THE SURGICAL TREATMENT OF MENINGITIS, ITS SCOPE AND ACCOMPLISHMENT.

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TABLE OF CONTENTS.

- CHAPTER I. Introduction and Historical Review.
- CHAPTER II. Anatomy and Physiology.
- CHAPTER III. Operative Treatment of Meningitis.
- A.—Foreword.
 - B.—Critical Review of Past Operations.
 - C.—Symptoms Which Furnish a Guide for Operation.
 - D.—What May an Operation Promise?
 - E.—When Should Operation be Undertaken?
 - (a) To Save Life.
 - (b) To Prevent Complications.
 - F.—Where Should the Operation be Performed?
- CHAPTER IV. Surgical Anatomy of the Sub-occipital Region.
- CHAPTER V. *Drainage of the Cisterna-Magna for Meningitis.*
- A.—Purposes of the Operation.
 - B.—Steps of the Operation.
 - C.—Difficulties of the Operation.
 - D.—Advantages of the Operation.
 - E.—Secondary Remedial Measures.
 - F.—Other Conditions in which this Operation may be Indicated.
 - G.—Instruments and Appliances.
- CHAPTER VI. Records of Cases.
- CHAPTER VII. Conclusions.
- CHAPTER VIII. Bibliography.

CHAPTER I.—INTRODUCTION.

The term "meningitis" was introduced by an army surgeon, named Herpin,¹ in 1803. It indicates a septic process involving the membranes of the brain caused by various organisms. The mortality in meningitis varies from twenty per cent to one hundred per cent, depending upon the kind of infecting organism. Its lethal effects are due to three separate and yet inseparably intermingled factors, the poisonous effects of the toxins manufactured by the bacteria themselves, the toxins generated in the tissues and cerebro-spinal fluid as a result of bacterial action upon them, and, to the mechanical effects of the pressure produced within the skull by the products of inflammation. *Septic conditions are usually surgical opportunities and demand surgical treatment.*

The treatment of suppuration within the meninges of the brain is not on a par with the treatment of sepsis elsewhere in the body. In most all other forms of septic infection, special or general, local or diffuse, surgery has secured a great diminution of mortality and a remarkable preservation of function. But, concerning meningitis, with the exception of the serous and diplococcic forms, its mortality is just as high as it was in 1870, before the dawn of cranio-spinal surgery, which since then in other lesions of the brain and cord has achieved such notable results.

I propose to review the records of the past forty years, to ascertain, if possible, the reasons for the present deplorable situation in the treatment of this disease and to show that there is hope for the future.

After correlating the experiences of the past, the opinions of the present and the latest results in practical and laboratory research, with a firm belief in the reason and justice of our contention, I desire to submit for critical examination and actual test a rational, safe and efficient surgical procedure for the treatment of meningitis.

HISTORICAL REVIEW.

As a preliminary observation in regard to the operative treatment of intra-cranial suppuration the following quotation from a paper by Gross² is given; this was published in 1873:

"The treatment of compression of the brain from effusion of pus is purely surgical, and all authors are unanimous in the opinion that, unless the matter be evacuated, the patient will die, although they are equally agreed that this measure holds out but little chance of life."

A little farther he says: "No case is recorded of recovery from "effusion of pus into the arachnoid cavity," that one feels that he let out, * * * on the other hand, if a free incision be made into the dura mater so as to admit of its ready escape, one-half of the patients, as I have just shown, fight their way through. The necessity of operation is, therefore, not to be questioned."

While Gross referred to intra-cranial suppuration due primarily to traumatic causes, his statement is so explicit in reference to "effusion of pus into the arachnoid cavity," that one feels that he fully comprehended the necessity of surgical measures in all such cases of whatever origin, and their utter hopelessness when otherwise treated.

We go a long ways before we come to anyone else suggesting surgical intervention for "effusion of pus within the arachnoid cavity."

Ventricular puncture and drainage is the next deliberate procedure offered for the relief of the effusion in meningitis.

According to von Beck,³ this conception was first expressed theoretically by Wernicke, in 1881.

Further that von Bergman was the first to use it in 1888, in a case of tubercular meningitis. He was closely followed by a number of operators, as Keen, Robson, Franks, Wyss, Hahn, Kocher and McCosh, in such cranial lesions as meningitis, brain tumors, and epilepsy.

Von Beck reports a case of "Acute Internal Hydrocephalus" following a chronic otitis media, in a boy of 14, in which the lateral ventricles were punctured at three different times, with the withdrawal of 26, 40, and 40 ccm. of cerebro-spinal fluid. The child recovered.

He also described a case of "A Traumatic Cerebral Abscess" in the frontal lobe that was incised and drained. This was followed by diffuse, purulent meningitis with acute internal hydrocephalus. Fifteen days after the first operation the lateral ventricle was punctured, 40 ccm. of turbid cerebro-spinal fluid drawn off. The boy, (7 years old), was moribund at the time of the last operation, but recovered after an illness of 126 days.

Quincke⁴ describes a case of a child, 12 years old, with hydrocephalus, upon whom he performed ventricular puncture on June 25, 1888, because all other forms of treatment had been unavailing. The lateral ventricles were tapped at different points five times thereafter, but the child finally died from meningitis.

W. Mayo Robson⁵ was among the first to conceive the idea of ventricular drainage in meningitis, and, while antedated in its execution by both von Bergman and Quincke, is entitled with them to receive credit for this operative suggestion. He writes:—"In 1888, while sitting powerless by the bed of a child dying of coma, due to meningitis, a train of thoughts passed through my mind, which culminated in the ideas set forth in this paper. If we have a serous, purulent or tuberculous peritonitis, we do not hesitate to open the abdomen and drain it; and if we have a plura full of fluid, we feel it our duty to perform paracentesis, or if the fluid be purulent, to incise and drain the chest. Then why do we allow the brain to suffer compression, even unto death, when we can, as the following case will prove, tap the ventricles and remove the pressure?" Here follows the report of a case, in which he operated on February 7, 1889, by puncturing the lateral ventricles through a trephine opening over the left motor area. Six ounces of clear fluid were removed. Recovery followed, without superficial suppuration, in a month.

The plan next suggested and executed for relief in meningitis, attacked the disease at an entirely different point, namely by draining the spinal subarachnoid space in the lumbar region.

To W. Essex Wynter⁶ must be given the credit for the conception and first operation of spinal drainage in the treatment of meningitis. His first case was operated upon, February, 1889.

Of course, to Corning⁷ belongs the honor of the first lumbar puncture, but this was for the injection of drugs, not for drainage of inflammatory exudation.

In his paper, Wynter says: "In many cases of fatal tubercular meningitis, coma supervenes with great rapidity and with all the signs of cerebral pressure, whilst after death little can be found except an excess of cerebro-spinal fluid, often at a considerable positive pressure, to account for the symptoms and the fatal issue. The possibility of recovery in this class of cases, where there is commonly little development of tubercle, together with the feasibility of draining away the fluid continuously by the theca vertebralis, suggested this mode of procedure."

His first case was a boy of 3 years of age in the comatose stage of tubercular meningitis. The operation did not require an anesthetic. The child was held in a sitting position. "A tiny incision was made in the skin beside the spine of the second lumbar vertebra and a Southey's tube and trocar inserted till the point impinged against the lamina; the point was then directed slightly downward and was pushed through the ligamentum and theca with

an inclination toward the middle line. Clear fluid at once welled up into the tube on withdrawing the trocar, a fine India rubber tube was arranged for continuous drainage and the child put back to bed." Although all the symptoms were immediately improved, the fluid ceased to flow after twenty-four hours and the child died.

Wynter's second case, operated upon February 21, 1890, was a lumbar laminectomy. Briefly, it was as follows: Girl, aged 11. Wynter cut down upon the second lumbar vertebra, removed the spine and right lamina and punctured the theca with a knife. Clear fluid escaped with force. A drainage tube was placed in the canal. Improvement in all symptoms followed immediately, but with the stoppage of the flow of fluid three days later, they became worse and the child died on the next day.

It was not until December 12, 1890, that Quinke⁴ performed lumbar puncture according to a technic devised by himself and accepted and universally practiced ever since. It is due to his careful experiments and explicit directions for performing this operation that his claims for pioneer work in this field rests, because he was clearly antedated by Wynter by a year and ten months, in the actual performance of the operation.

Please note that Wynter's first case was a deliberate lumbar puncture with provision for continuous drainage, whereas his second case was a lumbar laminectomy with tube drainage. Quinke's first case had very marked hydrocephalus, with acute cerebro-spinal meningitis. A boy, 18 months old. Quinke did his first lumbar puncture December 12, 1890, between the third and fourth lumbar vertebrae and drew off a cubic centimeter of clear fluid. The puncture was repeated on December 14, with removal of 10 ccm. fluid in 20 or 30 minutes. Again on December 17, puncture below the fourth vertebra was done and the pressure of the cerebro-spinal fluid noted at 13 to 15 cm. of water, or 10 to 11 mm. Hg. When the child cried the pressure rose to 20 cm. of water but quickly dropped back to 15 cm. again. The flow was about 8 drops per minute. The child was convalescent by December 23, and fully recovered by January 10. Quinke considered this a lepto-meningitis infantum or simple acute hydrocephalus. He states in a footnote that the normal pressure of the cerebro-spinal fluid, with the child in a horizontal position was about 4 mm. of mercury.

