoulders are permitted to extend somewhat beyond the back support, so as to permit of ready approach beneath the posterior occipital protuberance. The assistant holding the head turns it sidewise or bends it forward, as the necessities demand. An assistant is detailed to watch the pulse and respiration. The region of the medulla oblongata, with the center of respiration and that of the heart, are likely to be disturbed, indeed, twice I was compelled to interrupt the operation for from ten to fifteen minutes to permit of reestablishment of function in this connection. The patient reacted very nicely; however, had the pulse and respiration not been closely observed a fatal issue on the table would no doubt have been the outcome.

Narcosis

I use chloroform for the purpose of narcosis, omitting previous administration of morphin. I observed the use of morphin-chloroform narcosis for seven years in *Volkmann's* clinic and have not been convinced of its advantages over simple chloroform narcosis, which latter I have employed since 1889. I do, however, use morphin in moderate doses in adults, to control the pain in the wound after the operation. Despite the great safety of ether, its use is not to be advised in brain cases, as its administration enhances venous bleeding. In rare instances I have used ether in cases of non-compensated heart lesions when operating for removal of the ganglion of *Gasser*. Chloroform lowers blood pressure, and if the exposed brain presents a marked hyperemia the dosage of chloroform may be increased, provided there be no indication to the contrary. As a general rule the administration of chloroform in operations on the central nervous system should be carefully executed, for in cases of cerebral tumors sudden death may occur without the additional dangers of narcosis. Death in these instances is due to paralysis of respiration, and the heart may go on functionating for a considerable period of time.

Because of the ready control of dosage I prefer the *Roth-Draeger* oxygen-chloroform apparatus. This apparatus possesses the additional advantage of permitting of the inhalation of pure oxygen which probably is desirable in the event of respiratory or circulatory disturbances. *Horsley* states that the inhalation of oxygen lessens both venous and capillary bleeding. When the color of the flowing blood changes from dark purple to light scarlet the hemorrhage usually ceases.

The brain itself is not sensitive. The actual attack upon the brain substance, which is, of course, the disturbing factor with regard to respiratory and cardiac failure, may be executed with very light narcosis. The scalp, periosteum and dura mater are exceedingly sensitive, the bone when denuded of periosteum is quite devoid of sensibility.

In discussing this portion of the problem the question arises as to the applicability of local anesthesia, and thus eliminates the dangers of narcosis. My experience leads me to the conclusion that only very minor manipulations of the brain, as for instance, brain puncture may be accomplished under local anesthesia. Pain is not the only factor entering into the proposition. The preparation for operation, the posture and complicated necessary manipulations, together with the mental disturbance and the extreme suffering the patient has already been subjected to, lead the observer to the conclusion that a carefully controlled general narcosis is by far more desirable. Still more important is the consideration that mental disturbance may cause a fatal outcome as shown in instances when cases previous to the introduction of narcosis died on the table before the operation had been commenced.

Rapidity of technique, as far as is consistent with safety, avoidance of unnecessary loss of blood, prevention of exposure to cold and strict asepsis, are the most important determining factors in this class of cases.

As far as

Asepsis

is concerned, I have the entire head shaved twenty-four hours before the operation and encase the cranium in a gauze dressing liberally soaked with a one-half per cent. formalin solution, and maintain the moisture by the application of a rubber tissue protective. Immediately before the operation the scalp is cleansed with warm water and soap, lavaged with a solution of corrosive sublimate 1 in 1000, then ether is poured over the surface, and last a normal saline solution is employed to dislodge the agents mentioned. For the purpose of cleansing the hands I have used since 1889 a free scrubbing with hot water and soap, followed by lavage with corrosive sublimate solution 1 in 1000. I have abandoned the use of alcohol in this connection as my own hands, and those of several assistants, did not bear well its use. I regard the care of the hands an important consideration, as smooth, soft skin is more readily cleansed than if it be hard and cracked. The use of glycerin and partially dried soap will be found a useful application to this end.

The sterile towels used in isolating the operative field are held in place with a few stitches to avoid their being displaced during the operation. Antiseptics are not permitted to come in contact with the wound. The sublimate solution is removed from the hands by drying them with gauze. In aseptic cases, iodoform is not employed either in powder, etherial solution or glycerin mixture. Iodoform gauze is also not placed in contact with the wound. If it be necessary to employ tamponade for the purpose of arresting bleeding, the cavity is filled with either sterile or vioform gauze. For ligatures and scalp transfixion (except the longitudinal sinus, page 37) I use thin linen thread. For suturing I employ silk.

The results obtained from dry dressings are sufficiently satisfactory to warrant continuance of their employment. Of sixty-four cases of extirpation of the ganglion of *Gasser*, together with numerous aseptic brain operations (excluding abscess and neglected compound fractures) we did not lose one case from meningitis, and, indeed, neither as an immediate outcome or after protracted lapse of time, as shown by the uncomplicated repair of the wound and the post mortem findings in those cases resulting in death. We operate with bare hands, which I use extensively for the purpose of palpation and enucleation of tumors, and do not employ—in aseptic cases—either gloves or the face mask. Of course, we guard carefully against manual contact with infectious material.

The Dressing

The portion of the dressing in immediate contact with the wound should consist of sterile gauze to avoid irritation of the skin which may arise if antiseptics be employed for the purpose. However, as brain operations in which tamponade is made are followed by discharge of large quantities of cerebrospinal fluid which soaks very soon the dressing, the outer layers of gauze should be impregnated with sterile iodoform with the view of furnishing a certain amount of antiseptic. A soaked dressing should not be permitted to remain *in situ* longer than a day, for this condition affords a favorable medium for the growth of bacteria. When the dressing is changed the surface contiguous to the wound is cleansed with gauze wipes soaked with ether.

The removal of sutures and tampons has already been sufficiently discussed.

Patients are not permitted to leave the bed for at least three weeks following the operation in cases of trephining for *Jacksonian* epilepsy. In instances where the brain has been extensively invaded confinement to bed for several months may be necessary.

Wound Complications

It is not within the scope of this work to discuss all the occurrences which may become manifest during repair of the trauma consequent to brain operations. The reader is referred for additional information in this regard to the added clinical histories. At this time only such complications will be taken up as call for surgical interference.

In clean cases, brain operations may be executed with the reservation that septic infection is avoidable. We aim to prevent the occurrence of moderate local sepsis, removing the sutures on the third to the fifth day, thus obviating occurrence of small necrotic areas of the soft parts. Especially is this desirable when a second step operation is to be undertaken.

Bone Necrosis

If separation of the periosteum is avoided necrosis of the bone rarely occurs in aseptic cases. Bone necrosis is very likely to occur if the periosteum is widely separated at the edges of the flap, and especially is it liable to occur in purulent processes. In the latter cases the cavity is tamponed, and this causes interference with nutrition in the bone. Owing to the consistence and thickness of the cranial vault demarcation and separation of necrotic bone areas is a prolonged process, and this together with carious degeneration of the edges of the bone sections may be maintained for months before ultimate healing takes place. No general rule as to whether removal of the diseased bone is indicated may be given the reader for guidance.

Early in my experience I had two cases in which extensive necrosis of bone occurred. Both cases were operated upon for removal of the ganglion of *Gasser* by my own osteoplastic flap method at the temporal region. The one case was one of one-sided resection of the ganglion, the osteoplastic temporal flap being fashioned with the circular saw. (August 23d, 1895.) The patient had been subjected to peripheral trifacial resection at which time a certain degree of hemophilia was discovered. Owing to the severe and persistent bleeding at the time of the intracranial neurectomy the operation lasted three hours. The prolonged hemostatic manipulations subjected the flap to considerable trauma and the periosteum was largely separated from the bone. Replacement of the flap was nevertheless made. The other case (the second attempt of the kind made by myself in 1892), that of a man, aged sixty-two, the intracranial resection of the second branch of the nerve required chiseling of the bone. The operation was performed on both sides at the same time, and owing to the enfeebled general condition of the patient the second wound was tamponed for five days before resection of the ganglion was undertaken. The consequent prolonged interference with nutrition resulted in necrosis. I have, however, quite abandoned tamponade, and close the wound with sutures in the manner already stated (Page 28).

In these two cases the bone necrosis was not accompanied by fever. The process expressed itself in an œdematous swelling of the skin flap and adjacent tissues together with puffiness of the lower eyelid. On the tenth day the wound was opened and the bone flap removed. The excised bone showed a thin layer of fibrinous pus on its inner surface. The scalp flap was replaced and sutured, and drainage introduced into the two lower angles of the wound. A small amount of purulent discharge accompanied the healing, which latter was achieved without rise of temperature.

Exfoliation of small portions from the edges of the bone flap occurred in two other cases under my observation. In neither case was interference called for. The necrotic bone was eliminated in the form of fluid discharge. The process was exceedingly protracted, the fistulæ remaining patent for eight and ten months respectively. To prevent occurrences of this sort the edges of the bone flap which have been denuded of periosteum should be removed with the biting forceps. Accidental separation of periosteum is prevented by the application of my claw forceps, depicted on page 19.

Secondary Hemorrhage

Secondary bleeding into the defect in the brain remaining after operation gives rise to dangerous manifestations which not infrequently threaten life. This may be illustrated by the case of a merchant, aged twenty-three, (Observation VII, 1) who presented all the symptoms of tumor of the cerebellum.

After opening the posterior cranial fossa a cyst was incised (Page 65) and the cavity tamponed with vioform gauze. At the end of five days the tampon and the drain were removed at which time no fluid secretion was discharged. During the few days following the operation the marked symptoms of cerebral compression had disappeared and the less manifest symptoms had much improved; however, four days later the evidence of cerebral compression again appeared. When the dressing was removed a large quantity of clear fluid poured from the lower right angle of the wound. The osteoplastic flap manifested definite pulsation. Despite this fact the compression symptoms did not diminish, the temperature rose in the evening to 39.5 and 40. There was no rigidity of the neck, but dysphagia and subconsciousness rapidly developed. For these reasons I felt justified in opening two days later (eleven days after incising the cyst) the entire wound. Clear fluid dripped constantly from the lower left corner of the wound, and the osteoplastic flap, which had quite advanced toward repair, pulsated visibly. While the skin was being shaved and cleansed with ether a rather forcible stream of clear fluid bubbled out of a grayish granulating area located at the center of the wound (about 20 cm^3. in quantity). However, I regarded it as proper to expose the entire operation field in view of the patient's menacing general condition. The osteoplastic flap was rapidly turned down with the closed scissors.

The exposed cerebellum appeared normal, its surface was smooth and shining and of the same color as at the previous operation. There was no swelling, softening, necrosis or pus present. The only abnormality presented on the surface of the left cerebellar lobe in the form of a slightly protruding area the size of the distal phalanx of the thumb, which was dark blue in color and corresponded to the site of the cyst opened at the previous sitting. The incision into the cerebellum had quite healed, but was now bluntly separated, exposing a cavity the size of a plum which was tensely filled with coagulated blood. This was gently expressed and the cavity tamponed with vioform gauze. The osteoplastic flap was sutured into its original position. The following day the more marked symptoms of compression disappeared. The tampon was removed on the fourth day, and two days later the sutures were removed.

The disturbance was evidently due to the fact that after the tampon had been removed (five days after the operation) the cerebellar wound became glued together, and bleeding occurred from the not yet obliterated vessels in the cyst wall which distended the cavity. The coagulum, acting like a tumor and together with the retained fluid, provoked the symptoms of compression. After the second operation recovery went on to completion without interruption which was still maintained at the end of a year and a half.

In two cases of cortical excision for *Jacksonian* epilepsy it was necessary to reopen the operation wound because of blood and fluid collections which produced menacing compression symptoms. The first case was that of a man, aged thirty years, (Observation I, 9) who was subjected to cortical excision on October 15th, 1902, after locating the primary spasm area with the Faradic battery in the forearm, hand and face centers. The operation did not make any serious impression on the patient's general condition. The pulse was regular, quite full and strong (80). The immediate course was favorable, the drain and gauze strip being removed on the fourth day and the sutures three days later. The temperature reached 37.8 at the end of thirty hours, and fluctuated in the neighborhood of 37 until the eighth day, when it rose to 38.7 degrees. The evening of the day of operation the pulse rose to 128 but slowly dropped to 92. Simultaneously with the increase of temperature the pulse rose again to 128. There was no evidence of meningitis, and the wound was healed except for the drainage openings.

The patient became subconscious and complained of bladder tenesmus. Radiating pains in the thigh developed and the entire right leg was markedly weaker than it had been during the latter few days. The muscles of the thigh were contracted. The evidence of irritation pointed to a focus in the leg center. On October 23d, under chloroform narcosis, I opened the entire wound, which required the knife for the purpose, owing to the firm union already established, and turned aside the osteoplastic and dural flaps. We found a brownish red firmly coagulated clot lying on the surface of the brain at the upper portion of the exposed field by the side of which clear fluid oozed out. When this was removed the corresponding surface of the brain glistened, but was slightly infiltrated with bloody exudate. A few strips of iodoform gauze were laid on the involved area and the dural and bone flaps replaced after a small drain had been introduced. The next day the temperature fell to 37.9 degrees, and the following day to 37 degrees. The pulse dropped to 104. Restlessness and the other symptoms disappeared. Repair of the wound occurred without further complications. The tamponade was renewed with sterile gauze every three

Fig. 35.

days and continued for fourteen days (until November 7th), at which time the bone was pushed into the space in the skull. As hernia cerebri did not develop, the bone healed into place without disturbing the normal outline of the skull. (Fig. 35.) On December 29th the patient was discharged. In the other case of *Jacksonian* epilepsy the disturbances were the outcome of

Retention of Fluid

The patient, a feeble boy, aged twelve years, had quite overcome the effects of excision of the hand center (Observation I, 5). The temperature had risen once, on the evening of the day of the operation, to 38.5, the pulse to 136. On the second day the record showed temperature 37.5, pulse, 96. Despite this the patient at this time became restless and vomited persistently, although he had quickly recovered from the effects of chloroform after the first operation. There was no interference with the movements of the head, and indeed, he showed no symptoms of meningitis. His appearance was unfavorable and the general condition so enfeebled that he did not retain the smallest nutritive enema. As the conditions continued to grow more menacing and endangered life, I lifted, on the third day after the operation (October 27th, 1907) the large osteoplastic flap (60x80 mm.) and the dural flap (50x78 mm.) emptying out a small quantity of coagulum and a large amount of cerebro-spinal fluid. After the introduction of vioform gauze the dura and superficial flap were replaced without suture. The next day the patient retained a soft boiled egg and four rectal injections of 100 cm^3. each. The color of the face improved and was no longer greenish yellow, as it had been the day before. Improvement continued with slight fluctuations. On October 30th the flaps were again lifted and the gauze removed. At the site of the cortical excision a single strip of gauze was introduced which was removed on November 2d. The dressing continued to be saturated with cerebrospinal fluid until November 16th. The flap was not sutured, but nevertheless healed in place on the level with the contiguous skull without any residual bulging. On November 29th the boy was discharged, in perfect physical and mental health. Six months later the patient reported in perfect health.

Unfortunately, I am unable to explain the severe symptoms which presented as the outcome of the comparatively moderate local findings. In none of the other numerous cases subjected to operation for epilepsy did I observe similar manifestations.

Oedema and Softening of Brain Substance

Even in thoroughly aseptic wounds œdema and softening of the brain may occur, in the region of the operative field.

These changes are, as regards intensity, primarily dependent upon the extent of surgical trauma. If the operation be restricted to simple cortical excision for *Jacksonian* epilepsy, the more or less extensive paralysis immediately following the operation disappears at the end of a few days. The characteristic disturbances dependent upon removal of a certain motor center, however, remain. (See Chapter on **Epilepsy**.) If traumatic degeneration develop in the contiguous brain tissue additional paralyses appear, which are dependent upon involvement of adjacent foci. The process is not necessarily accompanied by systemic manifestations. The symptoms of œdema and softening appear usually, if at all (which is not frequently the case), about a week following the operation, and disappear in a short time.

Following removal of tumors the process is likely to be quite extensive, the outcome of severe trauma to the brain substance. The cause of these encephalitic, œdematous softening processes as they may be designated, may be explained as follows. The growth of the tumor has exercised a harmful pressure upon the invaded brain tissue, the extirpation has necessitated division of blood vessels which also has robbed the surrounding parts of nutrition. Division of nerve fibers always provokes œdematous saturation and swelling in the region of the trauma, as has been observed in the peripheral nervous system. All these factors aided, perhaps, by small hemorrhages cause a condition of softening, which, in the majority of cases of aseptic operations, is limited to the immediate neighborhood of the operative field and does no great harm. On the other hand the process may extend and lead to a fatal outcome, as shown in the following instance.

The patient, a laborer, aged forty-four, (Observation III, 5) was subjected to operation March 15th, 1904. I removed a cortical glioma from the lower portion of the anterior central convolution after deligating the approaching veins, excising an area 35x39 mm. in diameter and 20 mm. in depth. (Plate XXI.) The wound in the brain was covered with vioform gauze, over which the dural flap was laid. The osteoplastic flap was replaced and held with sutures except for a small area.

The dressing was changed on March 21st. The wound was healthy and the gauze strips were removed. The general condition of the patient was satisfactory. On March 29th the scar was normal, but a pulsating prolapse the size of a walnut protruded from the anterior inferior angle of the incision.

The patient stated that on this day the movements of the right leg were less certain and weaker than immediately after the operation. On April 12th the prolapse appeared considerably flatter. The general condition remained good. Appetite and intestinal functions were normal; however, the patient complained of intermittent headache. From the 29th of March the right lower extremity showed paretic symptoms. On April 4th clonic spasm of the quadriceps appeared. The aphasic disturbances which had followed immediately after the operation became more marked, though the psychic functions remained normal. The conditions in the trephine wound continued to improve. On April 20th the still decreasing prolapse showed signs of dermatisation and by April 26th the hernia had receded to the level of the surrounding skin.

However, the general condition of the patient became worse, vomiting occurred once. In the next few days the vomiting increased and the paralysis increased, though no spasm occurred. Beyond the headache no symptoms of brain pressure developed. Choked disk did not appear. After the 29th of April the patient did not speak except to answer questions; urine and fæces were passed involuntarily. The next day the general condition was slightly better. From May 1st matters took on a worse form, the left side of the body became paralyzed and deglutition became difficult. Up to this time the pulse remained below 76 and the temperature normal. May 2d the pulse was 98 in the morning and 110 in the evening, respiration 28 to 30. Death supervened on the morning of May 3d after paralytic and bronchopneumonic symptoms appeared. Vomiting and convulsions did not recur.

Autopsy showed the surfaoe of the brain richly covered with thick veins which quite effectually obscured the fissures. The sagittal end of the left

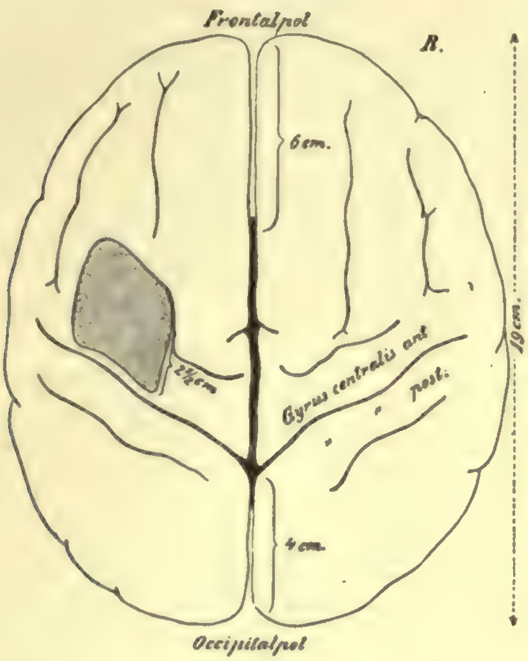

Fig. 36

fissure of *Rolando* corresponded to a point 4 cm. in front of the posterior pole of the left cerebral hemisphere, which latter measured, from its anterior to its posterior aspects, 19 cm. The fissure of *Rolando* met at the point designated the longitudinal fissure. Two and a half centimeters inferior to this point the anterior central convolution presented a defect which corresponded to the site of operation. (Fig. 36.)

The contiguous convolutions were slightly tinged with yellow. The irregular anterior border of the defect encroached upon the frontal convolutions. Frontal section disclosed beyond the defect mentioned the fact that the greater part of the left cerebral hemisphere was infiltrated with dark red and black

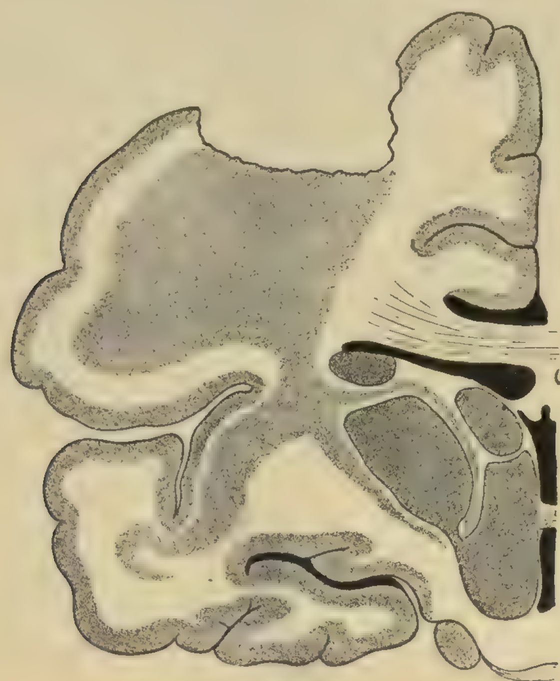

Fig. 37
Frontal Section at Middle of Third Ventricle

hemorrhages (the dark areas in Fig. 37 and Fig. b, of Plate XXI), which extended toward the median line to near the longitudinal fissure and downward to the level of the fissure of *Sylvius*, involving, however, only the white substance. The gray matter was not invaded, the crus was not involved, and the process had extended between the

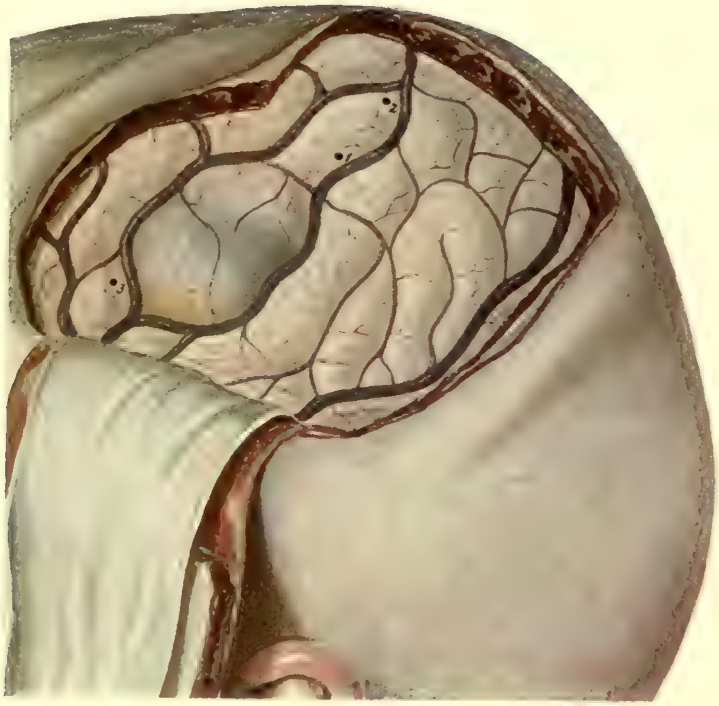

Fig. a.

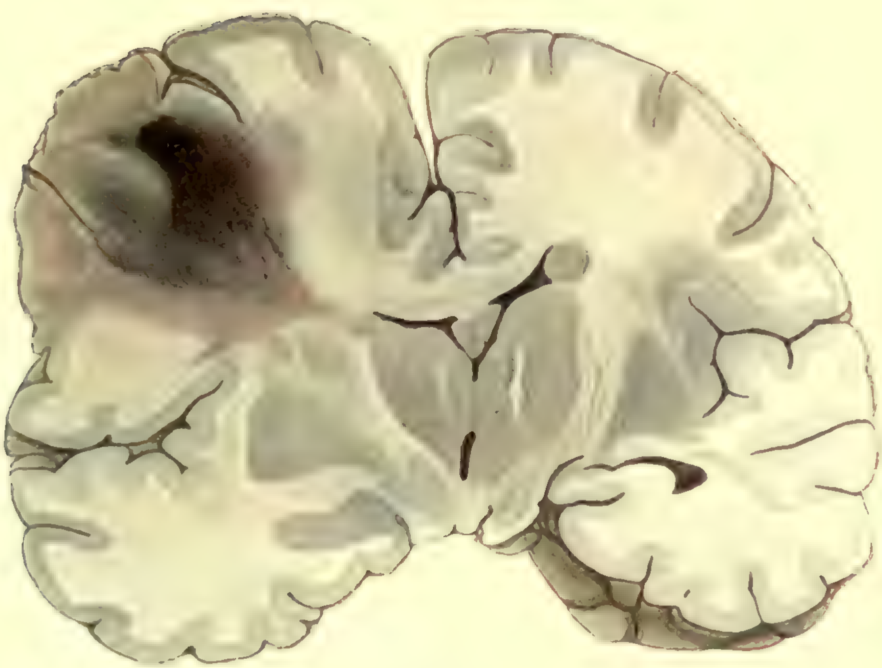

Fig. b.

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cerebral peduncles and the optic thalma, leaving the basal ganglia unaffected.

It was evident that the bleeding had begun beneath the fissure of *Rolando* and extended throughout the entire left hemisphere, involving an area of 11 cm. Judging from the anatomical and microscopical findings death had been caused by hemorrhage and softening.

In some instances a fortunate

Discharge of Degenerated Brain Substance

occurs and the threatening symptoms disappear. This is illustrated by the following case (Observation IV, 1). A woman, aged thirty-seven, had been subjected to removal of a fibrosarcoma, the size of a mandarin, from the left island of *Reil* (page 78). At the end of twelve days following the enucleation, a quite complete paralysis of the opposite arm occurred, which was followed by paresis of the lower portion of the face and muscular weakness of the leg a few days later. The aphasia which had improved after the operation became again manifest, speech disappearing entirely. The involvement of motor centers contiguous to the site of removal of the tumor justified the belief that the cause of the paralysis was either an œdema or softening of the respective foci in the central region. In addition, the patient showed some evidence of irritation, headache, pain in the wound, and increased pulse rate (100). Though the temperature did not rise sharply the remissions were more marked than had previously obtained. The consciousness was dull, though this cleared up in a few days. The paralysis, however, remained for several weeks and gradually cleared up entirely while speech returned but slowly. During this time the drainage opening discharged at first large quantities of serous secretion together with disintegrated particles of brain substance, which gradually lessened in amount. Further details of the case are related in the clinical history.

This observation would seem to teach that a policy of non-interference together with close espionage of the manifestations is justifiable. Every attack upon the brain, indeed, the comparatively simple reopening of the osteoplastic wound involves additional trauma to and pressure upon the brain substance, which may cause softening. On the other hand the discharge of disintegrated brain substance was manifestly of benefit in this case. Much experience and some good fortune are requisite to enable the observer to determine what is best in a given case.

This sort of

Superficial Necrosis of Brain Substance Contiguous to Tumors

has been but rarely encountered by the writer. They are not of importance, and will be discharged spontaneously provided the avenue of egress be of sufficient dimensions. A secondary operation may, however, be requisite if the necrosis occur beneath a healed trephine opening, and the process has not created a mode of egress at some distant part. In the case just mentioned the trephine wound had healed except for a small opening at the lower anterior angle of the wound, where the end of the gauze tampon had emerged. At this place a fistula remained, which did not heal despite the cessation of the discharge of brain substance and a small thin drainage tube was inserted. Removal of the drainage tube was followed in a few hours by clonic contraction of the muscles of the opposite side of the face and hand and forearm. At the same time the patient who, up to this time, had been entirely free from symptoms, became restless and complained of headache, which originated from the site of the trephine opening. When the drain was re-inserted a few drops of thin fluid pus were discharged, and the symptoms promptly disappeared. As the conditions did not improve, and each attempt at discontinuance of the drainage was followed by recurrence of the symptoms stated, it was concluded that a necrosis existed in the direction of the drainage which was located obliquely backward and upward under the bone flap. The drain entered the area to 1½ cm. from its point of exit at the anterior border of the wound.

Eleven weeks and a half after extirpating the tumor I exposed the bone in the direction of the drain with an oblique incision, and made an opening in the corresponding portion of the bone flap with the burr, the size of a silver quarter of a dollar. The bone was normal in appearance. The opening exposed at once the grayish red brain, which was covered with blood vessels of the arachnoid and pia. (The dura had been removed at the time of the operation of extirpation.) Immediately below and beside this normal brain area a surface the size of a finger nail and of bluish yellow color presented, which was evidently a thin layer of necrotic brain tissue. The sound introduced through the drainage opening reached this spot. The necrotic area was excised, using the sound as a guide, and the latter pushed through, making a counter opening for drainage at the posterior aspect of the original trephine wound. There was no exudate present. Introduction of a drain behind and tamponade with vioform gauze of the wound ended the operation, which healed by granulation in a few weeks.

It is evident that the spontaneous discharge of brain substance had not resulted in removal of all of the necrotic area. The trephine wound had healed posteriorly and the resisting osteoplastic flap prevented complete separation and discharge of the dead tissue. The fistula, which was 5 cm. long, was too narrow for the purpose, and only after a free avenue of approach had been made behind did the latter heal. If the technique employed would not have accomplished the desired end, it would have been necessary to split the bony roof of the fistulous tract with the *Gigli* saw or excise a narrow strip with the *Dahlgren* forceps.

Discharge of Cerebro-spinal Fluid

Cerebro-spinal fluid constantly trickles from the surface of brain prolapse in considerable quantity and especially so from the site of the wound in the brain itself, saturating quite rapidly the dressings. The illustration on Plate XXIII shows the fluid pouring over the field of operation. In one case of exploratory incision into the motor zone, which disclosed a tumor of inoperable dimensions, the subsequent discharge of cerebro-spinal fluid was so large in quantity as to arouse the suspicion that the lateral ventricle had been invaded. The autopsy performed several months later proved the contrary.

At times the amount of cerebro-spinal fluid discharged bears a relationship to the size of the hernia. I have observed variations in this connection in two instances of trephining for removal of neoplasms which proved inoperable. If the discharge of fluid was free the hernia became perceptibly smaller and less tense. This always occurred when large quantities of clear fluid had been thrown off for several consecutive days. As the lateral ventricle had not been opened in either instance it seems fair to assume that at these times the œdema had been relieved by the discharge of fluid.

The outflow of cerebro-spinal fluid may not occur even if large openings be made in the dura, if there be no increase of intracranial pressure at the time of the operation. In any event the loss of cerebro-spinal fluid ceases very soon if the wound is sutured. For this reason immediate repair of the wound is desirable. Under these conditions the dressing remains dry and need not be changed until healing takes place.

The loss of considerable quantities of cerebro-spinal fluid influences to some extent the condition of the patient. Patients complain of headache, especially marked at the posterior aspect of the cranium, feel weak, are apt to hold the neck rigid, though no other symptoms of meningeal irritation appear. Considerable rise of temperature frequently accompanies the symptoms just related. When the discharge of fluid lessens in quantity the symptoms promptly disappear. I have also observed these manifestations (minus rise of temperature), in some cases after extirpation of the ganglion of *Gasser*, when the dura has been torn while separating the upper surface of the ganglion because of firm adherence to the former. In these instances the brain itself is not invaded, and this proves the contention with regard to the influence of loss of cerebro-spinal fluid better than operations on the brain.

On the other hand, the well being of the patient depends upon maintaining the outflow of cerebrospinal fluid as shown in cases operated upon for hydrocephalus. In these cases arrest of the outflow gives rise to headache and other disturbances. In this connection I may state that considerable rise of temperature occurs when the dressing becomes dry.

If for any reason infection occurs, the trephine wound must be at once freely opened. The entire diseased brain area must be exposed in order to determine the necessity for incising the brain, enlarging the opening in the bone or of splitting the dura. All dead spaces should be lightly packed with sterile iodoform gauze and drainage strips introduced. The wound should be kept open until healthy granulations appear.

Brain Prolapse

In a previous chapter, the writer has already stated that primary suture of the wound should be made whenever possible. A great disadvantage of leaving the wound open is the consequent occurrence of hernia cerebri. Even though intracranial pressure is relieved and thorough asepsis has been observed, and the pia be uninjured, brain prolapse may occur in a few days to a sufficient degree as to preclude closing of the wound with sutures, although, indeed, this is not frequently the case under the conditions mentioned. In one case (an epileptic youth of eighteen), an unusually severe hemorrhage in the region of the longitudinal sinus necessitated leaving several forceps *in situ*. The exposed brain surface which had not been injured was tamponed. Three days later the tampon and forceps were removed under light narcosis. The bleeding had ceased, but the brain bulged so tensely from the opening in the dura that the osteoplastic flap could only be sutured at its sides, and, indeed, this was accomplished with considerable tension. Above at the sagittal aspect of the wound a strip 2 cm. in breadth was left open, and this was filled up with tensely protruding brain substance. At the next dressing (six days later) the prolapse had receded and the brain lay at its normal level. Twelve days later the wound was healed and the trephine area did not extend beyond the normal outline of the skull.

If it is feasible to close with suture the major portion of the wound, and tampon beneath the flap, the undesirable occurrence of hernia is most generally obviated. If the opening be small, hernia occurs (when the three factors mentioned above obtain) only when the injury to the pia mater is located immediately beneath the bone wound.

If it is found necessary to maintain tamponade for a prolonged period of time (if the pia be injured), the prolapse may reach enormous dimensions as shown in Fig. c, on Plate XXIII. This patient (twenty-eight years of age) was sent to me by *H. Oppenheim* with a diagnosis of neoplasm situated in the middle portion of the central convolution and the contiguous parietal lobe. (Observation V, 1.) I made the trephine operation, fashioning a flap 78x90 mm. on March 24th, 1906, and followed with the second stage on April 2d. After making the dural flap with its base toward the sagittal line to avoid invasion of the longitudinal sinus, I found in the situation mentioned two subcortical abscesses which were separated by a diaphragm. (Plate XXII, Fig. a.) The abscesses were sacculated, and when opened the lower one was found to be the size of a digital phalanx and the upper one that of a plum.

The dividing wall was incised and the two cavities converted into one. (Plate XXII, Fig. b.) The abscess cavity was lined with a thick, hard membrane. Extirpation of the membrane (the pus was full of tubercle baccilli) was abandoned because of collapse of the patient at this time and the wound cavity was tamponed. On April 11th a spherical prolapse protruded through the opening in the bone. The entire tuberculous focus (62 mm. high, 46 mm. wide and 28 mm. thick) was removed with the closed scissors, a portion of the contiguous normal tissue being included in the enucleation. Narcosis was not employed. (Plate XXIII, Figs. a and b.) Iodoform gauze tamponade of the wound was made. On April

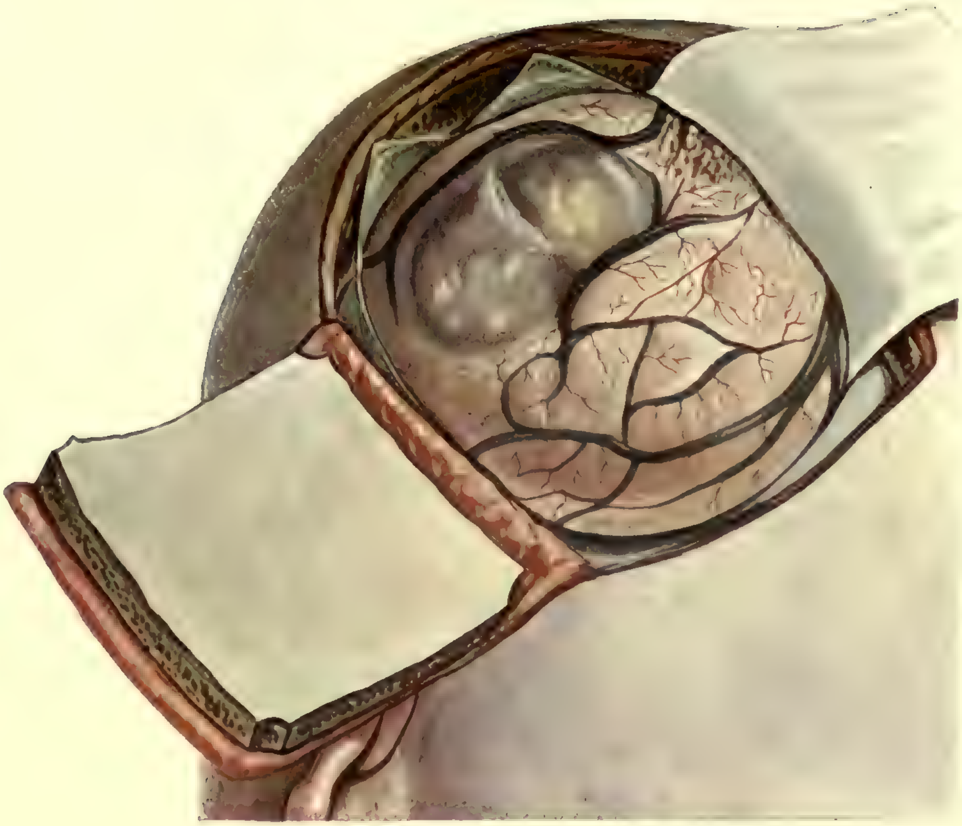

Fig. a.

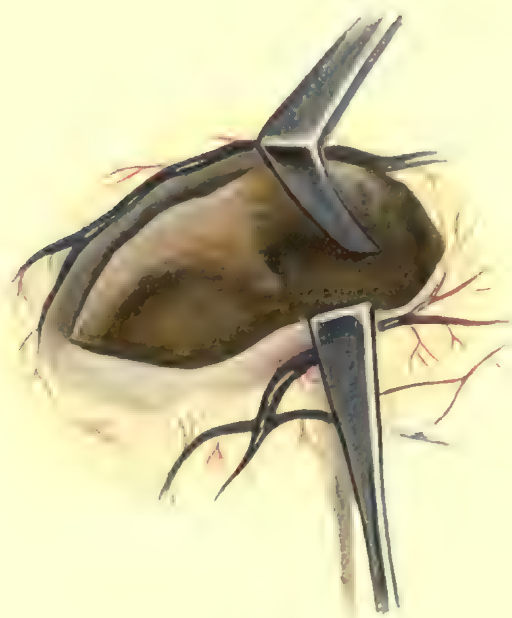

Fig. b.

Fig. a.

Fig. b ist der Schnitt α—β von der Fläche gesehen.

Fig. c.

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14th, the dural flap which had shrunk considerably was placed over the area.

The illustration (Plate XXIII, Fig. c) was prepared by the artist during a change of protective dressing, while the head was resting on its occiput. The prolapse was very soft in consistence, about one

Fig. 38

and a half the size of an adult fist, and sagged down over the posterior edge of the wound. At its dependent portion a fold was formed which looked not unlike a double chin. Where the brain substance had been excised (which part was slightly less protuberant than the rest of the prolapse) cerebro-spinal fluid constantly trickled drop by drop. The lateral ventricle had not been opened during the operation. On May 3d, the general condition of the patient and the local manifestations permitted of plastic closure of the wound, chloroform narcosis being employed for the purpose. The skin surrounding the wound was reflected to a sufficient extent to permit of approximation of the edges of the wound by suture, though this was accomplished under considerable tension. Small open spaces remained, however, which, at the sagittal aspect of the wound were about the breadth of the finger. In this situation the dural flap formed a satisfactory covering (page 34). By June 7th, the wound was entirely healed. The trephine area bulged but very slightly beyond the normal outline of the skull. (Fig. 38.)

Treatment of Prolapse of the Brain

As appears from the report just offered it is apparent that I attempt to cover the prolapse with the surrounding skin in order to obtain healing, even though this be accomplished with considerable tension. As this procedure was effective in the difficult case just related it follows that the method is more readily successful in the event of smaller, less pronounced protrusion. Relief from the small extrusions is obtained as the result of light but persistent pressure by the application of several layers of gauze held *in situ* with strips of adhesive plaster. In instances where the wound has been aseptic and no discharge of cerebro-spinal fluid occurs, I have seen protrusions the size of a hen's egg become dermatised without plastic aid, though occasional applications of copper sulphate crystals were made. At times a certain degree of protrusion of the healed area has been maintained for some time, though indeed, these ultimately disappeared as the result of cicatricial contraction.

How long conservatism and consequent delay in the application of radical measures may be justified is illustrated in Observation XIV, 3. The patient, a woman (aged thirty-six), was subjected on July 26th, 1899, to trephining by the *v. Bergmann* bone section method, the bone being resected. A large foul-smelling abscess located in the temporo-sphenoidal lobe was opened. The abscess cavity (4 cm. in diameter) was freely incised throughout its entire extent, the opening being made from before backward. The space was packed with iodoform gauze at intervals until August 4th. During this time a hernia formed which, by August 12th, reached the size of a large apple, and by August 20th had become still larger and markedly tense, displacing the external ear downward, causing its border to come in contact with the lobule. In accord with the discharge of a large quantity of cerebro-spinal fluid the prolapse slowly diminished in size without anything being done beyond the application of moderate pressure with dressings. On September 14th the prolapse had entirely disappeared, the granulating brain substance lying on the level with the opening in the skull. The patient was discharged from the Polyclinic two days later. Several weeks later the wound had entirely healed and the pulsating scar was no higher than the level of the surrounding skull.

Amputation of the prolapsed brain is deprecated by the writer. Of course, it is true, that the greater portion of the protrusion consists of œdematous, saturated tissue, the product of inflammatory infiltration, and that brain substance does not form a large proportion of the extrusion, also that removal by section of small herniæ does not do much harm. However, the protrusion recurs very soon after its amputation, if plastic repair of the normal restraining tissues be not made at once. For special reasons amputation of the prolapse is justified, as is illustrated in the case mentioned above (page 146).