The third case reported by Wynter was another laminectomy operation which was performed by Pierce Gould, on June 21, 1890. He cut down upon and divided the lamina of the first lumbar vertebra. The spinal canal was opened with a knife. A slight amount of fluid escaped, a drainage tube was inserted, the

symptoms improved for a short time but the patient died. (Boy, 2 years old).

A fourth case in Wynter's report was a girl of 13 months in convulsions, semi-conscious, head retracted. April 15, 1891, a Southey's tube was introduced into the spinal canal in the lumbar region. Death followed in a few hours. Wynter remarks: "Though none of these cases were ultimately successful, no harm in any one resulted from the interference. In some there was temporary relief of the symptoms and the necropsy in each case showed ample reason for the fatal termination, either in general tuberculosis or failure in maintaining the drainage. Further experience will, no doubt, enable a better selection of cases to be made, and the treatment to be carried out more effectually.

Charles A. Morton⁸ published a paper in 1891, upon "The Pathology of Tuberculous Meningitis with Reference to its Treatment by Tapping the Subarachnoid Space of the Spinal Cord." He says: "In view of the recent procedures of tapping the subarachnoid space of the spinal cord in cases of tuberculous meningitis, the pathology of the disease derives quite a new importance. The prospect of relief by surgical intervention in these cases depends on the relation which increased intraventricular pressure bears to other pathological changes and to the symptoms, and whether, from the conditions found after death, there seems a fair chance of our being able to relieve this pressure by tapping the subarachnoid space of the spinal cord." Morton's statements are introduced here to show that at this time he was thinking of the possibility of drainage in tubercular meningitis.

Victor Horsley,⁹ in December, 1890, in reference to the treatment of septic meningitis, proposed "Free drainage and disinfection, and the immediate consequences—relief." Further, "I have put down septic meningitis as a condition which might be improved by operation, such as free drainage and irrigation with warm disinfectants. I do not, however, believe that this course will always successfully rescue these otherwise hopeless cases. In fact, I have operated twice, once by way of exploration and once deliberately, but in both the moribund patients succumbed, after temporary though marked remission of their symptoms."

To Ballance¹⁰ probably belongs the credit for first attacking meningitis by the occipital route. His statements made in 1897, "with regard to the operation of draining the posterior subarachnoid cistern, which had been described by Parkin in 1893, who had first performed it in 1891. The occipital bone was trephined close to the

foramen magnum. One case died of hemorrhage from opening an abnormal sinus, which was an accessory lateral one situated lower than usual. Some cases had been opened on both sides of the middle line so as to prevent hernia of the cerebellum interfering with drainage."

While Ballance was undoubtedly the first surgeon to deliberately drain the occipital fossa for septic meningitis, his work was not made public until six years later, and to Alfred Parkin,¹¹ who independently planned, executed and published the following operation, we should accord as much credit as if he had, in point of time, been the first to perform the operation. His case is as follows:

On April 9, 1893, Parkin operated upon a child $4\frac{1}{2}$ years of age, who had been sick for a month with meningitis. At the time of the operation there was Cheney-Stokes respiration, swelling of the optic discs, transient rigidity of the limbs, unconsciousness almost amounting to coma. Pulse 150, and respirations 50. No anesthetic was required. "An incision was made below the superior curved line of the occipital bone and to the right of the middle line. The flap was reflected and a circle of bone, three-fourths of an inch in diameter removed and the opening enlarged in a downward direction. The dura bulged very much, no pulsation was felt. It was opened and a little fluid escaped. On passing a curved probe along the under surface of the cerebellum and raising it slightly a very large quantity of clear cerebro-spinal fluid (about two or three ounces), gushed out; pressure was relieved and the brain pulsation returned. The Cheney-Stokes rhythm ceased and the pulse became larger and regular, though still very quick. A very fine, almost capillary drainage tube was inserted beneath the dura mater and both it and the scalp wound were sewn up." In spite of free drainage up to the last, the child died sixteen hours later. Necropsy showed generalized tuberculosis of lungs, liver and meninges.

In this connection I wish to refer again to the work of Morton,¹² whose operation for subarachnoid drainage has been referred to by later writers who give an erroneous idea of what Morton really intended to accomplish.

In order to make the matter clear, I will quote from Morton's papers on "The Opening Between the Fourth Ventricle and Subarachnoid Space and its Condition in Tuberculous Meningitis," and the "Best Point for Direct Drainage of the Ventricles."

Morton states that in 1891 he gave a paper on the pathology of tubercular meningitis, to which reference has already been made with regard to its treatment by tapping the subarachnoid space of

the cord. Since then he has investigated the condition of the opening from the fourth ventricle into the posterior subarachnoid space, in seven normal and seven cases of tubercular meningitis. It is evident that if the foramen of Magendie be closed, drainage of the ventricles of the brain by tapping the subarachnoid space is impossible. His examinations show that the foramen is never closed.

"Morton's method" for exposing the foramen of Magendie so as not to disturb its condition or relations consisted in first removing the skull-cap, the section being carried low down behind. Then a wedge-shaped piece is removed from the middle of the occipital bone, with its base uppermost and with the apex, almost an inch wide, forming the upper boundary of the foramen magnum. The removal of this wedge exposes the dura which is incised, the arachnoid is exposed and also incised. The fluid is gently sucked up with a sponge. "In this method there is no possibility of rupture of the pia mater closing in the ventricle."

In reference to the second point in his paper, "the drainage of the ventricles," he advises that they be drained "through a trephine opening, situated one and one-fourth to one and one-half inch behind and the same distance above the external meatus."

"Morton's method" then, in so far as it referred to the posterior subarachnoid space, was a method of exposing the foramen of Magendie, *post mortem* so as not to disturb its condition or relations. It had nothing to do with drainage of this space except to show that the foramen of Magendie was never closed. Therefore this space could be drained by way of the spinal subarachnoid space (already demonstrated by Wynter and Quincke), or through the lateral ventricles (previously advocated and performed by Bergmann and others).

Ord and Waterhouse¹³ reported the recovery of a girl, 5 years of age, who was nearly moribund with "tubercular meningitis with increased intra-cranial pressure, the stage of coma rapidly advancing and unless pressure was relieved, a fatal termination seemed inevitable." The operation was done under chloroform, October 26, 1893. "A curved incision, two-and-a-half inches long, over the left cerebellar fossa of the occipital bone, commencing below and behind the mastoid process, passing with its convexity upward and ending externally to the external occipital crest. Furious bleeding from the occipital artery. Some bleeding from a torn mastoid vein. Pericranium raised in a flap similar to the scalp flap. A three-quarter of an inch trephine hole was made midway between the external occipital crest and the mastoid process. The dura bulged tensely

into the opening, there were no pulsations. The dura and the arachnoid were incised and some thirty drops of a slightly greenish serous fluid escaped. The cerebellum bulged into the trephine opening, fitting it tightly like a cork in a bottle. A probe was passed between the cerebellum and the arachnoid towards the falx cerebelli and some drachms of fluid escaped. A drainage tube was passed along the probe and left in position. Fluid slowly passed along it. The dura was sutured, the fragmented bone-button packed in the opening and the flap sutured with the drainage tube escaping through a stab-hole in its middle. Drainage continued until the end of the following month when recovery was complete."

In this connection we should note that Fischer¹⁴ refers to a case sent by Browning, of Brooklyn, to the Bushwick Hospital, in which an operation was performed at the occipital site.

After disappointments became numerous in the use of lumbar puncture as a therapeutical measure in meningitis, the introduction of various drugs into the subarachnoid space was attempted. Thus Rolgaus,¹⁵ in two cases of tubercular meningitis, injected into the "subdural" (?) cavity an emulsion of iodoform, but without result. Next Sokolov,¹⁶ reflecting upon the similarity between tubercular peritonitis and meningitis and, being familiar with the curative action of merely exposing the viscera to the atmospheric air in the former, attempted to carry out the analogy in the treatment of this form of meningitis. He trephined, aspirated the cerebro-spinal fluid through a lumbar puncture and then insufflated air into the subarachnoid space through the lumbar puncture. He did not state the results of this treatment.

A combination of craniotomy and lumbar puncture was performed by Gradenigo¹⁷ in three cases of suppurative otitic leptomeningitis, with recovery in all.

Chipault,¹⁸ in 1894, advocated opening the "Sylvian lake" for drainage purposes in chronic hydrocephalus and tubercular meningitis.

Witzel,¹⁹ in September, 1897, operated upon a boy, 16 years old, who had a circumscribed phlegmonous meningitis following right ear disease, by widely removing the squamous portion of the temporal bone and introducing gauze drainage after ventricular puncture had been negative. The patient died after four months of illness, with generalized meningitis. He also reports a second case of fracture of the base of the skull, followed by basilar meningitis, that was cured by the temporal operation.

In January, 1899, Rolleson and Allingham²⁰ treated a case of cerebro-spinal meningitis in a man, 24 years of age, by performing a laminectomy of the seventh and eighth dorsal vertebrae. Drainage was provided by a rubber tube which was removed on the ninth day. The patient recovered. They remark, "as far as we can find out the spinal dura has not been freely opened before in acute cerebro-spinal meningitis." Evidently they did not know of Wynter's case.

When we come to consider cerebro-spinal meningitis due to the extension from purulent foci within the skull, the rôle that suppurative ear disease plays is a very important one, and, while a consideration of this special aspect of the subject is foreign, at this time, to our purpose, yet to make the review more complete, these cases are introduced here.

To Macewen²¹ we unhesitatingly give the credit for pioneer planning and operating in this class of meningeal inflammation. He gives a summary of twelve cases of infective, purulent lepto-meningitis, of which six were operated upon and recovered. Five of these were of the cerebral fossa and one of the cerebellar fossa. Six other cases, considered hopeless for operation, died. Of six other cases of cerebro-spinal lepto-meningitis, five were operated upon with one recovery.