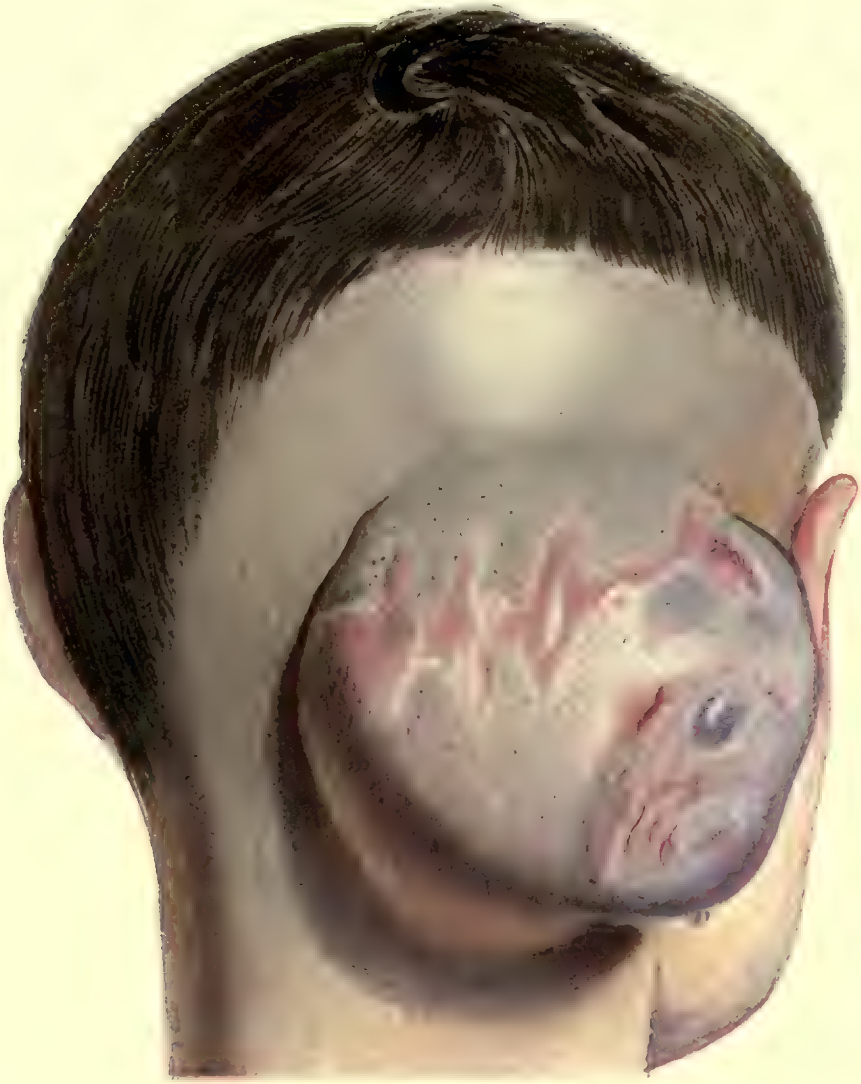
The conditions are quite different and more difficult to surmount when the prolapse occurs together with increased intracranial pressure, the result of tumor, hydrocephalus, hemorrhage, abscess or inflammatory products; indeed, from any cause. In these instances the brain crowds into the opening in the skull (especially if the causative factor, which has increased the intracranial pressure, is not discovered at the operation or is not removed) with such force as to convey the idea that its replacement into the cranial cavity is impossible. Yet this may be accomplished by elevating the upper portion of the body, replacement of the osteoplastic flap and suture of the latter, even though this be done under considerable tension. Thus, gradually, closure of the wound will be achieved throughout its greater extent, and the portion not susceptible of approximation will be exceedingly small. If it be necessary to keep the trephine wound open with tamponade, while increased intracranial pressure persists, enormous prolapse is likely to occur. The prolapse disappears, however, when the cause of the increased intracranial pressure is removed. In abscess of the brain, for instance, as has been shown in the illustrative case cited above, the hernia disappears when the inflammatory product recedes and the entire process may end in complete healing.

Decompression Trephining

In a wide sense prolapse of the brain includes those protrusions of the trephine area which occur as the result of recurring tumors, or when removal of the neoplasm has been impracticable. Depending upon the technique of the procedure, they are covered by skin and bone or skin alone, or in the region of the cerebellum also by muscle, and in addition are also covered to a greater or lesser extent by scar tissue. It would be more consistent to differentiate these conditions by designating the form of protrusion just described as hernia in contradistinction to those extrusions which protrude from the cranial cavity without the coverings mentioned.

An example in this connection is shown on Plate XXIV. This case was one of a woman of forty-four, which has already been quoted (page 135), from whom I removed a tumor located at the cerebellopontian angle on June 22d, 1905. The picture was taken in April, 1906.

In a general way the diagnosis of cerebral tumor is not attended with especial difficulty. Its localization is, however, an exceedingly difficult problem. In operating for cerebral tumor the surgeon must at all times retain the reservation that even after extensive osteoplastic resection of the skull, the tumor may not be found or again may not be susceptible of enucleation. The latter contingency is more likely to be pres-



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ent in cases where the tumor is located beneath the cortex than if it be a cortical process. Under these circumstances no other course remains than closure of the wound with sutures. Under the latter circumstances it is not rare to find a palpable improvement of the symptoms following the operation. The gradual elevation of the trephine area compensates for the lack of distensibility of the normal cranial vault. As a consequence the intracranial pressure is lessened or disappears, and hand in hand with this the disturbing symptoms are relieved. These favorable manifestations have led to the establishment of artificial cerebral hernia or so-called decompression trephining in cases of non-localized cerebral tumors.

The **technique** of decompression trephining does not differ essentially from that described above. *Horsley*[1] removes large sections of bone for the purpose, and expresses himself as opposed to the osteoplastic resection as is employed and strongly recommended by the writer. In order to obtain an effective vent it is, of course, necessary to fashion a large osteoplastic flap to allow for widening of the edges of the breach with the biting forceps. The latter is accomplished after the periosteum is removed. The width of excised bone should be no less than 1-2 cm. and should extend around all four sides of the opening.

The dura mater must be opened widely. It is true that I have seen several cases of tumor extirpation which have shown a certain improvement as re-

[1] On the Technique of Operations on the Central Nervous System. *British Medical Journal*, Aug. 25, 1906.

gards compression symptoms after the first stage of the operation, when the dura had not yet been invaded. In one case the patient had been somnolent and suffered from violent cephalalgia. Raising of the osteoplastic flap was followed by normal mental operation, the patient took part in conversation and partook of food with evident relish. The reason for this lies in that the lessened intracranial tension finds less resistance in even the slightly more elastic dura than obtained before the bone was sectioned. For the purpose of decompression trephining these exceptional occurrences do not enter into consideration.

In this operation the forcible protrusion of the brain, which occurs immediately upon incision of the dura, is exceedingly disturbing; indeed, in some instances, the extrusion is sufficiently great in extent to tear the soft investing membrane and the subjacent cortex as they come in contact with the sharp edges of dura and bone. This causes serious disturbance of function, and at times provokes hemorrhage with consequent œdema and extensive prolapse. To obviate this as much as possible I employ measures similar to those applied to abscess drainage. (page 103.) I make the dural flap considerably smaller than the bone opening and obliquely incise the rim of dura protruding from the skull with blunt scissors at each corner of the wound as far as the angles of the bone wound, forming thus four smaller dural flaps which are reflected outward over the rough edges of the bone, effectually covering them. A similar method is employed by *Beresowsky*.

The technique described also permits of coaptation by suture of the osteoplastic flap, which is accomplished without drainage, in such a manner as to bring the superficial wound at some distance from the edges of the opening in the bone. If the skin flap is made several millimeters larger than the bone flap, the line of union in the former corresponds to the middle of the breach in the skull. The basal dural flap is made to cover the brain and soft membranes and prevents contact of these tissues with the lamina vitra.

To obviate tearing asunder of the line of union, as is quite liable to occur in cases of large brain herniæ, *Harvey Cushing* proposes **a temporal submuscular method**,[1] which he describes as follows: A curved incision is made parallel to and 1 cm. below the origin of the temporal muscle. In front it reaches to the beginning of the hair area, and behind ends somewhat lower down on a level with and behind the pinna of the ear. The skin and superficial fascia is reflected downward exposing the temporal fascia. The fascia, together with the muscle, are incised in the direction of the fibers of the latter at its middle, *i. e.*, downward and forward, exposing the periosteum. The edges of the deep wound are forcibly retracted and the periosteum scraped away to the extent of the exposed area. A portion of the squamous plate of the temporal bone is now removed, comprising an area 5 to 6 cm. in its vertical and 8 to 10 cm. in its horizontal diameter, employing a biting forceps for the purpose. The dura is carefully sepa-

[1] The Establishment of Cerebral Hernia, etc. "Surgery, Gynæcology and Obstetrics." Vol. 1, October, 1905, No. 4.

rated during this step of the procedure to avoid injury to the branches of the middle meningeal artery. After making the breach in the bone *Cushing* excises the dura to the extent corresponding to the opening in the bone, not, however, until after the posterior branch of the middle meningeal artery is deligated. The muscle fibers and fascia are approximated with buried sutures, and the superficial fascia and skin closed separately and without drainage.

I have several times employed the *Cushing* method and wish to state that it is not always feasible to sew up the incision in the temporal muscle. In one case, that of a woman of thirty-four, who was afflicted with a cerebral neoplasm which, judging from the symptoms, seemed to be located in the middle cranial fossa, the brain bulged so tensely from the trephine opening that it was impossible to unite the separated muscle fibers. The sutures were drawn upon very forcibly and threatened to incise the brain. The same conditions obtained in the effort to suture the temporal fascia, and I was forced to content myself with approximation of the skin wound, an accomplishment which did not of course comprehend the *Cushing* method.

Again, in another case of large inoperable tumor of the brain, the bulging cerebrum forced asunder the wound, which had united primarily and protruded in several places in the form of mushroom prolapses. The autopsy made two months later disclosed the fact that the tumor was located quite some distance from the trephine opening. Prevention of these complications—for which we are always prepared—

is not obtained as the outcome of employment of the *Cushing* method. In this connection I have found it serviceable to locate the basal attachment of the bone flap to one side and that of the dural flap in the opposite direction. If the osteoplastic flap is elevated by increase of intracranial pressure and the edges of the bone become separated, the broad base of the dural flap on the opposite side has a tendency to prevent the occurrence of prolapse.

The immediate dangers of decompression trephining are not great, and the operation may disclose the location of the tumor and decide the question whether it be operable, presenting thus a blessed palliative measure. It is analogous in this regard to gastrostomy in cancer of the œsophagus, colostomy in inoperable sigmoid cancer and gastro-enterostomy in inoperable carcinoma of the pylorus. In addition the measure also, like those mentioned, prolongs life. Of no less import is the relief afforded in cephalalgia, vomiting and disturbances of vision. The first mentioned symptom is perhaps the most menacing, for the prolonged vomiting soon leads to exhaustion, which is not relieved by any other measure. Choked disk disappears, indeed, in some instances, with astonishing rapidity, and vision improves, provided that the optic fibers have not been subjected to the strangulating influence of œdema for too long a time, and thus patients escape until death from the most distressing of afflictions—blindness. This is of the more import for the reason that choked disk occurs very often early in the course of the disease, before the other more characteristic symptoms appear.

Lastly, convulsive seizures become less frequent, delirium disappears and vertigo becomes less obtrusively disturbing.

Horsley advises execution of the operation as soon as neuritis optica appears. His experience leads him to conclude that the measure is ineffective in this connection only, when the neoplasm involves the optic tracts themselves. At this time it seems proper to state that in most instances the optic neuritis involves only the side corresponding to the seat of the neoplasm.

Beyond this *Horsley* has called attention to the fact that subacute encephalitis may produce the symptoms common to tumors of the brain, and that in this class of cases decompression trephining affords relief.

The measure is of less value in the majority of cases of rapidly growing tumors located at or near the cortex of the brain. More especially glioma and gliosarcoma, which are diffuse in character and involve wide areas of cortex or white substance, present unfavorable conditions in this connection. Establishment of a vent affords only temporary relief, and soon the progressive growth forces the osteoplastic flap upward, and even though union of the wound may have taken place the line of incision is separated or the scar undergoes degeneration. The contents of the skull is extruded and cannot be restrained in any way. Each amputation or cauterization simply invites renewed protrusion. In cases of this sort the free use of morphia affords the only available modification of the distressing physical and unfortunately also, the mental suffering.

The Hamburg neurologist, *Alfred Saenger*, who reports favorable results following paliative decompression trephining[1] advises that in right-handed persons the opening in the skull be made over the right cerebral hemisphere, in the parietal region, behind the posterior central convolution, *i. e.*, corresponding to an unimportant cortical area.

The right temporal region may be properly mentioned in this connection. However important cortical areas may be injured in the *Cushing* method. Autopsy shows that the breach in the bone usually corresponds to convolutions located below the fissure of *Sylvius*. In all instances the lower section of the central region is involved, that is, the centers for tongue, lower jaw muscles, and inferior branch of the facial nerve. For this reason, viewing the subject from the *Cushing* aspect, two-sided decompression trephining (which seems to him to be rarely indicated) should not involve removal of the dura on both sides so as to obviate tearing of the brain substance, as the bulging brain protrudes beyond the rough edges of the opening in the bone, avoiding thus simultaneous trauma to both cerebral hemispheres.

In cases of suspected cerebellar tumor which have not been definitely located with respect to the side involved, I use the technique described above (pages 45 to 48), which may also be employed as a decompression measure. As this region is covered with thick muscles which afford ample protection, the trephining may be performed with resection of the bone.

[1] On Paliative Trephining in Inoperable Brain Tumors to Obviate Threatening Blindness. *Klinische Monatsblaetter fuer Augenheilkunde.* XLV, 1907, Feb. P. 145.

I have, however, in one case in which the osteoplastic flap was made, achieved an exceedingly satisfactory result which lasted for three years. The accompanying illustration (Fig. 39) was made from a photograph taken one and one-half years after the operation. This observation (VIII, 1) leads me to emphasize that in cases in which hydrocephalus simulates tumor

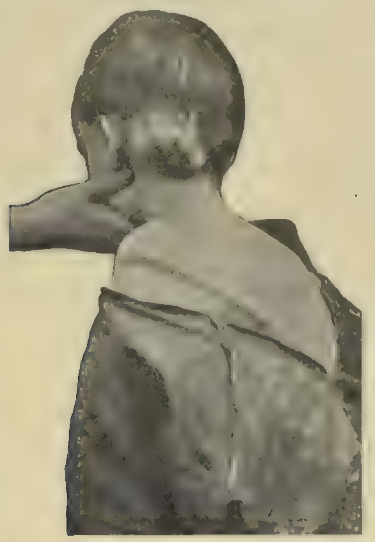

Fig. 39

of the cerebellum the opening of the posterior cranial cavity is a valuable measure of relief. Decompression by trephining over the cerebellum, irrespective of the seat of the pathological process, is not regarded as justifiable by the writer. I am not convinced that compression, the outcome of tumors of the cerebrum, even if located in the posterior half of the hemispheres, is relieved by trephining over the cerebellum, as the tentorium makes effectual resistance between the posterior cranial fossa and the cerebrum.

The following example is offered as illustrative of decompression trephining. The patient, a man, aged thirty-one, gave a history of daily vomiting, attacks of syncope, vertigo, violent headache, and occasional convulsions of one year's standing, to which partial paralysis of the left side of the body was latterly added. When he came under observation double choked disk and a few small hemorrhages in the retina were discovered. While under espionage the convulsions were observed to begin with contractions of the left arm and extend to the rest of the body. One hour after the general convulsion ceased the left arm remained feeble and the left side of the face remained paretic. In view of the fact that the patient had already been subjected to large doses of potassium iodid, and we further treated him with mercurial inunction for four weeks without effect, the right motor cortical zone was exposed in two stages.

The dura was found to be very tense and did not pulsate. As the dural flap, with its base directed sagittally, was made, the brain protruded at once through the opening (which measured 6 cm. in breadth and 7 cm. in its vertical diameters) with such force as to burst the pia and cortex in several places. At the same time about a teaspoonful of clear fluid was discharged. As the exposed brain presented no evidence of disease the forearm and head centers (Fig. 40, 1 and 2) were located by monople irritation with a rather strong electric current. Irritation of the thumb and index finger foci provoked the same kind of convulsions as had been previously clinically observed. Multiple puncture in these situations carried to the depth of 5 to 6 cm. brought forth about 2 cm^3. of clear fluid. The clinical history, taken together with the prolapse, pointed to

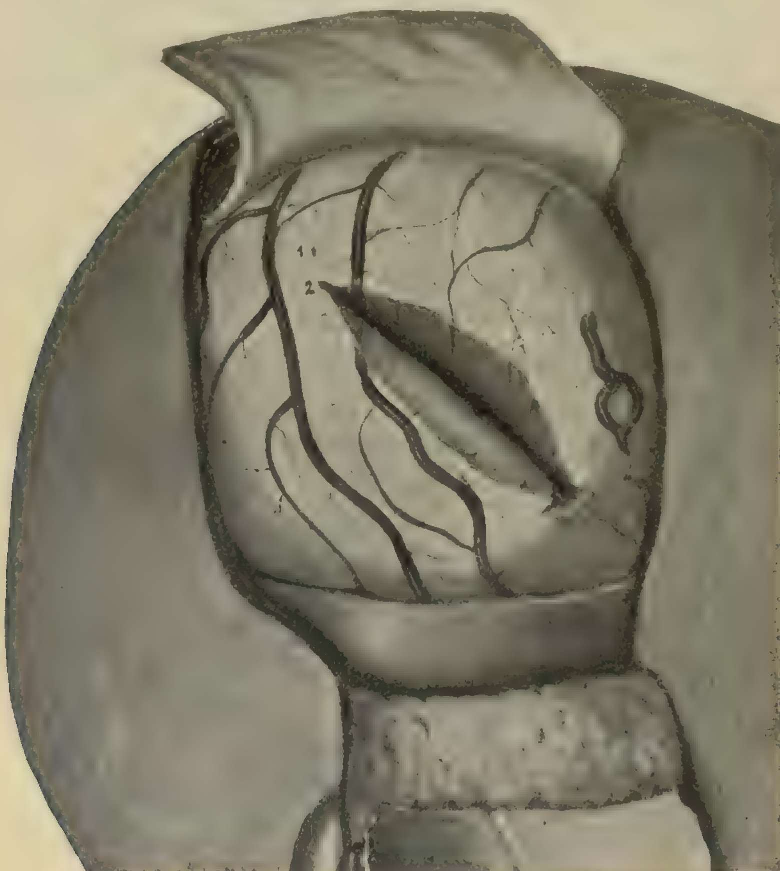

Fig. 40

the existence of a tumor, justifying an incision into the arm center of the anterior central convolution. This incision was oblique and followed the direction of the convolution, being gradually increased in size until it measured 6 cm. in length and 3 cm. in depth;

however, no tumor was discovered, nor did the cortex present any pathological alteration. The operation was arrested and the wound closed by suture.

Immediately upon return of consciousness the left

Fig. 41

arm was completely paralyzed, and the next day the left leg also became paralyzed. During the following three weeks a large prolapse formed, and the anterior and posterior portions of the wound burst asunder. The anterior prolapse dermatized completely, leaving a scar the width of the finger. The posterior portion of the wound still presented a prolapse the size of a goose egg, which three months later was covered with a plastic flap operation, using the scalp for the purpose. This was followed by repair with, however, considerable prominence (Fig. 41). The paralysis of leg and arm slowly improved (the leg more quickly than the arm) and five months after the operation the patient was able to go about with a cane. Motion of the arm four months after the incision into the cortical area had partially returned. The patient was able to move moderately the upper arm forward, backward and outward, to flex and extend the forearm, flex the fingers and extend the wrist to a slight extent. The other movements of the limb were quite lost.

When discharged, seven and one-half months after the operation, the patient could walk without a cane, the locomotion being accurate. The arm did not show any further improvement. All the general symptoms had disappeared, the ophthalmoscope showed the fundus normal, vision for both near and distant objects was not reduced. A half year later the patient's general condition was good. He complained only of the impaired utility of the left arm, though this had quite markedly improved since the last examination. The arm could be raised to the horizontal; flexion and extension of the forearm were forcible and normal in range. Active flexion and extension of the wrist obtained over a scope of 30 degrees. With little force, however, the finger functions were restricted to moderate flexion of the thumb. There was no atrophy, but the muscles of the limb were flabby. The leg could be moved in all directions, extension of the foot was lessened in force, active motion of the toes was impossible. The patient went about comfortably, using a cane as a precautionary protection. The bone flap was movable and elevated about 2 cm. above the outline of the skull. The fundus of each eye was normal. The operation may be regarded as having acted as a decompression trephining.

The attending physician writes that at the end of a year and a half the patient was again afflicted with convulsions, which were soon followed by unconsciousness, cerebral compression and death. No autopsy.

Closure of Large Defects in the Bony Skull

In the operation of trephining it is not always feasible to preserve the bone. In cases of extensive trauma, sarcoma of the cranial bones, tuberculosis and various other diseases, the bone must be resected to a greater or lesser degree. Small defects are filled, in the adult by formation of a firm cicatrix rendering additional repair unnecessary. In children, when the periosteum has been preserved, osseous repair takes place at the edges of the defect as the result of new bone forming from the periosteum and to some extent from the dura, which latter membrane has the same character as the former with respect to its outer layers, while the center of the area is filled up with scar tissue. Large defects at times lead to serious disturbances of the general and mental functions, and, indeed, may be the causal factor in epilepsy. Large cerebral herniæ occur when the dura is sacrificed. In these instances an attempt should be made to remedy the affliction by the application of a firm truss. If this proves ineffectual or produces disturbances plastic repair should be made, bearing in mind, however, that the failure of mechanical restraint is the indication for operative reparative effort.

One of the best methods of plastic repair is that of *Koenig* and *Mueller*, an illustration of which follows. (Observation XI, 1.) The case was that of a man aged twenty-four, who was afflicted with a sarcoma of the dura, which had extended to and through the posterior aspect of the cranium. Nine days after extirpation of the growth (January 20th, 1902) I made a plastic repair of the residual defect.

The defect presented within the area shown covered by the plastic flap (Fig. 42). The osteoplastic flap was taken from the place designated *b*, its pedicle being directed toward the right side of the head. The defect shown at *b* does not, however, represent the exact size of the original gap, as its edges were undercut and partial approximation made with retention sutures at the time of the operation. Traces of the location of the three sutures are visible in the picture. This markedly reduced in size the raw surface. It must be borne in mind that the soft tissues of the repair flap shrink quite a little after it is formed, and in order to close the bony defect the former must be made considerably larger than the latter. The incision is carried through the scalp and periosteum to the bone. A furrow is cut in the skull down to the diploea at the edge of the periosteal wound, employing a grooved chisel or the *Borchardt* plowburr for the purpose. The outer layer of bone is then carefully separated from the inner laminæ vitræ with a flat, slender chisel. The thin layer of bone may be inadvertently fractured during the manipulation, but this makes no difference, provided separation of the periosteum is avoided. The latter is quite essential to the preservation of the osteoplastic flap. In the region of the pedicle the flap consists only of scalp and periosteum for a space of

2 cm. In our case, the pedicle was twisted about 70 degrees, and the flap turned downward covering the defect, where it was held in place with sutures. In this way the chiseled surface came in contact with

Fig. 42
Plastic repair of Skull. *Koenig-Mueller*
a. Site of defect
b. Where flap was made from
c. Flat sequestrum

the pia mater, which after nine days of tamponade was quite covered with granulations.

The illustration (Fig. 42) represents the conditions on February 24th, that is, five weeks after the repair was made. The flap (Fig. 42 *a*) was entirely healed at that time, and had made a firm union. The defect

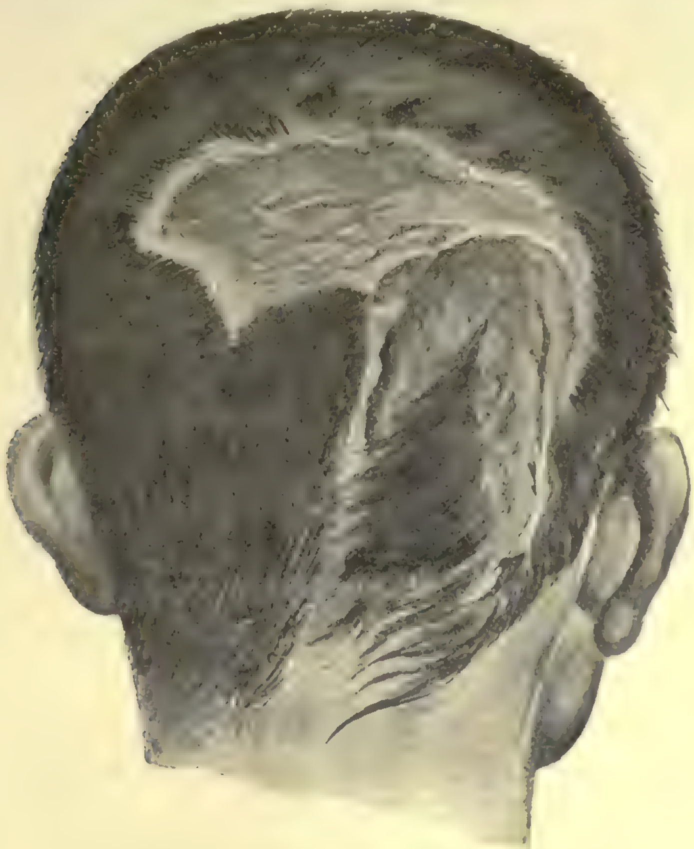

Fig. 43

Result after *Koenig-Mueller* osteoplastic operation. 94 days after extirpation of perforating sarcoma of the dura, during which the right cerebellar hemisphere and the posterior pole of the right occipital lobe were exposed. Observation XI, 1.

(*b*) was granulating, and after a flat sequestrum (*c*) had separated, was closed, March 5th, by means of *Thiersch* transplantation. The ultimate result is shown in Fig. 43 drawn from a photograph taken on

April 15th, 1902. The hairs at the edges of the flap were cut away in order to make visible its outline. The patient was discharged May 14th, 1902.

v. Hacker and *Garrè* employ subcutaneous and subfascial periosteal bone flaps by sliding. *Garrè*[1] makes the scalp flap so large that the defect is also exposed in order to observe carefully the latter. The repair flap consists only of periosteum and—like the *Koenig* method—the outer layer of the bone. This he slides into the bone opening in a curved line comprising 90 degrees. The periosteum is sutured around the edges of the defect. If the periosteum becomes separated from the bone during the manipulation, the bone alone is placed into the defect. Should this layer of bone, as happened in one of *Garrè's* cases, become curved convexly on its chiseled side, its outer smooth surface is brought in contact with the granulating dura and the periosteum placed over the raw surface separately and sutured as described. In this event the operation is not a flap plastic but consists in placing into the defect a living portion of bone which is entirely separated from the body.

In some instances the cranial bones are too thin to permit of employment of the osteoplastic flap method. It is then necessary to employ other methods, some of which are quite satisfactory. Use of portions of bone from the patient is a useful measure. After injury to the cranium the loose pieces of bone may be employed for the purpose, provided the wound has

[1] Oscar Sohr, Zur Technik der Schaedel-plastik. v. Bruns, *Beitraege zur Klinischen Chirurgie.* Bd. 55. Seite 465, 1907.

been rendered aseptic. This method is illustrated in the following case.

The patient, a man, aged thirty-one, had fallen (June 10, 1899) a distance of several meters, sustaining a compound complicated fracture of the left parietal bone. When primary unconsciousness had disappeared, the presence of paresis and loss of sensation of the right hand became manifest. As is usually the case the lamina interna was more widely splintered than the

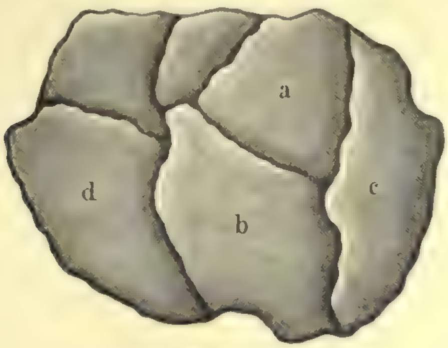

Fig. 44

externa. The dura, which was not torn, presented a deep indentation, the fragments were entirely loose and driven inward. After removal of the fragments they presented an oval outline measuring 5.5x4.9 cm. (Fig. 44). In order to exsanguinate the pieces of bone they were at the time of the operation submerged in a five per cent. carbolic acid solution for one day and boiled for one hour on the three subsequent days in a normal sodium chlorid solution and then preserved under water seal in the latter medium. On the 15th of June the iodoform gauze, which had been introduced into the wound at the operation, was removed with great care in order to avoid bleeding. The four larger fragments (a, b, c, d) were laid on the dura and their edges slightly pushed under the surrounding laminæ vitræ. The skin was sutured over the area without drainage, and the dressing applied with moderate pressure. After healing without reaction the implantation area showed (July 6th) a slight depression; closure of the defect, however, was complete. The pulsation which on June 30th had been quite discernible had disappeared. The paresis of the right arm had already diminished and ultimately disappeared except for a slight weakness of the ulnar group of muscles. The patient was presented at the meeting of the Physicians Society in Hamburg, on May 8th, 1900, quite recovered. (Deutsche Med. Wochenschrift. 1900. Vereinsbeilage.) The indentation was at this time still present.

On April 18th, 1901 (two years later), the patient was examined for the last time by the writer. The bony closure was complete, and inelastic. There were no cerebral disturbances and no loss of function beyond a lessening of sensibility in the last three fingers. A letter received in the latter part of August, 1907, informs me that there had been no change in the scar, that the patient suffered no pain, felt perfectly well, and was able to follow his occupation, that of a machinist. Instead of reëmplanting the fragments, flat portions of the tibia or other bones may be chiseled off and employed for the purpose. However, as (according to our observation) boiled, *i. e.*, dead pieces of bone, are effectual in this connection, it is just as well to use portions of bone taken from the cadaver or amputated limbs which, of course, are readily obtainable. Before placing the particles *in situ* they should be repeatedly boiled for long periods of time. Soda solution must not be used for this purpose as it is likely to soften too much thin sections of bone.

Bone tissue may be replaced by other material for the purpose as, for instance, the method of *A. Fraenkel*, who closes the defect with a celluloid plate, or metal plates of aluminum or silver may be used. Lastly, the silver filigree of *Witzel* may be introduced.

In the same manner small splinters separated during trephining may be used to close the defect. *V. Bramann* peels back the periosteum and removes narrow strips of bone from the contiguous skull with a flat chisel and uses them to cover the breach in the bone. If portions of bone entirely separated from nutritive connections are used a favorable outcome depends largely upon complete arrest of bleeding, suture of the periosteum and the fact that the grafts are intimately associated with living tissues. In fact very large portions of bone may be used in this way. Indeed, ten years ago I removed a piece of the anterior surface of the tibia (8 cm. in length) together with its periosteal covering, and transplanted it into a defect in the anterior aspect of the pelvis which was left after excision of a large osteosarcoma of the os pubis, with favorable result. At that time I regarded utilization of the periosteum as exceedingly important, a belief which has been proven to be true by *Lexer*.

Craniocerebral Topography

When the diagnosis of a pathological focus in the brain is made and its location determined with respect to a certain area, the trephine opening should, as closely as possible, correspond to its seat. For this reason the relationship of the cerebral convolutions to the surface of the cranium should be determined with accuracy. While we owe recognition of the original and most extensive observations in this connection to the anatomists of France, the importance of the relationship of the fissures to the convolutions is the outcome of the painstaking labor of *Adolph Pansch.*[1] The more accurate and more closely defined the recognition of the physiological functions of various portions of the brain are, and consequently the more certain the diagnosis of the location of lesions is, the more reliable a pathfinder will cranio-topography be and less extensive surgical trauma will be necessary to achieve the intent.

Localization is most readily accomplished when the situations of the fissures of *Rolando* and *Sylvius* are determined. The simplest method of arriving at a conclusion in this regard is the

Kroenlein Construction

[1] Waldeyer, Topographie des Gehirns. Vortrag in der Anatomischen Sektion des XIII Internationalen Medizinischen Kongresses zu Paris. *Deutsche Medizinische Wochenschrift* 1901. Nr. 26–29. I have used very largely this report for my topographical representations.

which is taken from his own illustration and shown in Fig. 45.

In order to rapidly locate these two lines *Kroenlein* employs a craniometer made for himself by the instrument makers, *Hanhart & Ziegler*, of Zuerich. It is my practice to delineate these lines on the shaved scalp twenty-four hours before the operation with the nitrate of silver stick (Fig. 46).

The following additional lines are outlined on the scalp:

1. The base line (the German horizontal line) is in accord with the Frankfurt agreement drawn from the lower rim of the orbital cavity, backward through the highest point of the external auditory meatus.

2. The upper horizontal line parallels the first on a line with the upper edge of the orbital cavity.

3. The front vertical (Z) line runs vertically between the first and second through the center of the zygomatic arch.

4. The middle vertical line (A) crosses the center of the articular knob of the inferior maxilla.

5. The posterior vertical line (M) crosses the posterior edge of the mastoid processes.

The linea *Rolandi* (RP) connects the intersection of the front vertical and the upper horizontal (K) lines at a point where the posterior vertical meets the median line (P).

The linea *Sylvii* (KS) halves the angle (Pkk_1). This is prolonged backward to the posterior vertical line. Further elucidation may be obtained from Fig. 45.

Kroenlein bases his work[1] on the observations of

[1] Zur Craniocerebralen Topographie. v. Bruns' Beitraege zur Klinischen Chirurgie, Bd. 22, Seite 364, 1898.

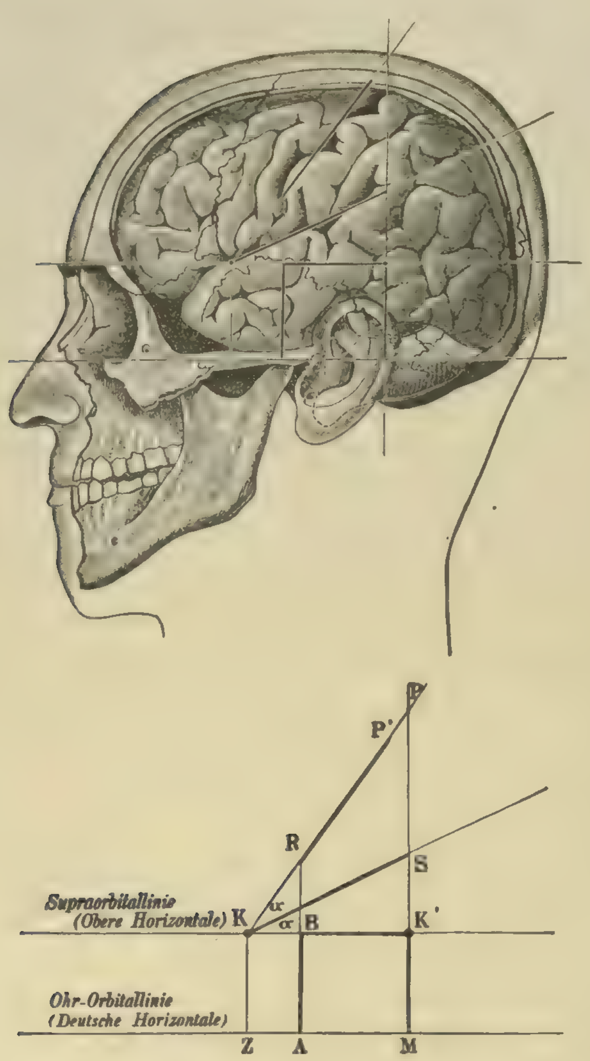

Fig. 45

Kroenlein's Construction for locating the central sulcus, and the Fissure of *Sylvius* on the surface

K = Division of fissure of *Sylvius*
S = Posterior end of fissure of *Sylvius*
R = Lower end of central sulcus
P = Upper end of central sulcus

(From *Kroenlein* in *v. Bergmann's* Handbook of Practical Surgery. Third edition, 1907, Vol. I, page 331)

A. Froriep[1], whose construction in general is figured with respect to various forms of skulls, taking into account short, high or long low forms of heads. In the first class of cases *Froriep* thinks the brain is crowded toward the forehead and would indicate

Fig. 46.
Location of the fissures of *Rolando* and *Sylvius* according to the *Kroenlein* construction

that the fissure of *Rolando* lies farther forward (frontipetal type). In the latter class the brain appears to make a turn upon its horizontal axis and

[1] August Froriep, Zur Kenntniss der Lagebeziehungen zwischen Grosshirn und Schaedeldach bei Menschen verschiedener Kopfform, Leipzig, bei Veit & Co., 1897. P. 30.

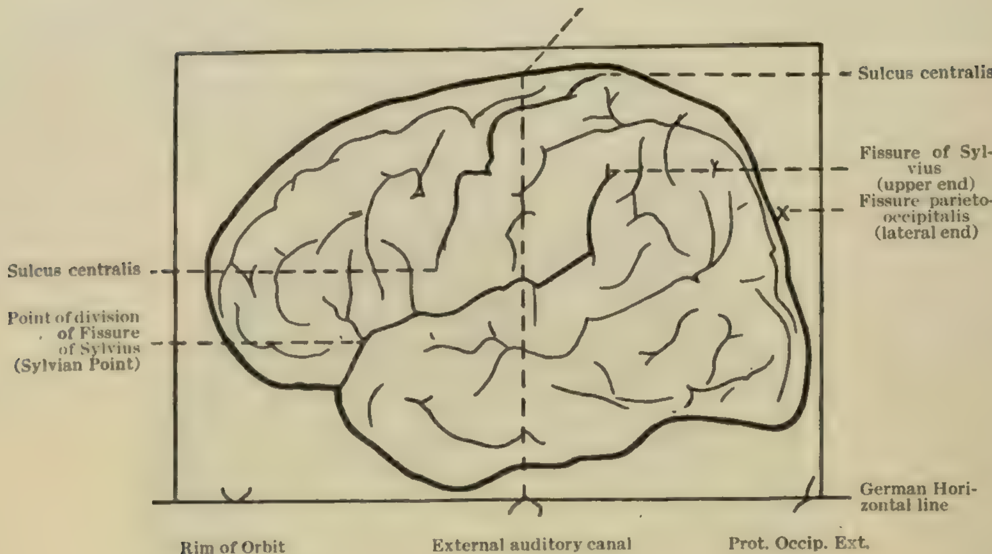

Fig. 47
Example of Frontipetal Type of Brain

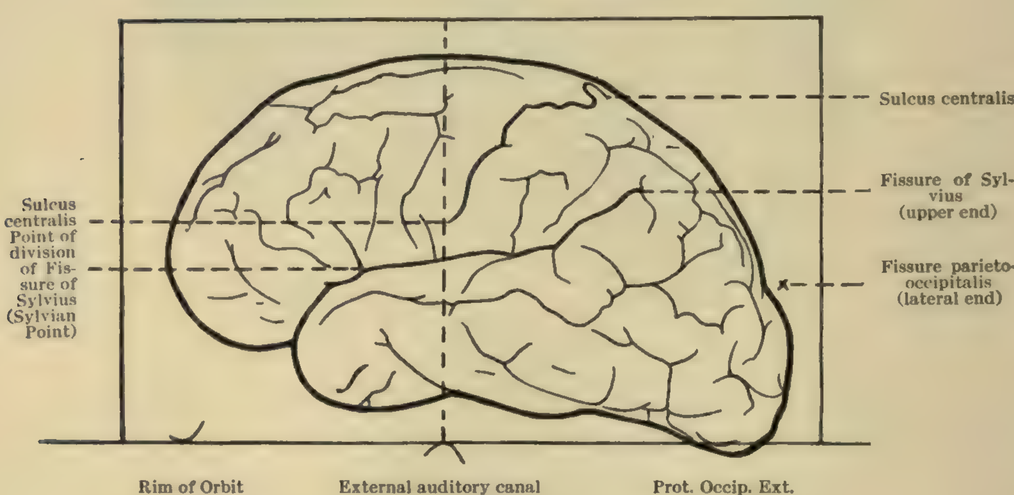

Fig. 48
Example of Occipitopetal Type of Brain

its posterior is crowded backward, constituting a displacement backward of the entire brain, thus causing the central sulcus to lie more obliquely backward (occipitopetal type). The same respective displacements of all convolutions and fissures occur in

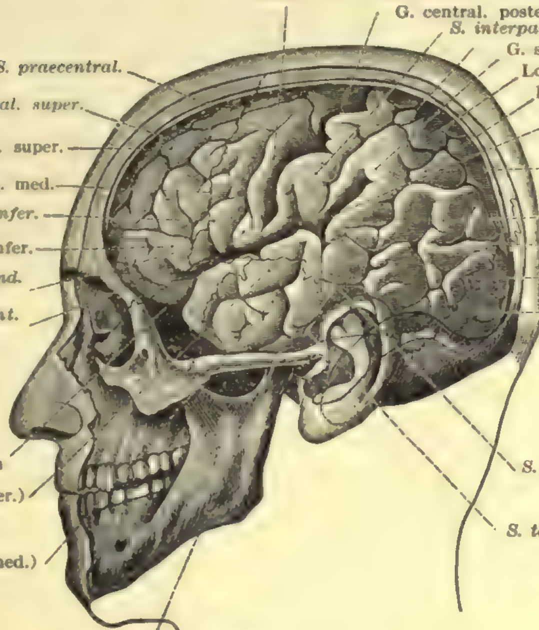

Fig. 49
Convolutions and Fissures of the Brain
(From *Kroenlein* in *v. Bergmann's* Handbuch der praktischen Chirurgie, Third Edition, Vol. I, page 239)

the same proportion. "The more marked," says *Froriep*, loco citato page 28, "the length of the posterior segment of the skull is and the more the external occipital protuberance lies toward the horizontal or beneath it, the more certain may the occipitopetal type with a corresponding position of the brain be taken into account. *Per contra* the frontipetal type is to be expected when the audito-occipital distance is short and the posterior segment of the skull is high."

Figs. 47 and 48 represent the two types as described by *Froriep*, though the differences are quite strongly drawn. The squares surrounding the sketch correspond to the long diameter and the height at the ear line of the skull. The inferior edge of the orbital cavity is indicated on the audito-orbital line, as is also the location of the auditory meatus. The dotted line running upward at the latter situation makes quite apparent the differences in frontipetal or occipitopetal types of brains. The averaging of a number of measurements would indicate that the most frequent variation in position of the brain is that of rotation on its transverse axis combined with displacement downward and backward.

For these types *Froriep* emphasizes that "the total length of the skull, rather than the longitudino-transverse index, indicates the conditions. If the total length is beyond a certain dimension the occipitopetal type presents and *per contra*, if this be below a certain measurement the frontipetal type obtains. Although the importance of increased vertical diameter is not to be disregarded, neither the brachycephalic nor dolicephalic heads need necessarily present the frontipetal nor occipitopetal types of brain position." These representations of *Froriep* are of importance to the surgeon, giving us the relative values of each type upon which to base a method of action.

Beyond the various types of skulls other deviations from standard are to be considered, such as race, sex and age. To avoid encumbering elucidation of the problem I proceed at once to a discussion of the most important considerations in connection with the convolutions and fissures of the brain.

1. **The Suclus Centralis** (fissure of *Rolando*) generally takes a course in which there are two knee-like bends; its situation, therefore, is only determinable on the calvarium at its upper and lower terminations. The former is located by dividing in one half the distance between the root of the nose (Nasion) and the external occipital protuberance (Inion) and measuring backward from this 2 cm. (*Thane*, 1 cm.). *Broca* employs for the purpose in addition to the nasion, which corresponds to where the nasal suture reaches the frontal bone, the ophryon, which is located at the middle of the glabella. Measuring backward from the ophryon in the median line the upper end of the central fissure is located 53/100 behind the former (*E. Masse* and *Woolingham*). The lower end of the fissure corresponds in the adult to a point determined by dropping a vertical line through the preauricular depression between the tragus and the articular head of the inferior maxilla on the upper edge of the zygoma, and measuring upward on this line 5 to 6 cm. from the upper edge of the external auditory meatus. In children the foot of the fissure is located 15 mm. below the middle of a line drawn vertically from the external auditory meatus to the sagittal line. This line, together with the fissure, forms an angle of 67 degrees (*Hare*).

The central fissure lies in the middle of the anterior third of the parietal bone, its lower two-thirds run nearly parallel to the coronal suture, while the upper one-third deviates sharply backward. The position it occupies is at its lower end 30, at the upper 40 to 50 mm. from the coronal suture. In women the distances are 27 to 45 mm., and in children 11 to 33 mm. respectively (*Poirier*).

As the *gyri centralis anterior* and *posterior* in the adult measure at their middle 18 to 20 mm. in breadth, determination of the situation of the central fissure locates the situation of the precentral and postcentral convolutions.

2. The **Fissure of Sylvius** runs with moderate ascending obliquity from *Broca's* pterion, which latter is located near the posterior end of the spheno-parietal suture (anterior vertical line 4 to 4½ cm. above the zygoma) to the middle of the lower portion of the parietal tubercle, though it does not in all instances reach quite to the latter point. As the fissure varies in development, and with regard to its upper terminal end and also varies considerably as to its course, the designation just stated is somewhat unreliable. In the frontipetal type *Froriep* found the upper end of the fissure more toward the anterior lower portion of the parietal tubercle, and in the occipitopetal type more toward its posterior aspect. In children during the first two years of life the squamous bone is quite small, and the parietal bone reaches to or extends below the first temporal sulcus. In these instances the fissure of *Sylvius* is covered entirely by the parietal bone.

The fissure divides into three branches, *ramus* *anterior horizontalis, ramus anterior ascendens* and *ramus posterior horizontalis.* The latter represents as the main branch the greater part of the fissure. The origin of the two anterior branches corresponds to the punctum *Sylvii* (*Sylvian* point of the English), which is located at the pterion. The ramus anterior ascendens lies vertically to the ramus posterior horizontalis, the ramus anterior horizontalis runs from the pterion beneath the sphenoparietal suture with reliable persistence in an anterior direction.