Hinsberg²² reported seven cures and five temporary improvements in meningitis of otitic origin, after drainage of the subarachnoid cavity.

In otological literature there are numerous similar cases on record in which a craniotomy in connection with the operation upon the diseased ear was performed to reach and drain a circumscribed or general purulent meningitis. Lumbar puncture, as above noted, has been used for purposes of diagnosis and a possible therapeutic effect.

Friedrich,²³ in cases of cerebro-spinal meningitis of otitic origin, advocated incision of the dura at the site of the infection and in addition performing a laminectomy. Held and Kopetzky²⁴ give the details of a remarkable case of purulent meningitis following a double otitis media in which pus was obtained from the subarachnoid space in the temporal region, through the enlarged mastoid wound, from the spinal space by lumbar puncture and from the lateral ventricle through puncture. The girl, 3 years of age, finally recovered after this widely disseminated infection in which were found staphylococci and streptococci, the latter predominating.

Kuemmel's²⁵ case, frequently quoted, is introduced here to fur-

ther emphasize the possibility of recovery from a purulent meningitis after a double trephining of the occipital bone and the institution of drainage.

The patient was a man of 33 years, who sustained a fracture at the base of the skull. Lumbar puncture drew off 20 ccm. of purulent fluid under a pressure of 235 mm. of mercury without relief. After the occipital operation the patient began to improve and fully recovered in six weeks.

In 1906, Widal and Ramond²⁶ treated a case of cerebro-spinal meningitis by injecting through a lumbar puncture 5 cm. of a 1-100 solution of collargol in water. This was repeated a second time on the twenty-ninth day and the patient discharged cured on the thirty-sixth.

In April, 1907, the anti-meningitis serum, prepared at the Rockefeller Institute under the direction of Flexner, was used for the first time in treating epidemic cerebro-spinal meningitis in human beings, by Ladd, of Cleveland (Dunn²⁷). This serum was introduced through a lumbar puncture made in the usual way.

Radman,²⁸ in writing upon the surgical treatment of epidemic meningitis, advocates drainage of the fourth ventricle by an incision through the atlanto-occipital ligament. Fischer²⁹ reports a case of cerebro-spinal meningitis in an infant, 2 months old, in which recovery seemed to follow repeated irrigation of the lateral ventricles with a normal saline solution, combined with several lumbar punctures. Pollack,³⁰ among some other cerebral lesions, recommends puncture of the brain in hydrocephalus after his method of introducing the needle through a small drill-hole in the skull. Bramann³¹ has treated eighteen cases of hydrocephalus by puncture of the corpus callosum. Brem and Zeiler³² suggest the treatment of influenzal meningitis by permanent spinal drainage combined with the internal administration of hexamethylenamin.

CHAPTER II.—ANATOMY AND PHYSIOLOGY.

It is assumed that the reader is familiar with the fundamentals of brain and cord anatomy and physiology. Some parts, however, which are especially concerned in the problems before us, must be emphasized.

THE ANATOMY.

The Cerebro-spinal Cavity:—The cerebro-spinal space in the natural condition is a closed cavity, limited by bones and firm ligaments. It is incapable of expansion or distention except in the infant with open fontanelles and then only to a very slight amount.

The Brain and Cord:—The brain consists of two symmetrical hemispheres which are united over a restricted portion of their opposed surfaces by the wide colossal commissure above and the basal structures below. From the base of the brain fibers emerge, crowded together to form the crura cerebri and passing downward to become the pons, medulla and spinal cord. The cerebellum, beneath the hinder portion of the cerebrum and behind the pons and medulla is united to these parts by masses of fiber. All these last parts together constitute the brain.

The Ventricles of the Brain:—Within the substance of the cerebral hemispheres lies the spaces called the lateral ventricles, while between the hemispheres is another space, the third ventricle. The cavity of the former spaces is continued into that of the latter by two semilunar slit-like openings, the foramina of Monro. Between the cerebellum, pons and medulla lies another wide space, the fourth ventricle, which is united to the third ventricle by the aqueduct of Sylvius, a narrow tunnel through the hinder part of the cerebral crura.

While the cavity of the fourth ventricle is mostly walled in by the substance of the cerebellum, pons and medulla its posterior wall or "roof" is furnished by the pia lined by a thin membrane (representing the attenuated roof of the primitive brain), and termed the tela choroidea inferior. This "roof" is incomplete in its central portion near the lower part of the fourth ventricle, where an opening is found—the foramen of Magendie—by which communication is established between these spaces within the brain and those (to be subsequently mentioned) without. Further, narrow gaps are found in the lateral angles of the fourth ventricle which also open into the spaces without the brain. These are the foramina of Luschka, or Key, and of Retzius. In passing, we should mention that the fourth ventricle is continued throughout the spinal cord as a small central canal.

The Membranes of the Brain:—The dura. This is a dense membrane lining the interior of the skull—forming its internal periosteum—also extending to the bottom of the spinal canal—but not acting as a periosteum for the vertebrae. It smooths out inequalities of the cranium and effectually blocks up all points of exit therefrom. From the dura are derived two large incomplete diaphragms, the tentorium cerebelli and the falx cerebri. The former aids in forming a chamber within which lie the cerebellum, pons and medulla: the latter is suspended between the cerebral hemispheres. Along the margins of attachment of these partitions to the skull, and to

each other and within the separated layers composing them are found large channels—the cranial sinuses—by which the venous blood is removed from the brain.

The Sinuses:—The cranial sinuses which enter at all into our consideration are the superior longitudinal, straight, lateral and occipital. The superior longitudinal sinus is especially important, not merely because of its size, but because of the connection with it of broad, irregular venous spaces called the parasinoidal sinuses or the lacunae laterales. These lateral lakes vary in width from one-half to one inch and into them, as well as into the sinus itself, open the cerebral veins and project the Pacchionian bodies (see latter).

The straight sinus receives the venous blood from the interior of the brain through the veins of Galen and opens, with the superior longitudinal into the confluence of sinuses from which pass off the lateral sinuses to the base of the skull where they are continuous with the internal jugular veins.

The occipital sinus is usually a small one in the falx cerebelli; it may be wanting entirely, may be double, and rarely may be of considerable size. It opens into the torcular above and near the margin of the foramen magnum bifurcates into two smaller venous tracts—the marginal sinuses—which course around the border of the foramen and empty into the lateral sinuses near their termination.

The Intradural or Subdural Space:—This is the very narrow interval left between the dura and the next membrane—arachnoid—it is a potential rather than a real “space” and harbors a very little cerebro-spinal fluid for purposes of promoting freedom of motion between the brain and the skull.

The Pia:—Immediately applied to the brain and the cord is the pia. A layer composed of blood-vessels with only enough connective tissue to hold them in place. The pia follows all the irregularities of the surface of the brain, dipping into all the sulci and, further, projecting into the ventricular cavities as masses of capillary festoons—the choroid plexuses of the various ventricles. A word further about these vascular plexuses. While they seem to lie free within the ventricles, in reality they are excluded from these spaces by a layer of epithelium which represents the thinned-out wall of the primitive cerebral vesicles. This construction is important to remember when we come to take up the physiology of these structures.

Besides these vascular plexuses there are other capillary tufts—the Pacchionian bodies—outgrowths from the pia which look like small masses of granulation-tissue and consist of a spongy trabecular network covered by a membrane continuous with the arachnoid. They project through the inner layer of the dura into the superior longitudinal sinus and the lateral lakes; also, they are found in fewer numbers along the upper surface of the superior vermis of the cerebellum. The Pacchionian bodies, before the age of three years, are wanting or very small and rudimentary. From the age of ten and onward they increase in number and size.

The Arachnoid:—This is a delicate membrane interposed between the dura and pia but so intimately connected with the latter as to seem on casual examination a part of it, especially over the convexity of the brain. However, at the various sulci the arachnoid and pia are seen to be separated, for while the pia dips into the sulci the arachnoid bridges them over. It is at the base of the brain that the existence of two layers is most easily demonstrated. Here, while the pia closely follows all the irregularities of the parts, the arachnoid spreads from one elevation to another as a well-defined sheet. The spaces which are thus left between the pia and the arachnoid are narrow channels, over the convexity of the brain; but at the base they are large spaces, and are given localizing names as cisterna basilis, cisterna pontis and cisterna cerebello-medullaris or magna. These spaces communicate with each other in the freest manner possible; also, with the narrow channels over the convexity of the brain, and especially, at the cisterna magna not only with the wide subarachnoid space of the spinal canal but also with the fourth ventricle through the foramen of Magendie and the lateral foramina of Key and Retzius.

While there is more or less of a spongy tissue connecting the arachnoid with the pia over the convexity of the brain, still, as Cunningham³³ says: "In these (cisternae) there is no longer a close network; the trabeculae connecting the two membranes take the form of long filamentous, intersecting threads which traverse the spaces."

In this connection the attention of the reader is called to the foramen of Magendie. The text-books give no description of this opening that would enable one to form any conception of its shape or size; therefore I shall quote the correct picture given by Morton,¹² which also expresses my own conclusions in this particular.

"The opening is not accurately described as a foramen, in the sense of a small hole in the pia mater. The opening in the nor-

mal brain reaches from the cerebellum to the calamus scriptorius below, and is a broad slit or a larger space. Sometimes a few delicate strands of membrane intersect one another across it but this is only occasionally seen."