3. The *three frontal convolutions* lie with their posterior ends in contact with the precentral convolution, *i. e.*, about 20 mm. from the central fissure. The first begins 1 cm. from the median line, taking the longitudinal sinus into account. The second is located with its middle (in children, *Féré*) under the center of the frontal eminence, while in the adult this point corresponds to the first frontal fissure or to the border between the inner and outer two-thirds of the second frontal convolutions (*Poirier*). The third is situated about the rami anteriores horizontalis and ascendens of the fissure of *Sylvius.*

4. The *three lateral temporal convolutions* occupy the space at the side of the brain between the fissure of *Sylvius* and the temporal border. The latter in the average corresponds to a line 5 mm. above the upper edge of the external auditory meatus, that is, in this situation, very near the level of the upper border of the zygoma, and at its middle to the incisura semilunaris of the lower jaw, where the lowest point of the temporal lobe is usually found (*A. Froriep*),

though it may dip down to opposite the lower edge of the zygoma.

The first temporal convolution measures at its center about 15 mm. in breadth, and is bounded below by the first temporal fissure which is, because it runs parallel to the fissure of *Sylvius*, at times called the *fissura parallela*. The second, which is rarely strongly apparent, lies about in the middle between the first fissure and the temporal border line.

The anterior two thirds of the first and second temporal convolutions are covered by the squamous portion of the temporal bone, the extreme front ends by the greater wing of the sphenoid. The anterior portion of the third (and fourth) temporal convolution may be reached from the anterior part of the inferior temporal fossa, which is formed by the greater wing of the sphenoid bone.

All three lateral temporal convolutions end at their posterior aspects in the gyrus angularis and supra marginalis, both of which are most largely formed by the parietal lobes.

5. The location of the *gyrus supramarginalis* corresponds to the situation of the tuberosity of the parietal bone (***Huschke***), and winds around the posterior end of the ramus posterior horizontalis of the fissure of *Sylvius*.

6. The *gyrus angularis* winds around the posterior upper end of the first temporal fissure. Its location is determined upon the unopened skull in its relationship to the tuberosity of the parietal bone lying a little behind and above it, *i. e.*, about 3 cm. behind the gyrus supramarginalis (*Poirier*).

7. The *sulcus parietalis* (*intraparietal fissure*) consists of two divisions; its ascending branch connects with the retrocentral fissure, and lies about 20 mm. behind the central fissure (*Waldeyer*). The longer horizontal branch runs close to the upper portion of the tubercle of the parietal bone, 45 mm. lateral to the median line, and when it reaches to opposite the lambda it approaches to within 33 mm. of the latter (*Thane*).

8. The *parieto-occipital fissure*, in the occipitopetal type of skull, lies with its upper end immediately above the lambda (tip of the squamous portion of the occipital bone) or corresponds exactly to this point, and in the frontipetal type and in young children, 1 cm. higher up and 2 cm. lateral from the horizontal line. The lambda is, in the adult, located 6 to 7 cm. above the external occipital protuberance (Inion), and 8 to 10 cm. behind the upper end of the *Rolandic* fissure.

Prolongation of the lines KS and KK^1, of the *Kroenlein* construction (page 212) to the sagittal line, leaves a space between it and the median line. If this be divided into three parts the parieto-occipital fissure will be found to correspond to about the junction of the middle and upper thirds.

A knowledge of the course of the fissures of *Rolando* and *Sylvius* reveals the location of the central convolutions, the operculum, the temporal lobe and also the seat of the frontal and parietal lobes of the cerebrum. As the external occipital protuberance is palpable in all skulls, the location of the occipital lobe is also readily recognized.

9. The **Cerebellum**, with its hemispheres, lies in contact with the squamous portion of the occipital bone, the posterior third of the mastoid process of the temporal bone and rests with its inferior surface upon the foramen magnum. Upward it reaches to the linea nuchæ superior, which corresponds to the lower edge of the transverse sinus. "The white substance of the vermis runs on a quite horizontal line to the confluent sinus." (*Waldeyer.*)

10. The large **Basal Ganglia**. As I have not made any observations and have had no experience in this connection, I quote *Waldeyer* (l. c.) verbatim: "My investigations substantiate on the whole those of *Féré* and *Dana*, but to be exact the three localization levels of these authors should be supplemented by three additional ones. According to *Dana* a frontal level 18 mm. behind the fronto-zygomatic suture corresponds to the anterior end of the corpus striatum, a second, at the posterior border of the base of the mastoid process or the upper end of the fissure of *Rolando* corresponds to the posterior knee of the *corpus striatum* or posterior border of the *thalamus*. A horizontal level 45 mm. below the vertex of the cranium skirts the upper surface of the striatum. I add to this that the lower border of the cerebral ganglionic mass corresponds to the nasion-horizontal line, its lateral dimensions lying between the middle level and the lateral ventricle.

The anterior horn of the latter, however, lies (according to *Poirier*) at the forehead, 6 to 7 cm. from the scalp, the posterior and inferior horns 4 cm. *Tillaux* states with truth that the basal ganglia, *in*

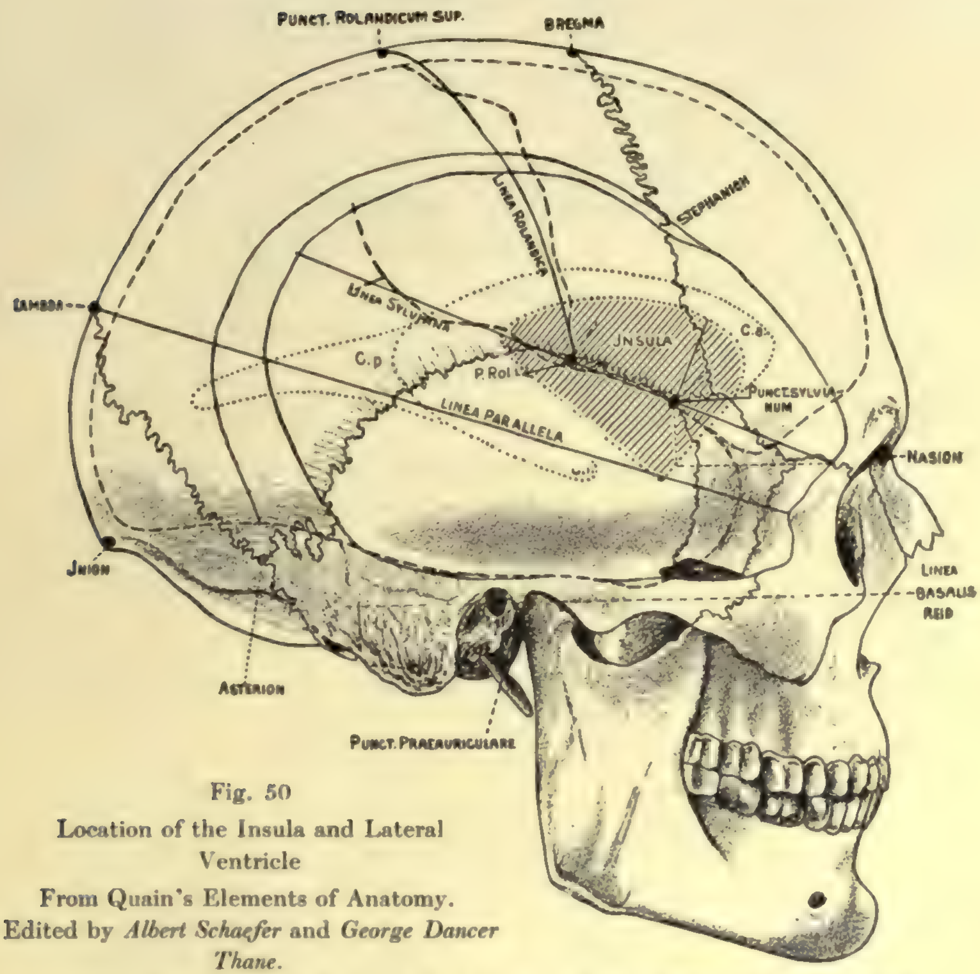

Fig. 50
Location of the Insula and Lateral Ventricle
From Quain's Elements of Anatomy.
Edited by *Albert Schaefer* and *George Dancer Thane*.

Appendix by *G. D. Thane* and *R. J. Godlee*, Tenth Edition, London, 1896.

Island of *Reil*. The punctum *Sylvii* designates the pole of the island, its posterior end lies on the linea *Sylvii* 35 mm. behind this point. The shaded outline of the island acts as a guide to the basal ganglia, which extend only slightly beyond it, about to the outer borders of the main portion of the lateral ventricle.

The lateral ventricle is outlined by a dotted line, its three horns (anterior, posterior and inferior) are also indicated in the same way.

The fissures of *Rolando* and *Sylvius* are indicated with broken lines.

Reid's base line (horizontal line of the skull) is the "*Frankfurter Linie*" of the German Anthropologists. It begins at the lowest point of the inferior edge of the orbital cavity and crosses at the highest point of the upper edge of the external auditory meatus.

toto, are situated above the external auditory meatus and that this opening corresponds about to their middle.

Between the levels mentioned the island of *Reil* is situated, for the exact localization of which additional guides are necessary. *G. D. Thane* locates the pole of the island at the punctum *Sylvii*. A point on the linea *Sylvii* 35 mm. behind this indicates the posterior end of the island, and the anterior end lies 15 mm. in front of the punctum *Sylvii*. The upper border runs from behind in a curve through the upper end of the **ramus ascendens anterior sylvii** to the anterior upper end, the lower from the posterior end to a point 15 mm. forward from the punctum *Sylvii* on the linea zygomatico-lambdoidea, the anterior border being outlined by the union of the two anterior end points mentioned. (Fig. 50.)

Kocher's Method

Kocher, in his widely distributed work[1] submits his own method, which he more completely describes in *Nothnagel's* Handbuch,[2] based on average measurements of *Hare* and *Müller* and recommends it as the best procedure in respect to craniocerebral topography. (Fig. 51.) For rapid demarcation he employs the idea of *John Chiene*,[3] using an apparatus (*Kyrtometer*) made of flexible steel bands which he has modified in the following way:

[1] "Chirurgische Operationslehre," 5th Edition, Jena, Gustav Fischer, 1907, p. 291.

[2] Hirnerschuetterung, Hirndruck und chirurigische Eingriffe by Hirnkrankheiten, in "Nothnagel's Spezieller Pathologie und Therapie," Bd. IX, Teil III Wien, 1901, Alfred Hoelder.

[3] Described by Hare, Lancet, March, 1888.

The base of the skull is encircled with a telescoping, adjustable band (N O) which is held in place with a screw. The lower edge of the band rests on

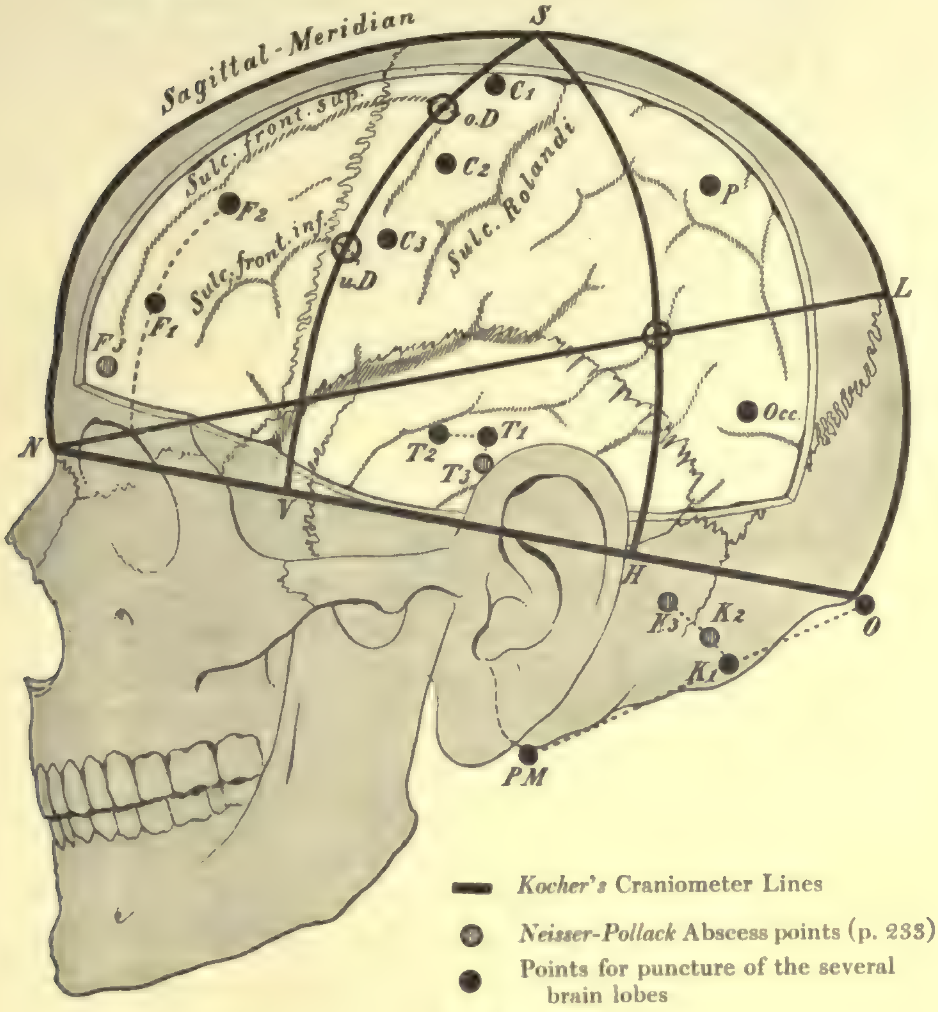

Fig. 51
Kocher's Craniocerebral Method

the lowest point of the glabella and on the lowest part of the external occipital protuberance. This band marks the horizontal circumference of the skull (*Rieger's* base level, *Kocher's* æquatorial line). Vertical to this (line N S O) the sagittal meridian is reached. The steel band outlining this line is fastened behind at right angles to the encircling base band, being firmly drawn beneath the latter and fastened also in front. A third band, which is adjustable on the sagittal band and capable of being turned on the axis of a circle, is fixed at a point midway between the glabella and external occipital protuberance (S) "Scheitelpunkt" and placed *in situ* at a forward angle of 60 degrees, corresponding to the course of the precentral fissure (Linea praecentralis S V). If this line, down to the æquatorial line, be divided into three equal parts, the "third-points," o. D, and u. D, correspond to the posterior ends of the sulcus frontalis superior and inferior.

When the third band is turned backward 60 degrees, so that it forms an angle of 60 degrees with the sagittal band, it indicates the "Linea limitans" (S H). This is only of service, however, when the band is pushed farther backward, or if the Linea naso-lambdoidea (N L) is indicated with an added band. The linea limitans begins, according to *Kocher*, 1 cm. above the point of the lambdoid suture and reaches to the glabella. Below the crossing of N L, the linea limitans indicates quite closely the border line between the temporal and occipital lobes. Above this line of crossing is the border of the gyrus supramarginalis (in front), and the gyrus angularis (behind). Lastly, still farther above, is the border line between the central and parietal lobes.

The linea naso-lambdoidea "indicates the length of the first temporal convolution between the precentral line and the linea limitans"; for this reason *Kocher* calls this portion of the line the linea temporalis I, "because it indicates in front the upper edge of the temporal lobe and behind the lower edge of the same." "At the point of intersection of the precentral line, the linea naso-lambdoidea indicates the situation of the anterior end of the fissure of *Sylvius*. The posterior end of the line corresponds to the parieto-occipital fissure, and at the same time the border of the occipital and parietal lobes." When (according to *Poirier's* statements) the linea-lambdoidea is drawn from nasion to lambdoid it indicates the course of the fissure of *Sylvius* only as regards its anterior 4 to 6 cm., and, indeed, barely to a vertical line drawn from the anterior border of external auditory meatus upward to a point 6 cm. above this line. Consequently this calculation is not to be recommended for the purpose of locating the fissure of *Sylvius*, and still less so as the lambda is not readily palpable on all skulls. *Kocher* disregards an accurate localization of the fissure of *Sylvius*, and is content with locating its anterior end, relying upon the first temporal convolution in this connection.

Kocher's method is exceedingly valuable for the purpose of locating the precentral convolution and the frontal convolutions. It is a question, however, whether the determination of the precentral region is as important as *Kocher* thinks. I do not believe so. It is true that he states on page 298 of his Operative Surgery, "We cannot understand how *Krause*, after dwelling on the importance of the precentral fissure, still clings to the necessity of determining the location of the fissure of *Rolando*." As this question involves a principle I am justified in making it the subject of some remarks. If the surgery of the brain were restricted to exposure of the central region, especially as is undertaken for the relief of *Jacksonian* epilepsy and only the location of the anterior central region were to be determined by electric stimulation, upon which procedure *Kocher's* conclusions are largely based, his statements would be justified. However, the time that *v. Bergmann* characterized the surgery of the brain, as far as tumors are concerned, as that of the surgery of the central region, is long passed, and *H. Oppenheim*, in his "Monograph"[1] clearly enunciates, that of his twenty-seven operative cases only four or five were located in the motor zone, and that none which recovered were afflicted with tumor in the latter region.

The central fissure is and will be to us for purposes of localization, on the surface of the skull, the pathfinder, and when its course is outlined, it is a small matter to find the precentral fissure which parallels the former 18 to 20 mm. in front of it. Determination of the location of the fissure of *Sylvius* is of equal importance. That *Kocher's* method is not reliable in this regard I show in a normal skull (Fig. 52). Although the lambda was distinctly palpable in this instance, and for this reason the linea naso-lambdoidei easy to outline, the linea temporalis is manifestly too

[1] Beitraege zur Diagnostik und Therapie der Geschwuelste im Bereich des zentralen Nervensytems. Berlin, bei S. Karger, 1907, p. 63.

high, while the location of the fissure of *Sylvius* after *Kroenlein* is correctly marked.

In the vast majority of my operative cases, which have involved invasion of all of the sections of the

Fig. 52

Illustrates Observation III, 4

With *Kocher's* Kyrtometer......Drawn according to *Kroenlein*.

1 and 2 *Neisser's* puncture points in the anterior central convolution.

1 Leg center, 2 Arm center.

brain, I have been satisfied with the *Kroenlein* construction. Nevertheless I have often employed the *Kocher* kyrtometer, as it is of service to employ various methods for the purpose of determining the location of the main fissures. No construction may be regarded, at the present time, as absolutely reliable in all instances; for this reason we are forced to make rather large trephine openings.

Waldeyer regards the *Kroenlein* construction as the most reliable. *Schwalbe*[1] is also of the opinion that the location of the sulcus centralis is most readily obtained by following the method of *Kroenlein*. According to his investigations it is feasible not only to define certain parts of the brain, but also to locate certain convolutions on the outer surface of the skull in accord with protuberances which are palpable on the cranium of the living subject.

[1] Ueber craniocerebrale Topographie, Vortrag in der Strassburger militaeraertzlichen Gesellschaft am I. October, 1906. The detailed report of the author's work did not appear after his personal communication to the writer.

Brain Puncture and Puncture of the Ventricles

Puncture of the brain and ventricles may be made through the skull for diagnostic and therapeutic purposes. In the latter regard puncture has been of service in several forms of hematoma. *Hartmann* (Gratz) has used the method to advantage, withdrawing fluid blood from the ventricle after the diagnosis had been made by lumbar puncture. The beneficial effect of brain puncture in cyst formation is of doubtful utility, for the reason that cysts frequently are complicated by neoplasms (page 58). Also the method is of use in intracranial medication. *A. Kocher*, following the experiments of *Roux* and *Borrel*, injected antitetanus toxin into the normal nondilated lateral ventricle with a fine needle.

The important rôle played by ventricular puncture relates to the diagnosis and treatment of hydrocephalus internus, and this is taken up under a separate head. At this time the diagnostic value of brain puncture will be discussed.

The Neisser-Pollack Brain Puncture

To *Neisser* and *Pollack*[1] belongs the credit of placing on a scientific basis the method of brain puncture. The history and literature of the subject will be found in their report. (See footnote.) It is

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[1] Die Hirnpunction. Mitteilungen aus den Grenzgebieten der Medizin und Chirurgie, XIII, 1904.

proper to state, however, in this connection, that *Middeldorp* first bored into the skull for the relief of encephalocele, cephalhematoma and hydrocephalus. Recently *B. Pfeifer*[1] reports the work done in *Wernick's* clinic at Halle, in connection with puncture in cases of brain tumor.

Neisser and *Pollack* have indicated on the *Kocher* schema all points at which

Puncture of the Several Brain Sections

may be made with the greatest certainty of achieving the purpose without injuring the middle meningeal artery and its branches. I repeat the illustration in Fig. 53.

The two points for the frontal lobe (F_1 and F_2) are situated vertically above the middle of the supraorbital border at a distance of 4 and 8 cm. from the latter respectively.

Three points are designated for the central convolution ($C_1C_2C_3$). Next the course of the **sulcus centralis** according to *Kroenlein*, or with the aid of *Kocher's* kyrtometer, that of the **sulcus praecentralis** are determined, which indicate the course of the anterior branch of the middle meningeal artery. The posterior branch of this artery corresponds (according to *Pfeifer*) quite closely to the linea nasolambdoidea. As the anterior central convolution is 18 to 20 mm. in breadth, I keep about 1 cm. away from either central line. C_1 corresponds to the focus

[1] Ueber explorative Hirnpunction nach Schaedelbohrung zur Diagnose von Hirntumoren. Archiv fuer Psychiatrie. Bd. XLII, Heft 2. *Habilitationsschrift*, 1907, und *Jahrbuecher fuer Psychiatrie und Neurologie*, Bd. XXVIII, 1907.

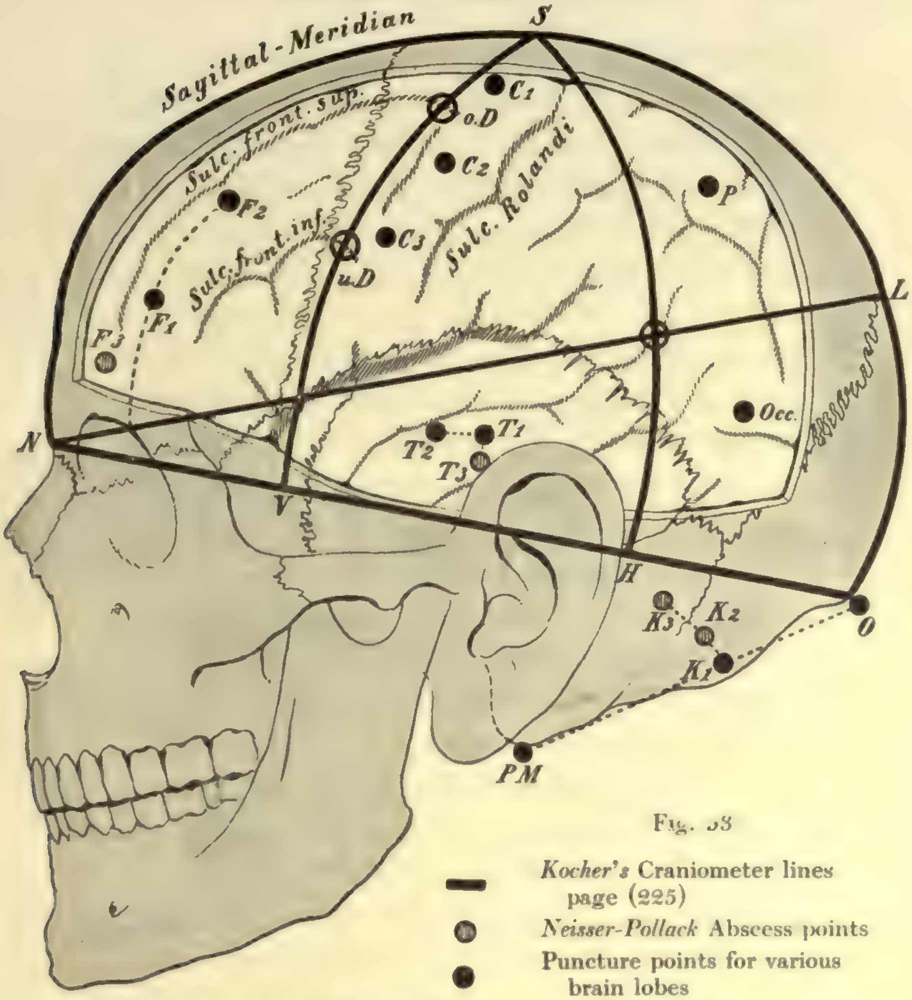

Fig. 53

Kocher's Craniometer lines page (225)

Neisser-Pollack Abscess points

Puncture points for various brain lobes

Cut taken from *Neisser* and *Pollack*. Die Hirnpunction. Mitteilungen aus den Grenzgebieten, 1904, p. 823. In the scheme for determining the Cranio-cerebral Topography (after *Poirier-Kocher*) the *Neisser-Pollack* puncture points are added.

S = Scheitelpunkt = Midway between *N* (root of nose) and *O* (external occipital protuberance).

NVHO = Æquatorial or base line.

NSO = Sagittal meridian.

SV = Anterior oblique meridian, Præcentral line.

SH = Posterior oblique meridian, Linea limitans.

NL = Linea naso-lambdoidea, between *SV* and *SH*, called linea temporalis I by *Kocher*

o. D = upper } "Third-points" of præcentral fissure.
u. D = lower }

PM = Tip of mastoid process

for the lower extremity, C_2 to that of the upper extremity, and C_3 to the face area. No puncture must be made lower than C_3, to avoid injury to the fissure of *Sylvius* with its artery. *Broca's* convolution is located in the blunt angle made by the anterior oblique meridian (S V) and the linea lambdoidea (N L).

To puncture the parietal and occipital lobes a point corresponding to their center (P and Occ.) is selected for the purpose. The lateral ventricle is reached on both sides at a depth of 3 cm. from the surface of the brain.

The two points for the temporal lobe are T_1 and T_2. The first lies 1 to 1½ cm. above the origin of the external ear and corresponds to the center of the lobe; the other (T_2) is found on the upper horizontal line (not the German horizontal line: Fig. 45), about 1.5 cm. in front of the first. At this point the lower horn of the ventricle may be reached at a depth of 3 cm. from the cortex.

The cerebellum is punctured at a point corresponding to the middle of a line drawn from the external occipital protuberance (O) to the tip of the mastoid process (P M).

For the purpose of

Puncturing Brain Abcess Located in Typical Situations

Neisser and *Pollack* submit the following points:

Point T_2, for the temporal abscess, lies ½ to ¾ cm. vertically over the origin of the external ear. As this is also the point at which the inferior horn of the lateral ventricle is reached, the needle must be very slowly and cautiously advanced, at the same time making suction with the syringe. In large abscesses the puncture points (T_1 and T_2) may be used.

For the purpose of reaching cerebellar abscess of otitic origin, the best point is K_2 which, as already stated, is located midway between K_1 and K_3. The latter point is located at the most posterior palpable point of the mastoid process. Point K_2 corresponds to the angle formed by the sigmoid sinus, but is sufficiently far removed from its knee to avoid its being invaded. The puncture must be made vertically to the plane of the bone. This precaution applies also to points K_1, in puncture of the cerebellum, but not to K_3. At the latter situation the canula is directed slightly downward and forward, toward the face and base of the skull. In this way the bend of the sigmoid sinus is traversed, and the lateral anterior portion of the cerebellum is invaded. Large abscesses may be reached from K_1.

Abscesses of nasal origin are punctured from F_1, however, as the anterior pole of the frontal lobe is located medianly at F_2, and somewhat below F_1; this point would be the most rational one to puncture were it not for the danger of traversing the frontal sinus in the event of the sinus being unusually large. A second bony resistance to the entering needle would mean that the sinus had been entered.

All other abscesses located in the medullary portion of the brain are reached through the puncture points indicated with regard to the respective lobes.

Extradural Hematomata

are the result of injury to the branches of the middle meningeal artery when puncture is made at the points indicated by *Kroenlein* (B and K_1, Fig. 45). To avoid involvement of these vessels the drill should puncture the skull a little posterior to these points. Hematoma of the posterior cranial fossa, which is rare, may be reached from the *Neisser* point K_1.

The recorded clinical experiences of *Neisser* and *Pollack* have led to conclusions which were not obtainable in any other way. Their positive conclusions are based (hydrocephalus internus excluded) on intracranial hemorrhage, and their resultant residue (hematoidin) on the contents of cysts, pus and seropurulent exudates, also regarding pathological tissue removed by aspiration (necrotic brain tissue and particles of tumors) and lastly on a case of bloody œdema of the pia in the course of a syphilitic leptomeningitis. In some instances negative findings caused a change of diagnosis, which previously pointed to abscess or tumor of the brain. Menacing symptoms which might properly have been regarded as the outcome of the procedure never presented in the 138 punctures made on 36 patients by the two observers mentioned.

For the diagnosis of cerebellar cysts, brain puncture has been employed by *Lichtheim*[1] in two cases, and *H. Scholz*[2] regards the measure of determining import as to the location of the side involved. If the cysts be small and unfavorably located the measure

[1] *Deutsche medizinische Wochenschrift*, 1905. No. 28.

[2] Ueber Kleinhirncysten. *Grenzgebiete der Medizin und Chirurgie*, Bd. XVI, 1906, p. 759.

may not avail; again in a case, in the same clinic, puncture led to a diagnosis of cerebellar cystic tumor which proved to be erroneous.

In my earlier cases I employed brain puncture only when the dura or the brain itself was exposed. The method is of signal service in all cases where the pathological process lies beneath the cortex and is not visible to the eye. The chapter on page 96 may be consulted in this connection. Subsequent to the publication of the work of *Neisser* and *Pollack* I have made punctures through the intact skull, and as the outcome of examination of the aspirated brain cylinders (which varied in accord with the diameter of the canula up to 1.5 cm.) been enabled not only to diagnosticate the presence of neoplasms, but have in addition been able to determine their histological character. My assistant, *Dr. Emil Heymann*, has, in numerous instances, subjected freshly obtained specimens, prepared by teasing, paraffin imbedding and series sectioning, to examination and determined the location where the pathological process merged into the normal brain substance.

For the purpose of brain puncture it is important to determine the thickness of the total brain coverings, the scalp and the breadth of the space filled with cerebrospinal fluid. It is also to be borne in mind that the thickness of the skull varies not alone in various situations but also in accord with age, sex and the individual. The scalp, calvarium and brain membranes average in the adult between 1½ and 2 cm. In the temporal region the skull is considerably thinner; however, the temporal muscle with its fascial and interfascial fat forms a portion of the covering in this situation. In the frontal region the varying extent of the frontal sinus must be considered. I have seen it reach to the temporal region in two cases, and opened it during the approach to the ganglion of *Gasser*. Beneath the external occipital protuberance the thick muscles of the neck must be taken into account when puncturing the cerebellum. The bone is particularly thick over the posterior fossa immediately above the linea nuchae superior. In introducing the canula these general facts should be borne in mind. Disappearance of resistance means that the coverings of the skull have been penetrated and subsequent advance should be made under close scrutiny of the graduated canula, the scale acting as a guide to the depth of penetration.

In a general way it may be said that puncture of the calvarium at its various portions is not attended with especial difficulty, as the soft parts are comparatively thin. In the temporal region the thick muscular tissue offers some hindrance inasmuch as the canula does not reach so directly the bone. In one instance while exploring the cerebellum at the *Neisser* point 1, in the case of a woman (aged twenty-eight) who had an inordinately thick neck, the layers of fat prevented my locating the drill hole for the purpose of introducing the canula. As we regarded the puncture as essential the patient was narcotized with chloroform and the scalp incised, the periosteum pushed aside and the dura exposed with the burr. The puncture was then made through the exposed dura.

I follow the latter method at all places where there is danger of injuring a sinus. In the case of a man afflicted with hemianopsia, whose case was regarded as a possible traumatic hematoma, I punctured the pole of the occipital lobe in the neighborhood of the transverse and longitudinal sinuses. In this instance I exposed with a 15 mm. burr the dura and the upper edge of the transverse sinus and then punctured with the canula.

As far as the **technique** is concerned I undertake, in most cases, the puncture without narcosis, and after the scalp has been thoroughly prepared. For the purpose of anesthesia of the soft parts I employ either the chlor-ether spray or inject subcu-

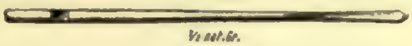

Fig. 54

taneously a solution of ½ per cent. novococain and 12 drops of 1–1000 adrenalin to 100 cm^3. of water. Without incising the scalp a 2 mm. drill (Fig. 54) is made to penetrate the skull and bored through the skull, taking cognizance of when the diplœa and the laminæ vitræ are reached. I use for the purpose the same hand drill I use for trephining. To conserve speed and yet not injure the brain, I attach to the drill, 1 to 1½ cm. above its point, a metal shoulder which prevents the point from engaging beyond this guard. The drill is then withdrawn, and while its point is still in the skin or while an assistant presses firmly the surrounding soft tissues against the skull, the graduated canula is introduced. In some cases I displace the skin slightly so as not to have the wound on the surface correspond to the place of penetration of the skull. The depth to which the needle (which is, of course, furnished with an obturator) is made to penetrate depends upon the purpose for which it is introduced. I employ canulæ which are slightly oblique at their ends, are about 1.8 mm. in transverse diameter, and have an exceedingly thin wall, so as to remove brain cylinders of sufficient size to permit of satisfactory microscopical examination. At first I introduce the canula alone to determine the presence of fluid. If none appears I aspirate. *Pfeifer* recommends for the purpose needles of platino-iridium, as they do not rust.

Aspiration is most readily achieved with the Record syringe, which has a metal piston. I use the smaller one (1 cm^3.) which is easily handled, but also use barrels which hold up to 10 cm^3. With the smaller size the syringe barrel must be disconnected and reapplied in order to get a cylinder of sufficient size for the purpose. With the large size a single suction with the piston suffices.

As the resistance is considerable an assistant steadies the instrument while suction is being made. Despite all precautions a cylinder is not always obtained by a single aspiration, irrespective of the size of the syringe employed. In these cases the syringe, together with the canula, is withdrawn from the brain, and as a rule the cylinder follows the needle. To remove the cylinder from the needle the piston is slowly pushed down and the specimen expelled into a sterile salt solution.

When several days, or perhaps weeks, after puncture the dura is opened and the site of puncture inspected, it will be found to present a tiny blood coagulum covering a slit-like opening in the brain. At times a few small splinters of bone, the result of the drilling, will be found resting on the dura.

As illustrative of the conditions I offer the following example, which is more extensively gone into in the clinical history. (Observation III, 4.) After locating the left anterior central convolution by the combined *Kroenlein* and *Kocher* methods, the soft parts were anesthesized with æthelchlorid and the skull perforated with the drill over the leg center (1). As the canula reached a depth of 2 cm. from the skin a considerable quantity of dark venous blood was discharged. The syringe was now affixed and suction made, withdrawing some additional reddish-black blood mixed with a few glassy soft particles. Microscopical examination of the fresh specimen revealed closely conglomerated cells with large clearly defined nuclei. There was no interstitial tissue between the cells, though a few cells contained fine capillaries filled with blood. The diagnosis of large, round-celled sarcoma was made. It was not feasible to withdraw a cylinder.

In order to invade a deeper area the canula was advanced an additional ¾ cm., burying it to the total depth of 1½ cm. in the brain. Aspiration withdrew only blood from this situation, which meant that the deeper puncture had extended beyond the tumor. This act has the objection of being capable of carrying portions of the tumor into normal tissue.

A second puncture was made in the arm center (2).

The canula was at once pushed to the depth of 3 cm. and aspiration made. The microscopical findings were essentially similar to those obtained from the first specimen: sarcoma cells, a few bundles of inter-

Fig. 55

Præcentral fissure with the two "third-points." Central Fissure.
——According to *Kocher's* kyrtometer. . . . According to *Kroenlein.*
D and 2 *Neisser's* puncture points in the anterior central convolution.
1 Leg center. 2 Arm center.

stitial tissue and several small particles of yellow blood pigment.

The first stage of the operation was performed immediately subsequent to the exploratory punctures. The tumor had extended to the dura to which it was attached over a small area, and had caused considerable changes in the lamina vitra, necessitating removal of the bone. The first drill opening had hit the lower edge of the tumor, and for this reason only the superficial portion of the aspirated specimen contained tumor particles and the deeper parts gave no evidence of pathological process. As shown, when sixteen days later extirpation of the tumor was performed, the second puncture had entered the middle of the large growth. This puncture opening was located 1 cm. behind the anterior branch of the middle meningeal artery. The grooves of this vessel were plainly visible on the lamina vitra. The two drill holes in the dura had not caused any alteration in the contiguous tissues. The dark venous blood which was discharged from the puncture openings came from the veins of the dura mater, which were adherent at this point to the tumor. At the trephine operation there was considerable venous bleeding from the cortex. This occurrence leads to discussion of the

Danger of Bleeding

when brain puncture is made. The branches of the middle meningeal artery, the most of the arteries of the brain and the large sinuses are quite readily avoided, as they usually follow a certain definite course. Any one who has frequently exposed the brain will admit that the veins of the pia are not susceptible to being standardized in the same way. At times very large veins occupy unimportant shallow fissures, and the central sulcus may be occupied by very thin vessels. Besides this they have only two coats and are easily injured. In the normal brain, with no increase of intracranial pressure, they are of course of small diameter, but when the brain pressure is increased they swell up to a considerable extent, and their injury becomes a matter of some import. The thinnest of canulæ would not offer any safeguard in this regard. I have seen the veins of the dura dilated to the diameter of a medium-sized lead pencil in cases of brain tumor. Also growing tumors displace the veins and arteries to so great an extent as to make anatomical localization impossible. The writer has several times experienced disturbing bleeding in making brain punctures.

In one case, in which the posterior portion of the fissure of *Sylvius* was exposed, the puncture was accompanied by a sharp arterial hemorrhage, evidently from an anomalous branch of the artery of the fossa of *Sylvius*. If this accident occurs when the brain is exposed and all precautions are taken, it will more likely obtain when the puncture is made through the intact calvarium. In this instance as search was being made for fluid and no attempt to extract a brain cylinder was contemplated, a small needle only 1 mm. in thickness was employed.

In another case, that of a man (aged thirty) who was afflicted with suppurative otitis media following influenza, and who ultimately died of suppurative meningitis, brain abscess was suspected, and I made several exploratory punctures, employing a 1.2 mm. needle for the purpose. In this connection it is of importance to state that because of a left hemiplegia I drilled through the skull over the right posterior central convolution at its middle. A sharp arterial bleeding occurred. The soft parts were at once incised, and the drill hole enlarged with a large spherical burr. When the dura was exposed it was found that a medium sized artery had been invaded by the drill. The bleeding was controlled by encircling the vessel with a ligature passed with a needle. At the autopsy considerable difference in color of the two cerebral hemispheres was apparent. When the skull was removed the right was dark blue; the left greenish white. When the dura was removed the right hemisphere, especially at its posterior aspect, was covered with a thin layer of coagulated blood several mm. in thickness, which was readily removed. The puncture at the base of the posterior central convolution had involved an end branch of the middle meningeal artery, as was recognized by the hole in the dura. The brain at this situation was slightly infiltrated with blood. On the whole it was fair to assume that the subdural hemorrhage was the outcome of the puncture.

It is also to be feared that aspiration subsequent to puncture may, especially in cases with diseased blood-vessels, lead to dangerous bleeding which may invade the ventricle.

It seems to me that the greatest danger in puncture attends cases of angioma racemosum venosum. Considering the proposition from the viewpoint of the case reported on page 87, it is easy to see how each puncture would have invaded one of the thin-walled veins which were as large as the finger, giving rise to so violent a hemorrhage into the arachnoid space that the patient would have been in imminent danger of death despite the fact that he was on the operating table, and a rapid trephine opening for the purpose of arresting the bleeding could have been performed. Even the encircling of the approaching veins at the time of the operation, though carefully executed under the eye with a curved round needle, was attended with portentous bleeding which required prolonged compression before it was controlled.

A diagnosis before the operation was impossible. Indeed, one authority who saw the case had recommended employment of the *Neisser* puncture a short time before the operation was done. I had formed certain conclusions regarding the case beyond the *Jacksonian* epilepsy. The progressive involvement of the anterior central convolution and subsequently the posterior central convolution led me to believe that the process was one of a growing tumor or cyst. I had discussed the problem with the attending physician (who was related to the patient) and had mentioned the possibility of the existence of angioma just before the operation, as a short time previously one of our best surgeons had lost a patient on the table from hemorrhage, the result of injury to a large blood-vessel, in just such a case. However, the question was one of probabilities and no more. Of course angiomata of this sort are exceedingly rare; however, this fact does not excuse employment of a dangerous measure.

Pursuant to the symptoms the *Neisser* puncture would have had to be made in the arm center of the anterior central convolution, for the convulsions began in this limb. At precisely this point the puncture would certainly have invaded the smaller convolute, and probably one of the larger veins, and it would have been a fortunate circumstance which one would not have a right to expect had the needle not injured some vessel in this labyrinth of dilated veins. (Plate VIII.) Injury to even a small vein would have caused a diffuse infiltration of the meshes of the arachnoid, so that even under the most fortunate conditions the field exposed by the trephine operation would, at least, have been effectually obscured.

The Danger of Infection

must not be disregarded. Of course, the danger of infection from without can be avoided, but this does not apply to menace in this regard from within the cranial cavity. I illustrate this in the following way. (Observation V, 1.) *H. Oppenheim* had sent me the case with the diagnosis of tumor in the parietal region, which, indeed, was true, the condition being that of a solitary tubercle which had undergone purulent liquefaction in two places. Puncture, which was not made because of the certainty of the diagnosis, would have opened the pus areas, as they were only covered by a thin layer of cortical substance close to the free non-adherent arachnoid. At the operation it developed that the pus was under considerable pressure, so that the puncture, which was made after the cortex was exposed, caused the pus to ooze out beside it. This would have occurred had the puncture been made through the intact skull. It is true the pus was not septic and did not contain any staphylo-or streptococci but was thoroughly infested with tubercle bacilli constituting a pure culture of this bacterium. It may be regarded as a serious matter to permit of the invasion of these infection-producing bodies in considerable quantity into the meshes of the arachnoid. The only protection against this contingency would have been an immediate trephining.

In cases of suspected brain abscess it is my universal practice not to puncture the brain until the dural flap is widely fashioned and turned aside. I then pack around in the space between the dura and the brain surface with iodoform or vioform gauze strips (page 104).

Beside infection with pus the possibility of conveying particles of tumors into the contiguous normal brain substance as the outcome of pushing the exploring canula beyond the limits of the diseased area, is to be taken into consideration. This may generally be avoided by proceeding by the "layer" method of *Neisser*.

There are, however,

Additional Disagreeable Occurrences

which may be the outcome of brain puncture, as is illustrated in the following manner. The patient (aged twenty-nine) was sent to me by *H. Oppenheim* with a diagnosis of a tumor in the left central region. This area was punctured under chloroform narcosis in four places, using a 15 mm. (wide) canula for the purpose. The first puncture was made at the left anterior central convolution 1 cm. in front of the fissure of *Rolando*, 3 cm. below the sagittal line. Under normal conditions the longitudinal sinus did not require consideration; however, a forcible venous hemorrhage occurred which was projected from the wound in pulsating form. The canula had penetrated 2 cm. beneath the surface, that is, as the skull coverings were $1\frac{1}{4}$ cm. in thickness, was buried $\frac{3}{4}$ cm. in the brain. Compression arrested the bleeding. Two more punctures in the anterior and another in the posterior central convolutions did not provoke any bleeding. The brain cylinders did not reveal anything determining upon microscopical examination. In a few of the specimens from the anterior central convolution there was an unusual amount of fine fibrilar network which aroused suspicion of fibroglioma.