Further, Lees³⁴ states that it is larger in infants than in the adult. Anatomically, there is no direct connection between the subdural, or better, the intradural space, and the subarachnoid or intra-arachnoid spaces, but the arachnoid tissue is so porous that, anatomically, physiologically and pathologically the intradural space may be considered as identical with the subarachnoid spaces.

The Blood Vessels:—The internal carotids and vertebrals furnish arterial blood to the base of the brain, which, through the mechanical construction of the circle of Willis is adequately distributed to the entire brain, both externally and internally. It is sufficient for our purpose to state that from the arteries, capillaries are formed, which again converging, unite to form gradually the various intra- and extra-cerebral veins. The former are chiefly gathered up into the main trunks of the veins of Galen and these two empty into the straight sinus. The external veins course mostly over the convexity of the cerebrum and end in the superior longitudinal sinus or the lateral lakes opening into it. There are other venous connections with the sinuses, with each other, and with the veins of the diploe which we can disregard at this time.

The Lymphatics:—(Macewen,²¹ page 38). "The lymphatics of the dura are abundant. There is besides, a wide-meshed capillary network with peculiar dilations near the inner surface of the cranial dura. * * * The subdural space communicates with the lymphatics in the dura, while the latter communicate with the dural veins. The intra-cranial lymphatics have their origin in the cerebral pia mater and in the choroid plexuses. They pass out of the cranial cavity along with the internal carotid and vertebral arteries and the internal jugular vein to the deep cervical glands. Others pass from the choroid plexuses of the lateral and third ventricles, coalescing into a lymphatic vessel which accompanies the veins of Galen."

Physiology:—The chief facts of interest to us respecting the circulation of the blood within the skull is that by various mechanical means the intermittent arterial flow is converted into a constant, steady stream. The details of this mechanism are well given by Macewen²¹ (page 35), but do not require elaboration here. We, also, should note that there is always a positive pressure in the cranial sinuses, amounting to a few millimeter of mercury. (Bal-

lance.³⁵) Of more importance to us is the cerebro-spinal fluid and its functions.

The cerebro-spinal fluid is secreted chiefly by the various choroidal plexuses. The current sets from the lateral ventricles through the foramina of Monro into the third ventricle and thence by the aqueduct of Sylvius into the fourth ventricle and from here it freely escapes into the cisterna magna and pontis through the large foramen of Magendie and the smaller foramina of Key and Retzius. From the cisterna magna the fluid passes slightly into the subarachnoid space of the spinal cord but mostly streams upward through the other cisterns and over the convexity of the brain into the cerebral veins and sinuses. "This direct passage of the cerebro-spinal fluid into the veins is one of the best established facts in the physiology of cerebral circulation, especially by way of the Pacchionian bodies" (Archibald³⁶).

The pressure of the cerebro-spinal fluid in the subarachnoid spaces always exceeds by a few millimeters of mercury the cerebral venous pressure; therefore the flow of fluid is from the subarachnoid space into the venous system. As the specific gravity of the cerebro-spinal fluid is less than that of the blood, any flow determined by osmosis would be, in the main, in the same direction. (Ballance).

The quantity of the cerebro-spinal fluid varies with sex and age and never exceeds 200 ccm. (Gray³⁷), or 60 to 80 ccm. (Howell³⁸). It may, however, under the stimulation of injury and disease, be secreted in immense quantities. Giss³⁹ reports a loss of 30 liters in 37 days. Thompson, (quoted by Archibald), a loss of 500 ccm. in 24 hours.

Another function of the cerebro-spinal fluid is to form a "hydraulic buffer" (Ballance) between the cranium and the brain. As to its action in "supporting the weight of the brain" this is very slight, if any. Any one who has made and studied sections of the head and neck and the relations of the brain and cord to the surrounding parts will agree with Ballance that "the weight of the brain is not wholly, or even to any considerable extent supported by hydrostatic pressure."

The function of the Pacchionian bodies is so interesting and important in this study, that further notice is taken of it. Kocher⁴⁰ states it as follows:

With the expansion of the arteries at the base of the brain at each systole of the heart, the Pacchionian bodies and the cerebral

veins are compressed and empty their contained cerebro-spinal fluid through the thin layer of the dura into the sinuses. This current is also aided, during the diastole of the heart, when the arteries again contract, by the expansion of the Pacchionian bodies aspirating the cerebro-spinal fluid from the subdural and subarachnoid spaces. The cerebro-spinal fluid does not leave the skull by the lymphatics unless there is venous obstruction raising the pressure within the sinuses. (Archibald).

The chief function, then, of the cerebro-spinal fluid is to maintain at a constant level the intra-cranial pressure, which tends to vary with cardiac action, respiratory rhythm and changes in bodily position.

In infants, until the closure of the fontanelles and while the Pacchionian bodies are rudimentary and their function unimportant, the normal intra-cranial pressure is maintained and the circulation of the cerebro-spinal fluid assisted by the alternate expansion and retraction of the fontanelles with arterial pulsation and respiratory movement.

CHAPTER III.—OPERATIVE TREATMENT OF MENINGITIS.

A. Foreword. B. Critical Review of Past Operations. C. Symptoms Which Furnish a Guide for Operation. D. What May an Operation Promise? E. When Should Operation be Undertaken? (a) To Save Life; (b) To Prevent Complications. F. Where Should the Operation be Performed?

A. *Foreword.*:—The historical review just given, while not exhaustive, is sufficiently comprehensive to give us a correct picture of meningitis treated by surgical measures. There is yet no medical treatment for this disease. What a picture it is of hopelessness, despair and death! The only ray of light cast on this dark field is given by the serum treatment of one particular form of this disease. But the mortality remaining after the use of this remedy is still sufficiently appalling, that were it in any other disease, it would fill us with consternation. While, in the other types of the disease death is the universal outcome. We have come to accept meningitis as a fatal disease. The facts of the past justify this conclusion. If, perchance, recovery did occur, how often would death have been preferable. A recovery with reason dethroned or weakened, with epileptic fits or other deplorable nerve lesions was more to be regretted than death. Is there, then, no hope? Must we fold our hands and let these patients die under stress of the greatest suffering?

We claim there is hope. We claim that if this disease is treated with common sense along lines of ordinary surgical technic used in other suppurative conditions, a fair percentage of these otherwise hopeless cases will recover.

What are the facts in the case? 1. That medical treatment is unavailing. 2. That surgical aid in every case reported has been deferred until the patients were moribund.

Ante-mortem surgery has never given, and can never give "good results." When the dictum is accepted in meningitis, as it is in appendicitis, mastoiditis and other suppurative diseases, that the only treatment is surgery, and that utilized at the earliest possible moment after the diagnosis is made, then, and only then, will the high mortality statistics of meningitis begin to fall.

The same fight is on here that was waged by surgeons with their medical confreres in the past over similar forms of suppurative disease. Take appendicitis. We know the steps in that contest. 1. Medical measures alone; 2. operating in moribund cases; 3. in abscess cases; 4. in the acute attack, before sepsis has had a chance to do any damage; 5. in the interval. How much fine hair-splitting was indulged in, in the past, as to when a case of appendicitis ceased to be a medical and became a surgical one.

What protests went up when Deaver announced, and adhered to it, that appendicitis is always a surgical condition and demands surgical treatment just as soon as the diagnosis is made.

Other similar affections, now relinquished to the surgeon, without a question, have had to go through the same cycle of evolution, and, I suppose, meningitis will prove no exception.

3. While admitting the futility of medical treatment and the desirability of surgical interference in the past, there has been no concerted action among surgeons themselves to develop an operation that would commend itself as reasonable, safe, and curative. The operations suggested and performed have had to do with some particular form of the disease and at the terminal stage of its course. Furthermore, they have been futile if simple, or so severe in their technic as to be contra-indicated.

4. The indications as to the proper time for surgical interference have not been clearly formulated. This has been due to the uncertainties of a positive diagnosis at an early stage in the disease; also, to the confusion arising from the multiplicity of types of meningitis, each one described as an entity based upon its etiology and post-mortem findings and none of them considered from the standpoint of possible surgical opportunities.

B. CRITICAL REVIEW OF PAST OPERATIONS.

Ventricular Puncture:—Ventricular puncture after the method of Kocher, Keen⁴¹ or Pollock, through the cerebral cortex, or of Bramann, through the corpus callosum, is a procedure only to be utilized in cases of chronic hydrocephalus or in non-pyogenic serous effusions of the brain.

"In infected cases with a beginning external meningitis there is always a certain risk of inoculating an uninfected ventricle." Cushing.⁴² In addition there is a real danger in infecting the cerebral cortex and more especially the meninges. Further, hemorrhage from a cerebral vein or from an injury to the choroid plexus is a not unlikely possibility. If ventricular puncture is performed for the purpose of draining a purulent effusion at the base of the brain, one only has to consider the anatomy of the parts involved to perceive at once the futility of such a procedure. Bruce Clark⁴³ states that he does not "think it possible to relieve purulent basilar meningitis by tapping the ventricles." That the operation in itself is a serious one is conceded by all. Frazier⁴⁴ says, "puncture of the ventricles (lateral) is unfortunately an operation of unusual gravity and the danger attending it is so great in comparison to the possible benefit as to make it a procedure of questionable propriety." If that is true of the operation in non-infected conditions, how much more is it objectionable in septic effusions at the base of the brain to which is added the severe constitutional effects of such disease.