At termination of the narcosis the patient's general condition was unfavorable, headache and restlessness obtained until night, though the pulse rate did not materially increase nor did it give evidence of increase of pressure. The sensory aphasia which had existed before the punctures was manifestly increased. Understanding of spoken language was difficult but not absent. These disturbances receded in five days to about the conditions present before the punctures were made. The paresis of the right arm, which had become a complete paralysis, immediately subsequent to the puncturing, improved slowly, but at the end of ten days was still more marked than it had been before the punctures were undertaken. Also the reflexes had become more involved and slowly returned to the same condition as had obtained before the punctures were made.

As these disturbances did not recede until after five days or later, and occurred on the side opposite to where the punctures were made, it is difficult to trace any other causative relationship than the obvious one. After the extensive trephine operation undertaken twelve days later, the patient was not so severely taxed as he was after the brain punctures, and again the disturbances of nerve centers occasioned by this operation were overcome at the end of the third day following the trephining. As the patient had been subjected a year earlier to the trephine operation at her home without formation of a dural flap, it was only necessary to incise around the original flap and turn it down. This revealed the presence of a tumor half the size of a chestnut situated at the inferior posterior angle of the wound. Later this proved to have perforated the dura and protruded beyond the convexity of the brain. The dura was covered with small areas of blood residue. Black blood oozed from the prolapse. An incision carried parallel to the sinus opened a cavity the size of a walnut which was filled with dark blood. As further investigation revealed the presence of a widely disseminated diffuse glioma, extirpation was not attempted. The patient was discharged with the wound healed and the general condition much improved.

I have felt it my duty to call attention to the dangers of brain puncture, not with the view of condemning it, but to warn against its indiscriminate and planless employment. Also I am too great an opponent to unjustified exploratory puncture as applied to other portions of the body not to be of firmer conviction in this respect when dealing with so vulnerable an organ as the brain. My intention is to see that the application of a measure which is scientifically correct and of great service as a means of diagnosis does not fall into disrepute. One must admit that brain puncture, as indicated by *Neisser* and *Pollack*, may be properly regarded as an important factor in arriving at a diagnosis. It should, however, only be employed when all other diagnostic measures have been used. At times in this way important conclusions with regard to the location, extent and character of pathological processes are obtained. Especially useful is the measure when the characteristic symptoms of brain tumor are not clearly manifest. At times the localization is only determined in this way when intracranial pressure obscures the diagnosis as between involvement of the cerebrum and cerebellum, a doubt which unfortunately arises at times. *H. Oppenheim* has called attention to the fact that in hemianopsia only brain puncture can determine whether the diseased focus is in the temporal, occipital or parietal lobes. In any event the experienced diagnostician who, in many instances, is able to localize with certainty a tumor, will more frequently disregard brain puncture than those who have not had the same opportunities in this connection.

In order to meet the dangers with as much hope of success as is possible, brain puncture should never be undertaken unless ample preparation for immediate trephining has been made, so that the indications for measures of relief may be promptly met.

Ventricular Puncture and Ventricular Drainage

The

Anatomical Situation of the Lateral Ventricle

must be accurately determined before puncture is undertaken. This is shown in Fig. 56, according to *Thane*. The legend explains the illustration. Beside this the results of *Poirier's* investigations are added. The vertical extent of the ventricle is indicated by two horizontal lines drawn 5 cm. and 2 cm. above the zygoma respectively. The deepest point in the latter level corresponds to the inferior horn. Of the two frontal levels which indicate the limits of the ventricle, one is drawn vertically at the junction of the anterior and middle thirds of the zygoma and corresponds to the anterior end of the anterior horn, which is located 6 to 7 cm. behind the skin of the forehead. The other vertical level falls 5 cm. behind the point of the mastoid process, and indicates the point of the posterior horn which is opposite a point 4 cm. in front of the posterior aspect of the scalp. Laterally from the scalp the anterior horn is located 5 cm. and the posterior horn 4 cm. from the scalp. The last two measurements are regarded by *Waldeyer* as being actually 12 mm. less than here indicated. The inferior horn is, as obtains in regard to the posterior horn, located 4 cm. from the outer surface of the scalp.

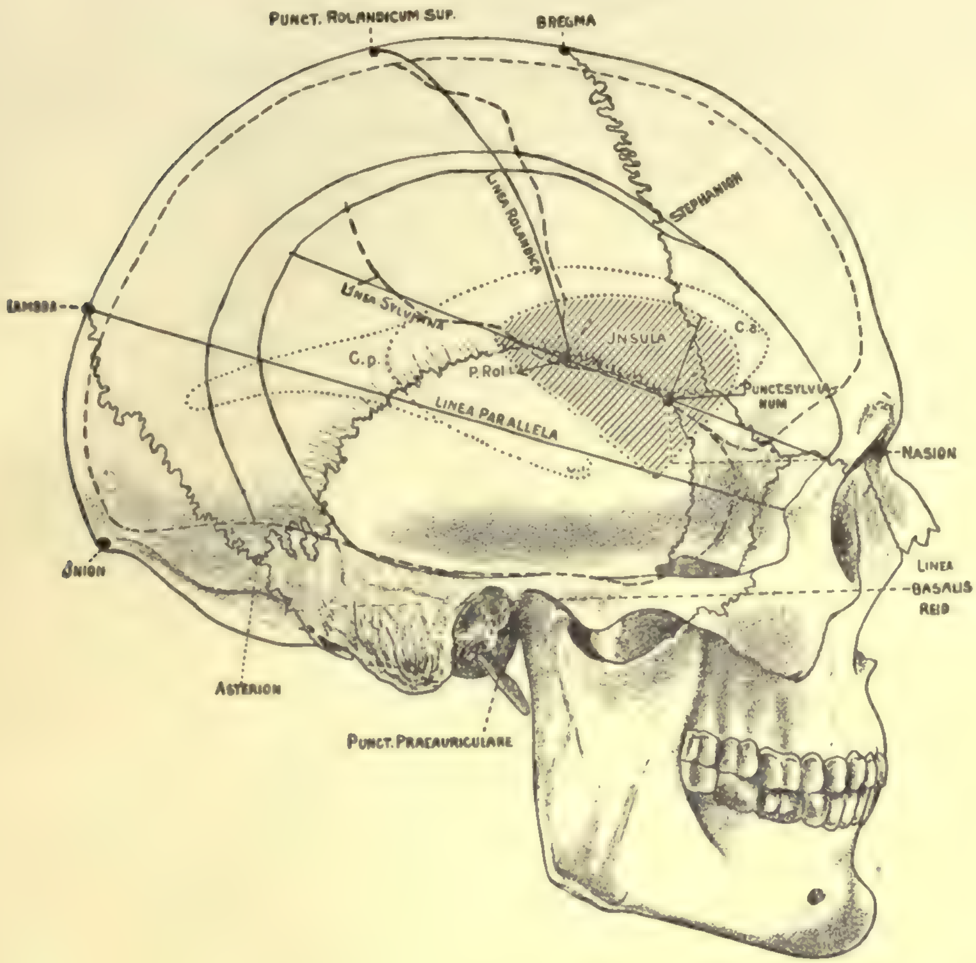

Fig. 56

Island of Reil. The punctum *Sylvii* indicates the pole of the island, its posterior end corresponds to a point on the linea Sylviana, 35 mm. behind the punctum. The location of the island is indicated by the shaded lines, which also constitute a guide to the situation of the basal ganglia, the latter extending but little beyond the borders of the island, about to the outer borders of the lateral ventricle. The *lateral ventricle* is outlined by the dotted line. Its three horns (cornu anterius C. a, posterius C. p, inferius C. i,) are also shown.

The fissures of *Rolando* and *Sylvius* are indicated by broken lines.

For the purpose of

Puncturing the Lateral Ventricle

T. Kocher prefers to invade the cavity in the sagittal level at a point which corresponds to this direction. His experience causes him to regard the most favorable puncture point to be in front of the bregma, that is, at the intersection of the sagittal and coronal sutures He punctures at a point 2 cm. (on account of the longitudinal sinus 3 cm. is better) lateral from the median line, directing the instrument downward and backward and at the depth of 5 to 6 cm. reaches the distended ventricle. *Kocher* also makes drainage in this way. It is his opinion that injury to the opposite ventricle is best guarded against if the tube is only pushed into the upper portion of the cavity and its further invasion prevented by fixation in this situation. On the other hand *v. Bergmann* punctured the lateral ventricle from the forehead, drilling into the skull at a point close to and a little to the median side of the frontal eminence, and introduced into the brain a long hollow needle in a slightly downward and inward direction until fluid appeared.

Keen employs for the purpose a lateral approach, selecting a point 3 cm. above the external auditory meatus. The instrument is introduced in the direction toward the tip of the opposite external ear, and at the depth of 5 cm. the ventricle is reached. He was able to make through and through lavage of both ventricles after simultaneous bilateral puncture in this situation. *Neisser* reaches the anterior horn at a depth of 2-5 cm. through the frontal lobe from F_2 (Fig.

53). From P and Occ the lateral ventricle is reached at the depth of 3 cm. from the surface of the brain.

Pathological accumulation of liquid may be sufficiently large to dilate the ventricle to a considerable extent, indeed, in some instances, the dilatation is sufficiently great to thin out the walls of the ventricle, giving the brain the appearance of a full bladder. Under these conditions puncture at almost any point on the calvarium achieves the purpose. In some cases of moderate hydrocephalus internus I have found it convenient to puncture immediately above the transverse sinus, about 2 cm. above the external occipital protuberance, in the horizontal level, entering the cavity either directly forward or slightly upward and forward. In this way the posterior horn is invaded. Drainage of the lateral ventricle may also be accomplished in this manner.

In the case of a girl (aged eighteen), a tumor of the cerebellum had been simulated by an enormous kyphos of the base of the skull. (Observation VII, 9.) When the two cerebellar hemispheres were exposed the tentorium bulged strongly downward. A scalpel was carried horizontally through the dura mater immediately above the left transverse sinus, and pushed on into the lateral ventricle. A considerable quantity of clear fluid was at once discharged. A drain, the thickness of a lead pencil, was carried along the knife blade and introduced into the posterior horn of the ventricle. This step was followed by a copious discharge of fluid (estimated at 200 cm^3.). The patient collapsed as the result of the sudden lowering of brain pressure, but reacted promptly after the head was lowered. Now as the intracranial tension was reduced the cerebellum could be readily inspected on all sides and to a considerable extent inward. No pathological alteration became manifest, and the writer was forced to be content with the ventricular drainage. The dural flap was sutured into place on both sides with catgut, and the superficial wound closed with silk sutures except for the point of emergence of the drain.

After the operation the patient recovered with amazing rapidity. During application of the dressing the pulse rate was 120 per minute and the quality good. A few hours later she answered questions and partook of large quantities of water without vomiting. No paralysis of motion or sensation occurred. In the evening the pulse was full, temperature 36.7, the same as the day before the operation. The further behavior of the case may be found in the clinical history.

In accord with the measurements of *Lannelongue* and *Mauclaire*, puncture of the inferior horn in children between the ages of two to fourteen, should be made above the external auditory meatus on a line running from the process marginalis of the zygoma horizontally backward, parallel with the sagittal level to a little above the external occipital protuberance. The inferior horn may also be reached at T_2 and T_3 (*Neisser*. Fig. 53), at the depth of 3 cm. from the cortex.

Puncture of the Fourth Ventricle

the writer has performed twice, but only after both cerebellar hemispheres had been exposed at the middle portion (Fig. 57) in one instance, and in the other after an entire lobe (Fig. 58) together with the occipital sinus had been exposed. The puncture was made exactly at the angle of the inverted Y (⅄) formed

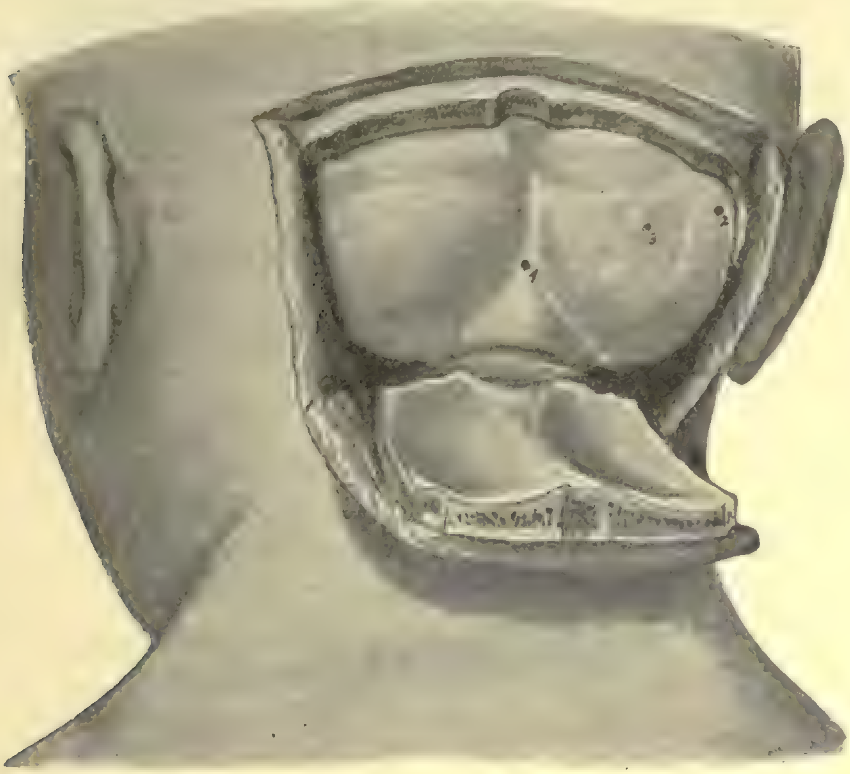

Fig. 57
Arch of Atlas

by the dura at the junction of the cerebellum and the medulla oblongata (point 1 on both figures), and the instrument introduced in the sagittal level in a forward direction at an angle of 45 degrees upward, advancing carefully and slowly until liquid flowed from the canula. In this way the cover of the fourth ventricle is perforated; however, the important nuclei on its floor are not invaded. In both cases no unfavorable outcome attended the punctures; on the contrary a desirable influence on the brain pressure resulted in each instance.

Subcutaneous Permanent Drainage of the Ventricles

If the tube draining the ventricle is permitted to emerge upon the skin, the persistent drenching of the dressings with fluid makes prevention of infection quite difficult. This may be prevented, perhaps, if the drainage be maintained for several weeks, and great care in the treatment be observed. In one instance of a male patient (aged twenty-nine), who presented severe symptoms of intracranial pressure due to hydrocephalus internus, I made drainage from the temporal lobe. The tube functioned very well for six weeks, the symptoms moderated, the discharged fluid was clear until death supervened, and was found free from bacteria after repeated careful examinations, which included attempts at cultivation upon various media. However, the patient's condition became materially worse during the eight days preceding the fatal outcome, though this was not accompanied by any signs of meningitis. Autopsy substantiated the clinical conception, the brain showing only hydrocephalic changes.

Death as the outcome of septic infection is, however, the more frequent history in these cases when drained in the usual way. *Broca* has concluded from a study of the literature that children with open skull sutures all die when ventricular drainage is made; however, he reports a case of his own which recovered as the result of prolonged drainage. *G. A.*

Fig. 58
Arch of Atlas

Sutherland and *Watson Cheyne*[1] use for intracranial drainage in hydrocephalus bundles of catgut, which they lead from the ventricle to the subdural space. *Nicholas Senn*[2] used for the same purpose a thin rub-

[1] Pedriatics, No. 98, 1899.

[2] Subcutaneous Drainage in the Surgical Treatment of Hydrocephalus Internus. *The Alienist and Neurologist*, St. Louis, August, 1903. Vol. XXIV, No. 3.

ber drain which is intended to lead the fluid from the ventricle to beneath the skin, and also is supposed to make elastic pressure on the skull.

Mikulicz[1] attempted to facilitate the outflow of the excess of fluid in the ventricles by establishment of a permanent connection between the brain cavities and the loose connective tissue beneath the scalp. The idea was to lead the ventricular fluid into tissue, from which absorption would take place. To carry out this plan he employed for the purpose a gold tube 2 cm. in length, with a lumen of 3 mm., attached to

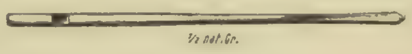

Fig. 59

a thin oval plate 1½ by 2 cm. in width. The report of this procedure did not obtain wide circulation, as I was not aware of it when I made the attempts described as follows:

The writer uses for the purpose a thin-walled gold-plated silver canula about 2 mm. in diameter. A small flap, consisting of skin and aponeurosis only, measuring 2 cm. at its base, is cut over the site of the proposed drainage. The periosteum is split longitudinally and pushed aside. The skull is perforated with the drill (Fig. 59), which is 2 mm. in diameter, and is the same as I use for puncture. Injury to the dura is avoided. The canula is telescoped over a hollow needle which it fits snugly, and carried through

[1] A. Henle, Beitrag zur "Pathologie und Therapie des Hydrocephalus." "Grenzgebiete der Medizin und Chirurgie I." 1896. Seite 26. Henle, Ventrikeldrainage. "Grenzgebiete der Medizin und Chirurgie," 1897. Bd. I, Seite 264.

the dura and into the brain toward the ventricle or horn beyond until fluid flows from the distal end of the instrument. The perforating instrument is carried onward an additional ½ cm. and firmly held, while the needle is withdrawn and a strong steel stylet (knitting needle) is introduced into the canula. An incision is now made into the canula at a point 1 cm. distal from the level of the bone, employing a bone forceps for the purpose. The steel staff is withdrawn and the tube broken off at the site of the incisure. The protruding end of the canula is then slit with a fine scissors at its two lateral aspects down to the level of the bone, and the two silver tongues thus obtained are bent outward until they lie in intimate contact with the surface of the contiguous bone. This measure prevents the canula from advancing farther into the brain. To prevent its expulsion the periosteum is postured over the two tongues of the canula and fastened with a few fine catgut sutures, so as to leave the lumen free.

Light pressure upon or a slight withdrawal of the canula will demonstrate whether it is efficiently situated, and this should be tested before the instrument is fastened in place. A slender probe is passed through the canula to assure its patency, after which the scalp flap is replaced and accurately sutured. The canula opens into the subcutaneous tissue and does not come in contact with the suture line. It may be permitted to remain *in situ* for months if no indication to the contrary is manifested. I cannot now state anything positively with regard to the length of time drainage should be maintained. When the canula ceases to give egress to fluid it may be removed. As this is readily accomplished through a simple incision, it is hardly necessary to use an absorbable metal like magnesium for the purpose.

At first the ventricular fluid oozes through the stitch holes, but after a time the wound closes and

Fig. 60

Seven-year-old boy with hydrocephalus, thirty days after subcutaneous drainage of the right lateral ventricle through the parietal lobe. The circumference of the skull had reduced from 55 to 52 cm. The fluctuating bleb over the right parietal bone could be emptied by pressure and the bent tongues of the canula were then palpable, under the periosteum. The bleb measured 40 mm. in diameter, and was elevated 25 mm. above the bone.

the fluid accumulates in the subcutaneous tissue, causing an œdema, or a bleb (Fig. 60) is formed, and the fluid is absorbed. If drainage of the lateral ventricle is made in the temporal region the eyelid on the same side, or both, becomes œdematous and swollen. This disappears, however, in a few days. This occurrence may be repeated at intervals showing that the fluid is flowing from the cavity. When the ventricle contracts, the canula may become obstructed by the collapsing brain tissue. In these instances fluid slowly escapes beside the canula; however, the diminution in the rate of flow is not undesirable at this time.

The position of the tube in the ventricle is shown in Fig. 61. A youth of twenty-six, who presented symptoms of general cerebral pressure, together with clonic spasm of the face, had been under the observation of *S. Placzek* for several months, under suspicion of a lesion in the anterior central region. Prolonged specific treatment and the serum treatment used in the *Wassermann* institute did not improve the conditions. Trephining was done, but no lesion beyond an œdematous infiltration of the arachnoid was revealed. Puncture of the ventricle caused the discharge of so large a quantity of fluid that I made permanent drainage of that cavity. The patient's condition did not improve, and a fatal outcome followed six days later. The autopsy (*Oestreich*) revealed an extensive gummatous basilar meningitis. After hardening of the specimen a frontal section along the tube was made. The section (Fig. 61) shows the canula in the quite collapsed ventricle, while the other lateral and the third ventricle are considerably dilated.

I have made permanent drainage of the lateral ventricle three times, for chronic hydrocephalus, from the parietal bone, or from the temporal bone, and once from the upper portion of the squama of the occipital bone entering the **posterior horn**. in this way, in order to avoid injury to the motor region. This case I would like to submit as an example. After the scalp flap and periosteum had been sec-

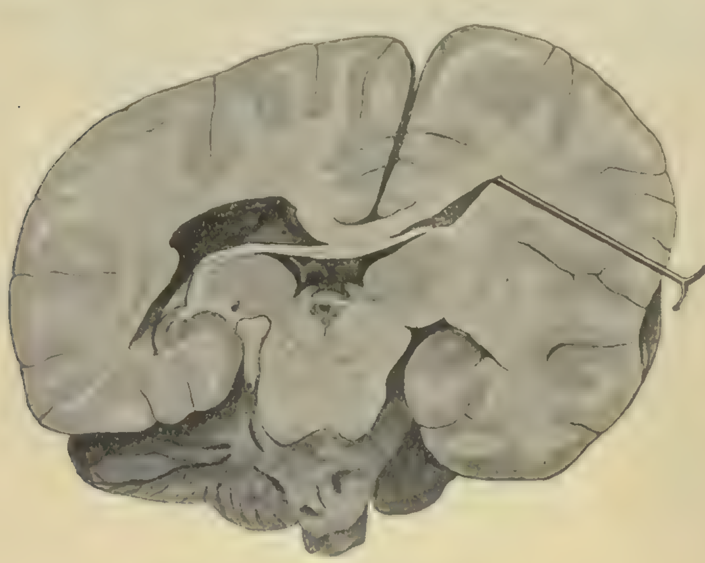

Fig. 61

tioned, the skull was drilled and the canula introducéd on a horizontal plane running 3 to 4 cm. above the line, connecting the external occipital protuberance and the upper edge of the auditory meatus at a point 7½ cm. backward from the attachment of the external ear and 5½ cm. from the sagittal line, in order to avoid the occipital pole. The canula was advanced horizontally forward, a little obliquely downward and inward, and at the depth of 55 mm. from the surface of the bone ventricular fluid was discharged, which spurted out in a quite forcible stream. The case was that of a boy (aged five) who showed normal development until the second year of life, when retrograde symptoms became manifest. The attendants regarded the condition the outcome of inflammation of the brain and meninges. At the fourth year the boy was idiotic, and passed the urine and feces involuntarily. The general development, with the exception of the head, was normal.