It is plain then, that ventricular puncture, as a therapeutic measure in the treatment of meningitis has no logical or clinical justification. It cannot drain pus. It may not relieve pressure. It adds a positive danger of infection of ventricles, cortex and meninges. Troublesome hemorrhage may be produced. The operation is a very serious one.

Lumbar Puncture:—The value of lumbar puncture lies in the positive diagnostic findings furnished by the cerebro-spinal fluid withdrawn by the puncture. As a means of diagnosis then, it is invaluable.

As a therapeutic measure it is inefficient except in the single condition of serous, non-purulent, meningitis. In all purulent conditions it has no curative powers. At its best, in epidemic cerebro-spinal meningitis lumbar puncture has a mortality of 66.6 per cent (Sladen⁴⁵) in cases treated at the Johns Hopkins Hospital, before the introduction of the anti-meningococcus serum. In the frankly purulent infections lumbar puncture never cures. Archibald says

in reference to it, "that value of lumbar puncture is therefore definitely proved to be minimal," also that, "lumbar puncture, while of temporary value, fails to save life;" further, "if a block has occurred at the foramen, magnum lumbar puncture only adds to its intensity" and "in ventricular obstruction lumbar puncture ceases to be helpful." Cushing also warns against the danger of too quickly withdrawing the column of cerebro-spinal fluid and causing a plugging of the foramen magnum by the brain stem. Frasier says, "the sudden disturbance of pressure is no doubt responsible for a large majority of the fatalities. * * * Furbinger, who is very much opposed to this practice, attributes the deaths to pressure exerted upon the bulb by the arrest of cerebro-spinal fluid from the ventricles at the foramen of Magendie."

Lumbar puncture then, as a therapeutic agent, is a failure. It possesses elements of danger, when repeatedly used, which disqualify it. Not only does it fail to reduce mortality, but its repeated use is attended with grave complications.

Lumbar Puncture in Combination:—(a) With craniotomy for through and through irrigation; (b) for the injection of various curative agents (except serum) into the spinal canal has been tried and discarded as "impossible of performance" (Cushing) and incapable of curing the disease and positively dangerous. The single case of recovery after the injection of collargol was a type of serous meningitis in which recovery might have followed the puncture alone.

Laminectomy:—There is more to be said in its favor as a curative measure than for lumbar puncture. Yet the danger of "corking up the foramen magnum by the brain stem," the failure to secure adequate and sustained drainage, the severity of the operation itself all weigh against it, if there is any other proposition which will attain the desired ends without these drawbacks.

Serum Therapy:—This is limited to the treatment of cerebro-spinal fever caused by the diplococcus intracellularis of Weichselbaum. (Flexner⁴⁰). It affects no other form of meningitis. In its particular field it has lowered a previous mortality of 72 to 95 per cent down to from 20 to 43 per cent (De Meric⁴⁷) or of a mortality of 66.6 per cent to 17.4 per cent. (Sladen).

There is no longer any question but that Flexner's serum is a potent agent in reducing the mortality of epidemic meningitis from a previous figure of about 75 per cent down to one around 25 per cent. The beneficial effects of the serum are more manifest if

given before the fourth day of the disease and between the ages of 2 to 10 years. If given later than the fourth day or to patients younger than two years, or older than ten, the mortality rate quickly rises.

In all other forms of infection the serum has no curative action whatever. At the best then, in a series of selected cases, (time and age most favorable), the mortality rate is 13.1 per cent while the highest is 43 per cent. (Dunn).

'The average we can take at 25 per cent, (it is above this*). What is to be done regarding this remaining fourth of epidemic meningitis cases and practically the total number of other forms of infectious meningitis?

While we believe in and advocate the use of the serum in the diplococcic form of meningitis, it must be remembered that there will be failures in its use amounting, as shown, from 10 per cent to 25 per cent of the cases. In addition, the serum in itself is not altogether harmless as shown by the cases reported by Hutinel,⁴⁸ four in number, in which death followed the second injection of the antimeningococcic serum. The danger of death is greater should the infection be the tubercular bacillus.

Ryfkogel⁴⁹ reported a case of coccidioidal meningitis in which death followed a second injection of the Flexner's serum. Netter, Courtois-Suffit and Dubosc⁵⁰ advise caution in the use of the serum, in too large doses or too frequently repeated.

'The remaining varieties of cranial operations will be discussed in connection with the operative procedure suggested in this paper.

C. SYMPTOMS WHICH FURNISH A GUIDE FOR OPERATION.

'The subject of meningitis is obscured by describing as separate entities various forms of meningeal inflammation. From an etiological and pathological standpoint, this is correct. But from a surgical point of view, such multiplicity of types only confuses the observer and serves no helpful purpose. He loses sight of these fundamental facts:—

*Sophian's⁵² latest figures based upon the serum treatment of meningitis in the late Texas epidemic give the general mortality as 25 per cent in a total of 185 cases. "Excluding the apparently hopeless cases in which the patients died in from a few minutes to twenty-four hours after admission, the mortality was about 10 per cent. In children the mortality after the exclusion of apparently hopeless cases was roughly about 5 or 6 per cent." This again gives the very best showing for the serum therapy after all the "hopeless" cases have been weeded out. As soon as one starts this weeding-out process you can get almost any kind of mortality statistics.

NOTE:—No attempt has been made to ascertain all the disadvantages and dangers attending the use of the serum. We have given it all the credit claimed by its advocates and merely cite the above to show that its use may not only fail to do good in meningococcal meningitis but also may prove dangerous in this and other forms.

1. That all forms of meningitis are essentially septic in nature except the toxic, and this may become septic.

2. That all forms of meningitis kill, some only 10 per cent, others 100 per cent.

3. That death is caused in the last analysis by increased intra-cranial pressure progressing to such a point as to finally shut the blood off from the "vital centers."

4. That death can only be averted by furnishing good blood to the "vital centers" by *removal* of the intra-cranial pressure. Other appropriate and secondary measures will contribute to but cannot take the place of this paramount requirement. Irrespective, then, of the particular type of meningitis, of what has or has not been done before for therapeutic purposes, the indication for surgical action rest upon an unfailing chain of symptoms that, in practice at the bedside, can be absolutely determined with accuracy. (See Part I, by Dr. Kopetzky).

These early symptoms are: 1. A rising blood-pressure; determined by the cardiac sphygmomanometer. 2. Edema of papillae. (Not "choked disc," which is so late a symptom that it ceases to have any value). 3. Absence of carbö-hydrates from the cerebro-spinal fluid. (Obtained by lumbar puncture). 4. An irritable or clouding sensorium.

In addition, there may be present: A vague pulse; respirations, irregular in depth and rate.

With these pathognomonic symptoms present, no possible consideration can justify delay.

The nearer a patient is to bulbar paralysis the less likely that any operation will save life. Recovery from such compression may not be at all or slowly. (ARCHIBALD.)

D. WHAT MAY AN OPERATION PROMISE.

While we concede that lumbar puncture may be all that is necessary in toxic meningitis, that by serum therapy epidemic meningitis has been rendered two-thirds less fatal than formerly, yet, for the remaining fourth of those sick with this form of meningitis and for all other forms of septic meningitis, death is the inevitable outcome.

NOTE:—The facts of cerebral compression as determined by experiment and shown in disease of the meninges have been given in detail by my co-worker on this subject, Dr. Kopetzky; (see part I). I should like to state, however, that we have repeated the experiments of Cushing in producing intra-cranial pressure, have demonstrated the accuracy of his observations, and the correctness of his conclusions, and, in addition, have produced in dogs, acute, septic meningitis and recorded the various changes resulting from such infection as observed through a glass window in the skull and by other methods of reducing physical phenomena to graphic record. The results of our experimental work demonstrates that intra-cranial pressure is the important feature of meningeal inflammation.

Further, while surgical procedures of the past have saved but a lamentably few cases, yet we must remember that surgery has invariably been resorted to as a last hope; that the patients were in the terminal stages of cerebral compression and also suffering from profound systemic poisoning, and that, as a rule, the operations performed upon the skull at a distance from or near to the seat of the trouble have all been, in themselves, of a very severe character.

We can readily understand, then, why surgery has thus far been unable to show any considerable number of victories.

CAN SURGERY RELIEVE THE COMPRESSION?

The evidence furnished by all cases operated upon show conclusively that pressure has been relieved—at least for the moment. Why, then, has death so invariably followed? 1. Because such relief has not been furnished at an early stage. 2. Because such relief has not been of sufficiently long duration. 3. Because, in addition to the evil effects of compression of the brain, constitutional septic conditions existed that continued to act after operative relief to cause death. 4. Because the meningeal infection had become so diffused and the products of such infection so organized as to make it impossible for Nature to further resist the progress of the disease or remove the effects of the inflammation.

All evidence warrants the conclusion that surgery has relieved all cases and has saved some. And it has succeeded in doing this in spite of the operation being performed at the very last, usually at some place unrelated to the seat of the disease and more frequently by a method of unnecessary severity of execution.

E. WHEN SHOULD OPERATION BE UNDERTAKEN?

a. *To Save Life*:—All the evidence, experimental ante- and post-mortem show conclusively that an early operation is absolutely necessary. Kocher advises operation in every case of cerebral lesion when there is only a *suspicion of pressure*. "It can no longer be doubted that in some cases of suppurative meningitis recovery may be brought about by active intervention. We are no longer justified in regarding such cases as hopelessly lost, and in remaining with folded hands. Rather must we attempt to save them by doing the utmost within our power." Hinsberg.⁵¹

"The reproach of such a death rate (in septic meningitis) will not be removed by refusal to operate, but by an early and universal recognition of the futility of the treatment by drugs" (Horsley). "All forms of meningitis, if unrelieved by art, tend to cause death." (Ballance).

The otologists as a class have recognized the importance of early operations in septic meningitis of otitic origin. Their teaching is to follow up the disease until all parts affected have been brought into the field of surgical relief. (Kopetzky.)

b. *To Prevent Complications*:—In serum treated cases complications attributable to the disease (epidemic cerebro-spinal meningitis) arose in 43.5 per cent. In non-serum cases these were 63.6 per cent of about the same character. (Sladen).

"Early recognition, followed by operation, have in certain cases checked the disease (infective meningitis), and as our experience ripens concerning them, the results will doubtless be improved." (Macewen).

"Energetic prophylactic decompression would reduce to a minimum such disastrous results as optic neuritis, deafness, oculo-motor disturbances, and some psychopathies, all of which are due to the mechanical effects of the excessive intra-cranial pressure." (Hultgen⁵²). "Probably, in some cases, the removal of fluid under pressure from the intra-dural spaces will prevent the occurrence of suppurative meningitis." (Ballance). Cushing states that the cause of death is "purely mechanical, and is due to intra-cranial pressure. Also that meningitis is a self-limited disease, and if pressure can be relieved and time gained the inflammation will subside and the exudate will be reabsorbed."

"While unconsciousness is a forerunner of paralysis of the vital centers, it should *not* be waited for." (Archibald).

If we have shown that operation is justifiable, that it must be invoked early, the next question is:

F. WHERE SHOULD THE OPERATION BE PERFORMED.

Clearly not at the far end of a long, narrow canal as in lumbar puncture or laminectomy for the reasons already adduced, which are, impossibility of adequate or sustained drainage and the inherent dangers of the procedure itself. Certainly not by a more dangerous and less efficient means, as ventricular puncture. But by an operation which will positively tap the *fons et origo* of the trouble at the base of the brain, namely, the cisterna magna. Ballance was probably the first to attack meningitis by the sub-occipital route. He was followed by Parkin, and Ord and Waterhouse. But the operations performed by them and by others who followed them have not opened the cistern easily and satisfactorily, they have all been attended with many difficulties and grave objections, as will be shown later.

Anatomy shows us that this is the largest subarachnoid space, that it is in the "freest communication" with the other spaces without the brain and cord and especially with the ventricular cavities within the brain through a foramen always large and seldom if ever closed.

Chipault⁵³ states that he has found only two cases on record in which a communication between the fourth ventricle and the subarachnoid space did not exist, one case reported by Quincke, of chronic meningitis, and one by Keen, of unilateral hydrocephalus.

Anatomy further shows us that the cisterna magna is located close to the lower portion of the occipital bone in a position favorable for operative attack.

Physiology demonstrates that the course of the cerebro-spinal fluid is from the ventricles into the cisterna magna. Normally the current is of moderate force and the fluid in small amount. But, comes infection, the increase in amount becomes enormous and the rate of flow must be proportionately increased, so that we can imagine the fluid streaming into this space like a turbulent river into a broad lake.

Pathology offers its evidence that in this region the fires of meningitis burn fiercest and the debris of such inflammatory conflagration are in greatest evidence.

Campbell and Rowland⁵⁴ comment on the pathological findings in 206 cases of pneumonic meningitis, "the base of the brain shows the most marked lesions. The exudate is almost entirely confined to the base of the brain." Koplick,⁵⁵ in basic meningitis, found "lymph at the base of the brain and cord." "Thickening of pia and arachnoid at base of brain, some adhesions between cerebellum and medulla." Barlow and Lees, quoted by Koplick, state that the "primary seat of the inflammation is the region where the brain and cord meet and where the cerebellum overlaps the medulla." "Adhesions may result in blocking the foramen of Magendie."

Adami and Nicholls⁵⁶ "the exudate tends to collect at the base of the brain and along the posterior aspect of the cord. It is largely serous, but may be turbid. The exudate is found chiefly along the vessels and fills up the cisterns at the base of the brain."

Therefore, the conclusion is inevitable that the cisterna magna is the best and only reasonable place for surgical interference in meningitis.

CHAPTER IV.—SURGICAL ANATOMY OF THE SUB-OCCIPITAL REGION.

1. The skin and subcutaneous fascia require no mention. They are divided by a vertical incision immediately in the median line.

2. The muscles lie in paired groups on either side of the middle line; consequently they are not divided in the operation, but merely retraction to one side. They are the trapezius, complexus and the rectus capitis posticus minor.

3. The nerves do not appear at all. The only one which might enter the field is the third occipital. As this is a purely sensory nerve, its division could only cause temporary numbness of the back part of the scalp.

4. The vessels are the only structures of the soft parts which deserve more than a passing remark. They are paired arteries and veins which are connected more or less freely by anastomotic vessels which cross the line of the incision. When divided they bleed, but the hemorrhage is easily checked by clamps.

5. The pericranium is easily stripped from the bone, and with it the portions of the origins of the muscles near the middle line. It is also directly continuous with the atlanto-occipital ligament at the margin of the foramen magnum.

6. A small median emissary vein may exist at about the middle of the occipital crest. It is not constant. If present it may be plugged by a piece of wood or by boring into the opening with the tip of an artery clamp.

7. The skull deserves a longer notice. There is a great difference in the thickness of the skulls in this region in adults. Of course in children it is very thin, with a slight thickening along the occipital crest. In both classes the thickest portion of the bone is at the occipital crest. On either side of the crest the bone becomes thinner, to again thicken up about the foramen magnum. In all cases it should be perforated with due caution.

8. The dura is thick and firm. It is readily separated from the bone. At the foramen magnum it is the most closely attached, but can be readily detached from the bone without difficulty. It is continuous here with the pericranium.

9. The occipital sinus "is the smallest of all the sinuses, about 2 mm. in diameter. It is composed of two parts: a vertical part which descends in the falx cerebelli; a horizontal or anterior part, also called the sinus marginalis, which courses around the margin of the foramen magnum and opens into the lateral sinus." (Poier and Charpy⁶⁷). They also give the following figures as to its varia-

tions: 5 times out of 50 it was very large (Dumont); absent twice in 44 cases; 10 times the marginal branch was absent; in 9 times there were two sinuses; in 33 times there was one trunk unpaired and median, bifurcating at its lower part."

10. The arachnoid presents in this region as a membrane of considerable strength and individuality. It is closely applied to the dura and consequently separated by a wide space from the pia beneath, over an interval corresponding to the apices of the cerebellar lobes and the sides of the medulla.

11. The incisura cerebelli posterior. This gap between the cerebellar lobes is bounded below and in front by the medulla.

12. Covering the surface of the parts will be seen the vascular pia, with the two posterior inferior cerebellar arteries (from the vertebrals) standing out conspicuously as they wind around the apices of the cerebellar lobes from its lower surface into the incisura cerebelli.

13. If the cerebellar lobes are gently raised and separated there will be seen the opening, usually vertically placed and with irregular borders, the foramen of Magendie, which exists in the pia extending from the cerebellum to the medulla.

14. As to the cerebellum and medulla, our surgical and anatomical investigations do not carry us that far at this time.

CHAPTER V.—DRAINAGE OF THE CISTERNA MAGNA FOR MENINGITIS.

A. Purposes of the Operation. B. Steps of the Operation. C. Difficulties of the Operation. D. Advantages of the Operation. E. Secondary Remedial Measures. F. Other Conditions in Which This Operation May be Indicated. G. Instruments and Appliances.

A. PURPOSE OF THE OPERATION.

1. To open the cisterna magna, relieve intra-cranial pressure, and restore the normal supply of "good blood" to the "vital centers."

2. To do this without danger of cerebellar hernia or of "corking up the foramen magnum" by downward displacement of the brain stem.

3. To prevent shock and possible death of the patient from too sudden escape of the cerebro-spinal fluid.

4. To provide for free and continuous drainage of the infected cerebro-spinal fluid and thus enable Nature to effect a cure of the disease.

5. To afford inspection of the foramen of Magendie, and if it be closed, reopening it.

6. To forestall possible complications, especially hydrocephalus. If hydrocephalus is present, its relief and cure is possible by this operation.

7. To accomplish these desirable ends by an operation of the simplest technic, in the minimum of time, with the least shock.

B. STEPS OF THE OPERATION.

The scalp has been shaved and the usual preoperative measures taken to secure and maintain absolute asepsis.

The proper position upon the operating table is maintained by the special head-rest (see figure) or by a competent, strong assistant, and sand bags.*

The anesthetic (ether) is administered through nasal tubes beneath the sterile sheet covering the patient.

The incision is in the middle line from the occipital protuberance to the spinous process of the axis and carried down to the occipital bone and posterior arch of the atlas.

Hemorrhage, slight and easily arrested, is checked by mosquito clamps and the vessels ligated.

The periosteum is now stripped from the occipital bone, taking with it the inner portions of the origin of the attached muscles, and the occipital bone is bared for about a distance of one and one-half to two inches vertically and an inch transversely, at the foramen magnum, less above (see illustration).

The posterior arch of the atlas does not require baring.

An emissary vein may be encountered in the mid-line. It is not constant. If present it may be plugged by a wooden toothpick or by boring into it with an artery clamp.

The self-retaining retractor is now introduced. There are two sizes of detachable blades provided, one for adults and the other for children.