Examination revealed a marked hydrocephalus with open fontanelles. The circumference of the head measured 57 cm. The rest of the body was normally developed, and no evidence of disease in other situations was discovered. The standing position was maintained with assistance, locomotion occurred with ataxic forward projection of the legs. The child had been timid and nervous since the beginning of the affliction. Sleep was restless. Beyond moderate bilateral choked disk no special symptoms presented. On October 1st, 1907, I made permanent drainage at the posterior horn. The child has now worn the canula for nine months (July, 1908), and no evidence of irritation at the site of the operation has appeared. During the first weeks following the operation, a bleb presented at the posterior segment of the head which was varyingly tense and limp. Since February this has disappeared. Written communications inform me that the boy's general condition is much improved, the head measures 52 cm. in circumference. The mental state is much clearer, and what is of importance, the need of discharge of the excretions is announced permitting of cleanliness.

This case shows that, if carried out as described, permanent drainage may be maintained for a long time, and that the canula may be permitted to remain *in situ* without causing any disturbances. In this regard, at least, the measure is not objectionable. As to cure in so short a time, this is, of course, out of the question. It will require the lapse of years before an opinion may be offered in this connection. It is also not possible to state at this time whether the canula is still functionating at the end of several months, or if it might not be best to introduce another tube at some other place. This case is reported thus incompletely for the purpose of showing that the measure is devoid of danger.

Whether the measure is applicable to cases of **acute hydrocephalus** the future must decide. The only child I operated on for this condition died. The boy (four months of age) twelve days after a normal labor developed a high fever and rigidity of the back of the neck which led to a diagnosis of "tuberculous meningitis." At the end of three weeks the general condition improved, but four weeks later the head began to increase in size, and the child became totally unconscious. When I saw the little patient the condition was one of acute hydrocephalus, the circumference of the head measuring 56 cm. The ophthalmoscope showed pale disks and dilated veins. The suture areas were widened and the veins of the scalp were tensely engorged. I selected the left temporal region for introduction of the canula. After making a small skin flap near the upper edge of the squamous plate of the temporal bone the thin muscle came into view. The muscle and periosteum were split vertically and pushed aside and the bone drilled. The dura was very tense and did not pulsate. The entering canula caused discharge of a

Fig. 62
Subcutaneous Permanent Drainage of Posterior Horn
Child (aged 5) operated upon October 1st, 1907. Radiagraph taken March, 1908

liberal stream of clear fluid when the depth of 3 cm. was reached.

At first the course of the case was exceedingly favorable, the temperature remained normal, the general condition was good, and intelligence improved to a remarkable extent. On the third day the circumference of the head measured 53 cm., and the veins of the scalp were no longer engorged. Fluid trickled from the edges of the scalp flap in moderate quantity, and the subcutaneous tissue, including the upper eyelids, were œdematous. Three days later the dressing was soaked with fluid and was changed. The wound had healed except for the stitch holes which latter permitted of the discharge of fluid. Eight days after the operation general convulsions occurred, and the head measured 52 cm. in circumference. The wound showed no reaction, but nevertheless it was bluntly opened and the canula (4 cm. in length) removed. At once a large quantity of fluid was discharged. Microscopical examination showed the fluid to be sterile. The convulsions continued, however, and the next day the child died. Autopsy was not permitted.

Despite this unfavorable outcome it does not seem to the writer to be fair to condemn the measure in cases of acute hydrocephalus. It is to be borne in mind that acute as well as chronic hydrocephalus frequently enough do not represent a disease *sui generis*, and may be a complication of a localized affection, as for instance solitary tubercle or tumor, which because of the absence of local symptoms has not been recognized. In this case drainage does not do any good, as it only controls the dominant symptoms.

Employment of the measure comes under consideration in acute accumulations of fluid, which occur in the ventricles, in inflammatory processes such as tuberculous basilar meningitis, and cerebrospinal meningitis. *W. Schulz* reports favorable effect following ventricular puncture upon the rigidity of the neck, in cases of epidemic meningitis, though this was only temporary in character.

Permanent Drainage with Ossified Sutures

Another question arising in this connection is that of whether, in instances in which the sutures have closed, *i. e.*, with stiff, unyielding encasement, the establishment of permanent drainage suffices, or, if

Fig. 63
Girl (aged 16). Operated upon February 19, 1908.
Photographed April 14, 1908.
Subcutaneous Permanent Drainage of Lateral Ventricle with Formation of Vent.

in order to rapidly reduce the intracranial pressure the formation of an opening in the skull should be also made. I have done this in a girl of sixteen. As the clinical manifestations pointed to a lesion in the right central region, in addition to hydrocephalus, the motor area was exposed in the usual manner. No lesion was found. The ventricle was punctured at a depth of 28 mm. from the cortex at a point in the upper portion of the arm center. The canula was not attached through a new drill opening, but was permitted to emerge through the anterior bone section. The periosteum to either side of the bone section was drawn over the two tube tongues and held with two catgut sutures. The canula did not cause any irritation, and has been *in situ* for five months. The radiograph (Fig. 63) taken eight weeks after the operation, shows the tube and the light strip around the bone flap which denotes where the bone was removed to allow of additional vent.

In this case the dura was opened for the purpose of examining the cortex of the brain. As supplementary to the permanent drainage it would have been sufficient to remove a strip of bone and periosteum 1 cm. in width surrounding the bone flap. The dura then conforms to the reduction of space resulting from the emptying of ventricular fluid. The intradural pressure reduces as soon as the fluid is removed. This factor renders the mechanical conditions quite different from those which obtain in the decompression trephining for inoperable brain tumors. Judging from the writer's experience, no lasting benefit arises if the dura is not opened in these cases, as the growth of the tumor progressively increases the intradural pressure and makes the dura correspondingly more tense. In hydrocephalus internus the dura contracts in accord with quantity of fluid expelled, and, indeed, in some instances, when the limit of its elasticity has been reached, arranges itself in folds, as I have frequently observed during operations. The measures employed for permanent decompression have been used for too short a period of time to permit of positive conclusions regarding their utility. My experience would lead me to believe them worthy of trial. I illustrate the proposition in the following way:

The patient, a man (aged twenty-eight), presented the picture of severe intracranial pressure without any local symptoms of a localized lesion. In view of the fact that ataxia had been a dominant symptom the trephining operation was performed over the right cerebellar lobe, the opening being made to extend beyond the median line to the left and upward beyond the transverse sinus with the intention of opening the dura at a second sitting, for the purpose of examining the brain itself. The trephining operation was not followed by improvement of the symptoms, and ten days after the first operation the exposed dura was punctured and the posterior ventricular horn tapped. The ventricular fluid escaped in a rather forcible stream. The patient's general condition was too much impaired to warrant extensive operative interference, and in order to achieve decompression with the least trauma I made a drill opening in the parietal region and established permanent subcutaneous tube drainage. At the end of eight days the improvement in the general condition was so marked as to render additional interference unnecessary.

Ventricular Tapping as a Preparatory Operation

The formation of a vent in the skull comes under consideration together with ventricular tapping in cases of brain tumor, in which the accumulation of fluid in the cavities of the brain is so great as to constitute in itself a menace to life. After unburdening the brain, when the menacing manifestations are lessened, the final extirpation may be undertaken under much more favorable conditions. Whether simple puncture or the introduction of the silver tube should be executed, the future must decide. I have seen a life-saving amelioration of the conditions follow simple puncture. A young man (aged eighteen) had been sent to the writer by *H. Oppenheim* with a probable diagnosis of tumor cerebelli dextri. The first stage of the operation was to be attempted while the patient was in the sitting posture. After a few whiffs of chloroform had been taken pulse and respiration ceased, making necessary artificial respiration and cardiac massage. The operation was now undertaken with the patient in the left lateral position with the head lowered. As asphyxia occurred again the ventricle was punctured 3 cm. to the right of the bregma. About 30 cm^3. of clear fluid were discharged, at first in a stream, later in rapidly falling drops. Pulse and respiration improved at once. It was now possible to expose by the osteoplastic method the right cerebellar hemisphere, the occipital sinus, a part of the left hemisphere and the pole of the right occipital lobe, under light chloroform narcosis without further disturbance. The dura was devoid of pulsation. To achieve additional decompression the posterior horn was punctured above the transverse sinus and about 40 cm^3. of fluid withdrawn, which, in this situation also came forth with considerable force in the form of a stream, ending in rapidly falling drops. After this the dura over the cerebellum and occipital lobe pulsated plainly. The pulse became irregular for a time, but soon steadied.

Judging from my other experiences I do not think that in view of the patient's serious condition, the extensive trephine operation could have been performed without the preliminary decompression measures. The immediate subsequent behavior of the case was very satisfactory. Eleven days after the operation *H. Oppenheim* found that all the severe symptoms had disappeared or were largely improved, indeed, the choked disk had moderated considerably.

In a case of cerebello-pontian tumor (male, aged forty-six), I was able to relieve a severe intracranial pressure, after completing the first stage of the operation, by simple puncture of the subdural space. The measure was followed by the discharge of a large quantity of fluid which was manifestly under great pressure, and an effective lessening of the brain compression symptoms obtained.

Contrary to my usual custom I offer the methods just described before a positive conclusion regarding their utility is possible. However, they seem rational to me and are, no doubt, serviceable in lessening the dangers of brain operations.

Lumbar Puncture

The *Quincke* method opens the subarachnoid space with a hollow needle at the lower portion of the dural sac. The discharged cerebrospinal fluid may be subjected to chemical, bacterial and microscopical examinations, also when the canula is connected with the water or mercury manometer, the pressure of the fluid may be measured.

When the diagnosis of brain tumor has been made, removal of the fluid by lumbar puncture must be avoided. Increase of brain pressure has occurred simultaneously with this seemingly unimportant measure, and death has resulted. We will see later how firmly the medulla oblongata, and especially the walls of the fourth ventricle, may be forced into the foramen magnum when the intracranial pressure is raised. A sudden decompression of the spinal canal, as obtains with lumbar puncture, may cause these vital centers to be still more forcibly crowded, and their function be endangered. Lowering of the head does not constitute a safeguard in this regard.

This does not apply to the *Kroenig* pressure measuring procedure, as this involves only the withdrawal of a fraction of a cubic centimeter of fluid which suffices to fill the requisite glass and rubber tube. In the instance of a patient (aged twenty-seven) who presented severe pressure symptoms without local indications, justifying localization of a lesion, no disturbances followed the employment of the *Kroenig* pressure measuring apparatus. The instrument indicated a pressure of 200 mm. However, as soon as

2 cm^3. of fluid were withdrawn for diagnostic examination, the patient immediately vomited, went into collapse and remained unconscious until evening. The next morning he was still weak.

In another case (Observation IV, 1) the lumbar puncture was also followed by severe symptoms. It had, however, the redeeming feature of defining more clearly the local symptoms, thus permitting of a diagnosis.

We may conclude from this that lumbar puncture as a diagnostic means (its therapeutic value does not call for discussion here) should only be employed when determining information is to be expected.

In the adult the normal pressure with the patient in the supine posture equals, according to *Quincke*, 40 to 60; to *Kroenig*, 100 to 150 mm. of water. An increase beyond 150 mm. is certainly pathological. A pressure as high as 700 mm. has been observed. In children the figures are only slightly less. The extent of pressure does not indicate the seriousness of the affliction. In this regard the rapidity with which the pressure rises is of indicative value. According to *Quincke*, moderate rise of pressure, together with severe pressure symptoms, indicate an acute exacerbation, a slight rise of pressure, a chronic affliction.

The normal cerebrospinal fluid is water-clear, of alkaline reaction, has a specific gravity of 1007, and is quite free from cellular elements. It contains a little albumin (0.2 to 0.5 per thousand), and a small quantity of sugar. Pathological conditions of the central nervous system are expressed by cloudiness of the fluid and the presence of blood, coagulated fibrin, pus and micro-organisms.

The *presence of blood* may originate from the puncture of a vein. This may be avoided if the puncture is made in the median line under the spinous process of the second lumbar vertebra, rather than when the oblique puncture from the side is employed. Blood which comes from a punctured blood-vessel coagulates much more rapidly than when it is mixed with the fluid. When the specimen is centrifuged a yellowish color of the blood would indicate that the hemorrhage occurred before the puncture was made. From a pathological viewpoint the presence of blood may indicate hemorrhage from the meshes of the arachnoid above the point of puncture —the quantity of blood is then small—or arise from a cerebral hemorrhage which has broken into the ventricle. *Hartmann* (Graz) in two cases of hemorrhage into the brain cavities, withdrew by means of lumbar puncture moderate quantities of blood which did not coagulate. On the ground of this finding in one case he withdrew a large quantity of blood from the ventricles by lumbar puncture achieving an amazingly favorable influence on the brain symptoms.

When the puncture fluid is left standing a coagulum separates when inflammation is present. This does not occur in cases of chronic hydrocephalus and with obstruction transudate from brain tumors. *Cloudiness* of the fluid occurs occasionally with tuberculous meningitis, and is quite constantly present with purulent inflammation of the meninges. If it be absent in the latter cases, the presence of a large number of cells in the fluid justifies the conclusion that pus is present. The presence of large numbers of polynuclear cells argues for purulent cerebrospinal meningitis, domination of lymphocytes speaks for tuberculous meningitis.

Quincke's puncture is of value in differentiating brain abscess from purulent meningitis; if the fluid contains pus or pus corpuscles which cloud it, the diagnosis of purulent meningitis is certain; if the fluid is clear and shows no abnormality upon microscopical examination, abscess of the brain may be present, or at least a purulent inflammation which is restricted to the membranes of the cranial cavity.

Characteristic tumor cells from malignant growths of the central nervous system have been occasionally discovered. In a few instances portions of cysticercus and echinococcus have been found. Microscopically the presence of streptococci, pneumococci, meningeal cocci and tubercle bacilli may be demonstrated.

The presence of albumin in considerable quantity argues against simple hydrocephalus. Traces of albumin would indicate an inflammatory or tuberculous meningitis; also, it renders improbable the existence of a transudatory exudate from brain tumor.

Radiography

In discussing newer methods of examination, radiography should be included. Above all other means of diagnosis it furnishes the most useful in

Tumors with Calcareous or Bony Deposits

as, for instance, in exostosis. If the neoplasm has its origin from the lamina vitra and grows toward the cranial cavity, its recognition by means of the X-ray is an easy matter. However, when exostoses originate at the base of the skull, and reach a certain size, they, too, will throw a shadow on the plate which may permit of a diagnosis being made. Figs. a and b, on Plate XXV, show the shadows of an enormous osteoma of the right frontal region which has grown in both inward and outward directions. Fig. a is taken from the forehead; Fig. b from the diseased side.

Tumors of the Hypophesis

may dilate the sella turcica. *H. Oppenheim*, in 1899, called attention to the fact that this dilatation can be depicted on the *Roentgen* plate, made of the base of the skull and aid in the diagnosis. However, hydrocephalus may cause enlargement of the Turkish saddle, owing to dilatation of the third ventricle, so the diagnosis will rest largely upon the appearance of acromegaly. Gummatous process in the region of

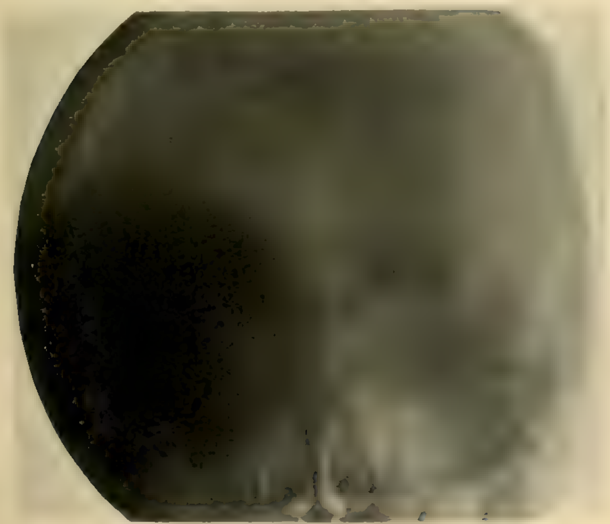

Fig. a.

Fig. b.

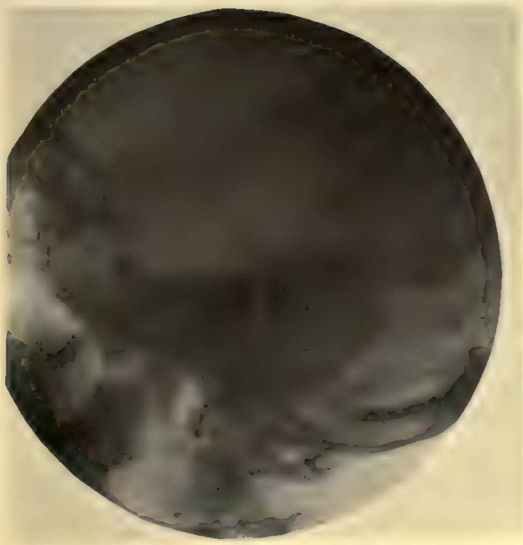

Fig. c. V = 1/2.

Fig. d.

Fig. e.

the chiasm must be taken into consideration in making a differential diagnosis. *A. Schueller* calls attention to the thinning and bowing forward of the dorsum sellæ when a tumor of the pituitary body is present. The plate of bone lies then on top of the neoplasm. At times the entrance to the saddle is widened and the cavity appears more shallow.

According to *Schloffer's* observations (page 126), too much importance must not be given to the appearance of the anterior and posterior clenoid process of the saddle dorsum as, although the entrance to the saddle may be enlarged, the tumor may grow beyond these in an upward direction.

Schueller reports an instance of calcareous aneurysm of the internal carotid which destroyed the body of the sphenoid bone. This threw a convex shadow line on the plate, the result of calcareous deposit in its dorsal wall. In the same way caries of the sphenoid, secondary to disease in contiguous bones or cavities, or the destruction of bone due to invading tumors of the base of the skull would be recognized.

Interpretation of the *Roentgen* plate must be carefully made. The fact that the plate is of some distance from the Turkish saddle influences very largely the conformation of the shadow. Each turn of the head on its vertical axis alters the picture of the cavity, and when to this is added the fact that in acromegaly an enlargement and thickening of the skull is present, it is easy to see that an accurate picture of the contour of the base of the skull is not easily obtained. The shadow should be compared with that of the normal skull, and exposures should be made at stated intervals in order to observe the extension of the pathological process. The examination may be regarded as associated with great difficulties. In a not inconsiderable number of instances we have assumed widening of the sella turcica, in which autopsy revealed the contrary.

The distance between nasion and the anterior wall of the Turkish saddle is, as accentuated by *Schloffer*, quite accurately determined by means of a radiograph, a fact of importance when operative attack, especially from the nose, is contemplated.

Radiography of the skull is of service in other regards. The growth of tumors causes **secondary changes in the calvarium** such as atrophy and pressure destruction with thinning of the bones and separation of the sutures. When the latter are already united their separation is a genuine bursting, which usually occurs in young persons. In the latter respect I have had, together with *H. Oppenheim*, under observation, a boy of sixteen, and obtained a clear photograph which is reproduced on Plate XXV (Fig. c.) (Observation VII, 5, already mentioned, page 143). This was a case of large sarcoma in the left posterior fossa of the skull. The sutures behind the petrous bone appear separated several millimeters.

In this connection it seems proper to state that the cracked-pot percussion note produced on some skulls with intracranial tumors may, in some instances, be ascribed to separation of sutures, though I would not like to be regarded as offering this as the only producing factor. In analogy I may state that I have developed the sign in the case of an officer (aged thirty-three), who had a fracture of the skull of three months' standing, and repeatedly demonstrated its presence at subsequent examinations. Cracked-pot percussion note is frequently obtained in hydrocephalus.

In a case of cystic degeneration of a large sarcoma (Observation VII, 3, also page 68, Plate VI, a), in a boy of seven, the sagittal suture burst asunder and could be plainly palpated as a shallow gutter.

At the base of the skull rachitic or osteomalacious deformations, which *Virchow* calls **kyphosis of the cranial base,** may occur. A severe case of this sort is reported in Observation VII, 9. The radiograph will reveal these peculiar conditions; also, it will make recognizable cartilaginous union or delayed ossification of the basal synchondroses. (Synchondrosis intersphenoidalis and spheno-occipitalis.)

The *Roentgen* pictures give valuable information when the bones are altered as the result of syphilitic or tuberculous processes. In the latter affliction defects in various forms are found, at times appearing as holes or excavations of considerable magnitude. (Plate XIII and XIV.) An unusually large tuberculous defect is shown on Plate XXV, d. In syphilis the destructive new growth of bone, periosteal thickening and bone hypertrophy, which, together with excavating defects and diffuse osteoporosis, give to the picture of the skull instead of the normal smooth outline a peculiar hilly appearance. (Plate XXV, Fig. e.) If thickening of the lamina vitra alone occurs, that is, from the outer layer of the dura mater, the cause of the severe pain can only be detected by means of radiography. *Schueller* has directed attention to these facts and also to the asymmetry of the skull found in epileptics, which is restricted to the inner surface of the bones, and could not be recognized in any other way.

As far as **injuries to the skull and brain** are concerned bullets and metallic foreign bodies are easily recognized on the *Roentgen* plate. Their location may be determined with considerable certainty by exposures made at various levels and in several directions. Fractures are of importance to us as their presence have a bearing on extradural hematomata. The radiograph shows quite clearly linear fractures which are near the plate and lie vertically to its position. Especially do fractures of the calvarium, which provoked hematomata from involvement of the middle meningeal artery, come into consideration with respect to contemplated operative measures of relief.

THE END