The De Vilbiss trephine (three-eighths of an inch) is applied in the mid-line and about one inch from the margin of the foramen magnum and the button of bone removed. With the special dural separations the dura is loosened from the bone and the De Vilbiss bone-cutter used to make two lines of incisions or grooves through the bone into the foramen magnum. The dural separator must be constantly used to detach the dura from the bone in advance of the bone-cutter. For this reason these separators are made in two

*A blood-pressure apparatus is attached to the patient and an assistant detailed to carefully watch this and the pulse and respirations and announce their variations.

sizes and with a narrow shank to easily pass through the groove in the bone.

The wedge of bone, cut loose, is about half an inch wide at the foramen magnum and a little less at the upper border. Of course the size may vary for each individual and according to complications. The detachment of the bone-button is carefully completed and it is removed.

The dura presents, probably under pressure, bulging into the bone gap.

The occipital sinus (or sinuses) will be seen, if present, showing a blue color through the dura. If the sinus is double, the dura should be incised between them. If single, it should be tied at the upper part and just beyond its bifurcation into the marginal sinuses. The special, full-curved, right-angled dural needles, right and left, are provided for this purpose.

Caution:—In dividing the dura, first make a very tiny incision into it, using the fine curved bistoury for this purpose.* This is necessary, for should the arachnoid be so closely applied to the dura as to be divided with it we need to prevent a too sudden escape of the cerebro-spinal fluid. Should it be found that the dura has been severed alone the incision in it should be carried up and down to the limits of the opening in the bone.

The arachnoid will now bulge into the field, unless it has been divided with the dura. The amount of its bulging will give some idea of the degree of intra-cranial pressure. The arachnoid is slightly nicked in the middle line and the cerebro-spinal fluid allowed to escape, a specimen being taken for laboratory examination. While it escapes slowly a careful watch is maintained upon the blood-pressure, pulse and respirations by one especially detailed for this purpose. Syncope may be prevented or lessened by arresting for a moment the flow of the fluid by gentle pressure of the finger.

As soon as the excess of fluid has escaped, open the arachnoid for the full extent of the dural opening. The condition in the cerebello-medullary angle should be very carefully investigated. Should there be an exudate about the parts the lobes of the cerebellum should be raised and separated by the "pushers" provided for this purpose and the patency of the foramen of Magendie assured. It may be necessary to enlarge the opening in the occipital bone. This is easily done by the ordinary rongeurs or by the bone punch

NOTE:—In our first case a small aspirating needle was inserted through the dura into the cisterna magna and the excess of fluid withdrawn. In the other cases the structures were cautiously divided with a knife.

devised by the writer. A small wick of rubber or gutta-percha tissue is placed within the margins of the dura and arachnoid and left protruding from the wound. The muscles are replaced and held together by two or three plain gut sutures (interrupted). The skin is closed above and below the drain with silkworm gut, interrupted sutures. Voluminous dressings are applied, sufficiently thick to fill out the normal hollow between the head and neck.

The patient is handled with care, remembering that the brain stem no longer has its protecting cushion of fluid. The entire operation takes from fifteen to thirty minutes.

C. DIFFICULTIES OF THE OPERATION.

As to the difficulties of the operations already performed by the writer, three in number, there were none. The cisterna magna was easily and quickly reached in all cases, so easily, that it demonstrated perfectly how simple the operation was. As to the emissary vein, it is not constant; it was found in one cadaver of 6, and in one patient of 3, and here bled so little that a twist of an artery clamp into the hole stopped the bleeding at once.

The devision of the bone in the two children was such an easy and rapid procedure that one needed to be careful not to crowd the trephine too fast. In the adult it took about the same time as on the vertex. The separation of the dura, the removal and reintroduction of the bone cutter took no appreciable time and was not attended with a single bad symptom or drawback. As to the occipital and marginal sinuses, they need not cause one a second's thought. If in the line of the incision, tie them, otherwise not (if double).

Regarding the danger of the escape of cerebro-spinal fluid. This danger attends this no more than any operation upon the skull. However, I think too much stress is placed upon this factor. In a fairly large experience in operating upon the skull and spine, and by perusal of the literature I am convinced that mere loss of cerebro-spinal fluid is not attended with any danger whatever. In cases of meningitis, however, where the brain is under pressure, its sudden escape might be attended with serious syncope. Yet in one of my cases there was an unintentionally large incision made into the cisterna magna and the fluid all escaped within a few seconds, yet no symptoms were observed. In the two other cases the fluid was slowly evacuated, in one through a tiny incision, in another by an aspirating needle, the stream rising in the adult to the height of six inches or more.

Our experience is not large; but in connection with that of others who have recorded their observations, it is helpful and confirmatory.

As to the danger of infection, infection is *already* present. The operation is undertaken to relieve the individual of its effects and possibly cure the disease. No more valid objection against operating in these cases exist than in the presence of infection in any other part of the body—even less—for often unrelieved suppuration elsewhere may spontaneously open and drain itself, but, from the cranial cavity, never.

D. ADVANTAGES OF THE OPERATION.

This operation opens the cisterna magna at its largest and most favorable spot for the evacuation of any fluid it may contain. Drainage established here effectually taps all other adjacent regions within and without the brain and cord. We do not seek to establish drainage merely to provide an exit for purulent cerebro-spinal fluid, but to *relieve intra-cranial pressure and restore blood to the vital centers.*

Furthermore, once drainage is established, the fresh secretions of cerebro-spinal fluid are more potent in their bactericidal elements than before, and every hour gained in life leads to greater probabilities of a complete cure. (We except from this statement cases moribund at the time of operation). The operation is not complicated by the protrusion of the cerebellum into the cranial opening, as occurs in all other operations in the cerebellar fossa. "Hernia of the cerebellum" interfered with Ballance. Parkin had to "push the cerebellum out of the way" before he got any flow, beyond a few drops. Ord and Waterhouse found that the "cerebellum bulged into the trephine opening, fitting it tightly like a cork in a bottle." Hall⁵⁶, in operating upon a case after Parkins' method, says "the cerebellum protruded so forcibly that its substance was lacerated against the edges of the bone." In the operation here suggested there is no hernia cerebelli. The reasons are plain, anatomy reveals and surgery proves them.

Meningeal infection is attended with an increased amount of cerebro-spinal fluid. This causes great intra-cranial pressure. The cortical surface of the brain is crowded against the inner surface of the skull. A trephine opening made in the skull anywhere over the convexity of the brain (cerebrum or cerebellum) and the dura divided, the brain is crowded forcibly into the opening and tightly 'corks it up.' At the site of this operation, over the cisterna magna,

and between the lobes of the cerebellum there is a *normal gap* or hiatus. The skull can be opened here in the presence of great intracranial pressure without a hernia cerebelli occurring or even a tendency to one appearing.

The entire central cerebello-medullary tract is under direct observation and, if required, surgical treatment. Moreover, drains can be inserted, laterally if necessary, for draining the lateral fossae on one or both sides. Should there be adhesions blocking up the foramen of Magendie, these can easily be broken up by merely separating the lobes of the cerebellum without disturbing the medulla. Plugging of the foramen magnum by the brain stem is impossible. The other varieties of operations suggested and performed in the sub-occipital region *do not drain*.

Ballance had to "trephine both sides of the middle line so as to prevent hernia of the cerebellum interfering with drainage." Parkin stated he got "free drainage up to the last," but he had to raise the cerebellum up in order to gain this. Ord and Waterhouse had a similar difficulty to contend with. Kuemmell had to trephine on both sides of the middle line to secure adequate drainage.

If a drain is inserted through a trephine opening as usually placed, the brain must be crowded back. It may be and usually is lacerated in the undertaking. If a drain is inserted it lies between the brain and skull and is pressed upon by the latter. It is soon isolated by enveloping adhesions and ceases to functionate. Drainage by the older operations is difficult and of short duration. But drainage from the cisterna magna is from a cavity. It is not subjected to pressure and there is no tendency to limiting adhesions. Ordinary peritoneal drainage and its speedy isolation by adhesions resembles the former class of cranial drainage, while supra-pubic drainage of the urinary bladder by rubber tissue closely imitates the method of drainage from the cisterna magna here advocated.

As to the plan of Radmann to drain this region by an incision through the occipito-atlantal ligament, the space is very narrow, especially narrow in children, the vertebral arteries come into dangerous proximity to the field of operation, the *opening is below the real seat of trouble*. Relief of pressure at this point is attended with the same objection as for lumbar puncture, the possibility of "corking up the foramen magnum by the brain stem."

Furthermore, no information as to the condition within the great cistern can be obtained and there is no possibility of determining if the foramen of Magendie is closed, and no relief of such a condition, if present, could be offered.

Extra-cranial advantages are that there is a single incision with separation, merely of the muscles. There is no extensive division of muscles as in Ballance's, Parkin's, Ord and Waterhouse's or Cushing's propositions, with their subsequent resuturing—time-consuming details. Nor can there be the "furious bleeding" reported by Ord and Waterhouse. Loss of any considerable quantity of blood is something to be carefully guarded against. Because it "is imperative that the blood-pressure be maintained" (Archibald), and loss of blood results in its lowering.

The operation is quickly done. Fifteen minutes in the child and, at most, thirty in the adult, is ample time in uncomplicated cases.

Further, an operation at this site will prevent future complications. Cerebral irritation and even epilepsy due to adhesions forming between the pia and dura is impossible, as these two membranes are so widely separated at this point. Hydrocephalus, that frequent complication of meningitis, and probably due to the closure at the foramen of Magendie, can be prevented. As to the frequency of hydrocephalus, Lees and Barlow⁵⁰ state that in 38 out of 50 autopsies it was the *hydrocephalus*, and not the meningitis, that caused death.

Cushing emphasizes this condition by stating "that basal meningitis of whatever nature, provided the exudate serves to obstruct the foramen near the fourth ventricle, is usually the immediate cause of death in the fatal cases of meningitis, and in those which recover, it is a common source of cerebral disturbance, owing to an incomplete re-establishment of the normally free outlets."

Furthermore, if hydrocephalus has developed, as a sequella of "cured" meningitis, it is probably due to the closure of this outlet. By means of the operation here described, which offers greater access to this region with the minimum risk, simple technic, ease of execution, advantageous position, relief may be secured for these patients.

E. SECONDARY REMEDIAL MEASURES.

Blood-pressure must be maintained and in no instance permitted to fall. A sudden fall in blood-pressure indicates a fatal end.

As to drugs, strychnine is our sheet anchor; adrenalin may be helpful.

Mechanical measures, bandaging the abdomen, over a small pillow, bandaging the lower extremities, lowering the head of the patient (and table if necessary).

Furnish good blood to the asphyxiated vital centers by the inhalation of oxygen.

Saline transfusions or injections during or following the operation. A Murphy drip or intermittent saline rectal enemas of a few ounces continued over the first 24 hours afford one of the best therapeutic measures. It furnishes fluid to the system, flushes the kidneys, aids the other eliminating glands and so assists in throwing off the infection.

Possibly the proper auto-vaccines or anti-toxins may be of some service in combatting the general infection. By large doses of hexamethylenamin the cerebro-spinal fluid may be rendered more anti-germicial and thus more quickly overcome the infection.

The chief point is, however, that by early resort to surgery all these evidences of systemic poisoning may be prevented, or, if present, to some extent relieved before they have overwhelmed the patient.

F. OTHER CONDITIONS IN WHICH THIS OPERATION MAY BE INDICATED.

I have written this paper to urge the early use of this reasonable and safe operation in meningitis. I feel, however, that it is not by any means restricted to this disease alone, but might prove a life-saver in those basal fractures extending into the posterior fossa of the skull, when death is certain from pressure due to the intracranial hemorrhage, as demonstrated by lumbar puncture and compression symptoms.

So many of these cases reach the surgeon in the terminal stage of cerebral compression and bulbar paralysis that it is realized but few may survive the operation. Is it not worth while, however, to give these otherwise fatal cases a chance? Ransohoff⁶⁰ states that in 190 cases of fracture of the base of the skull: 56 per cent died within 12 hours; 78 per cent within 24 hours, and 85 per cent within 48 hours. There is thus a margin of from 12 to 24 hours in nearly 30 per cent in some cases in which this method of decompression might be of use.

Furthermore, should infection be added, as not infrequently follows, and a basal meningitis develop, as in Kuemmell's case, would not this operation prove more advantageous than the extensive one proposed by him or similar ones suggested by other surgeons.

The indications are practically the same as in meningitis. But we do not, usually, have the opportunity of observing the cases early. Serious pressure exists, as a rule, when these cases come under observation, as shown by the coma, fixity of the pupils, vagus pulse and irregular respirations. With such extensive bulbar paralysis

operation would hold out very little chance of success. But if there was only delirium or stupor, with a rising blood-pressure, with fair pulse and respirations only stertorous and lumbar puncture gave a bloody fluid, under pressure, drainage of the posterior fossa by this route might be successful in a fair proportion of cases.

G. INSTRUMENTS AND APPLIANCES.

As far as possible "stock" instruments have been selected and tried out upon the cadaver and upon the living. While we have made a few suggestions, tending to meet certain contingencies and to facilitate the operation, the entire operation may be easily performed with the ordinary instruments for cranial surgery. No chisels, gouges or hammers should be used. We have had fashioned a self-retaining retractor by a little modification of a Jansen's mastoid retractor, extending and squaring the arms and using removable tractor blades. The right and left dural ligature passers had to be made especially. There is nothing small enough that has the strength with the proper curve. The dural separators are stock instruments, slightly modified. The sharp triangular periosteal scraper was found useful in separating the dura and pericranium at the foramen magnum. The rectangular bone-punch is intended for enlarging the opening in the bone, in children; in adults the ordinary bone cutters may be used for this purpose.

The hospital head-rest is constructed after the one described by H. B. Smith.⁹¹ We have aimed to make it applicable to any age and adjustable to any table.

The advantage of this head-rest consists first in securing immobility of the patient's head in the best position for work upon the region in question. Further in being attached to the table, the table may be elevated or depressed as occasion may require without disturbing the position of the patient upon it.

I have designed a portable head-rest which may be attached to any table (kitchen or operating), and is also easily adjusted to adults or children. It weighs 6 pounds while the above weighs about 15 pounds.

CHAPTER VI.—RECORDS OF CASES.

Case 1. A. M., Italian, 8 years of age; November 21, 1910. The child was taken sick with influenza one and a half weeks ago. Sickness began with general malaise, pains all over the body and a slight cough, no chills. Temperature 100° to 102°. Diagnosis: Broncho-pneumonia.

Ten days ago a purulent discharge appeared from both ears. There had been no complaint at any time of pain in the ears. Eight days ago the child became dizzy and four days ago had vomiting spells and then gradually became semi-comatose. Pupils did not react to light. Kernig's sign present, and Babinski sign present in both legs.

At this time a petechial rash appeared over the body. Temperature, 101° ; respiration, 30. Diagnosed now as tubercular meningitis. Spinal fluid was drawn and diagnosis confirmed by the Board of Health.

Dr. Kopetzky saw the child after this. He found it unconscious, pupils dilated and not reacting to light. Head retracted and rigid on body. Kernig and Babinski signs marked. He withdrew 30 ccm. of spinal fluid and sent the child to the Red Cross Hospital, November 20, 1910. Dr. Kopetzky's diagnosis: Otitic meningitis following a double mastoid.

On entering hospital, temperature, 101° ; pulse, 120; respiration, 28. Blood-pressure, Janeway's cardiac sphygmomanometer, 98 to 100 mm. Hg. Operations at midnight. Ether anesthesia by Dr. Garr, House Surgeon. Mastoid operations by Dr. Kopetzky, assisted by Dr. Imperatori.

Right side:—Outside surface markings of cortex of mastoid normal, but on removal of cortex, no mastoid cells were evident at all. the sigmoid sinus completely filled up the small mastoid protuberance. It was covered with granulations. The mastoid antrum was finally located, by pushing back the sinus wall, and the region found filled with detritus and pus.

Left side:—Nothing abnormal in structure. Pus and detritus in the process.

Drainage of the cisterna magna by Dr. Haynes, Dr. Kopetzky assisting, and Dr. Imperatori steadying the child's head. An incision was made in the middle line from the external occipital protuberance to, about the third cervical spine and down to the occipital bone and the arches of the atlas and axis. Hemorrhage was very slight, four clamps controlled the bleeding. The periosteum and attached muscles were elevated from the bone and pushed toward the sides until the occipital bone was bared from theinion to the margin of the foramen magnum and an inch or slightly more in width. There was no hemorrhage.

A DeVilbiss trephine (three-eighths of an inch in diameter) was applied to the bone midway between the inion and the margin of

the foramen magnum in the middle line. The skull was unusually thick in this place, but the button was turned out without difficulty and the dura exposed. This was loosened about the margin of the hole by the dural separators and a DeVilbiss bone-cutter used to make two furrows from the trephine opening to the foramen magnum. The intervening piece of bone was gradually removed by a flat rongeur. There was no bleeding. There was no appearance of any sinus, occipital or marginal. A medium aspirating needle was inserted through the bulging dura, into the cisterna magna, and enough fluid obtained for laboratory examination (about 10 ccm.).

The dura presented an injected appearance. It was carefully incised in the middle line and the cerebro-spinal fluid allowed to escape, which it did slowly but not satisfactorily. The incision was enlarged and the fluid escaped freely. It looked thin and clear.

The arachnoid presented in the wound as cotton (absorbent) looks when floating on the surface of water. It was somewhat milky in color. Nothing of the cerebellum or blood-vessels showed through it. It was severed in the middle line as deeply as I dared to go with the idea of dividing its meshes and allowing freer drainage. A rubber tissue-drain was inserted into the opening and the wound closed with interrupted plain gut sutures, No. 2. A large dressing was applied and the child returned to bed. Pulse, 144, good quality.

Comments on the operation:—The cerebro-spinal fluid did not seem to be under any considerable pressure, though several ounces flowed away. This was probably due to a lumbar puncture six hours before when 30 ccm. had been withdrawn. The meshes of the arachnoid were "fluffed" up by the fluid so as to be very conspicuous and to obscure all deeper parts. The hemorrhage was inconsiderable at all times. No sinuses were visible and there was no dural bleeding. The method of exposure gave ample room for all work. A much larger amount of bone could easily have been removed if deemed necessary.

Subsequent course:—The drainage of cerebro-spinal fluid was free. Patient roused up sufficiently to take nourishment well up to within a few hours of death. Retraction of the head disappeared the morning following the operation and the limbs became relaxed. Blood-pressure, 95 mm. Hg. The eyes reacted to light.

Patient died 34 hours after the operations of sepsis and toxemia. The heart stopped beating before paralysis of the vaso-motor center. Autopsy was not allowed.

Bacteriological:—Spinal fluid withdrawn by Dr. Kopetzky before the operations, showed a diplococcus without a capsule, probably a pneumococcus. There was, also, present in the culture, a large, unidentified bacillus. No report was made of the fluid obtained directly from the cisterna magna.

Cultures from both ears, showed diplococci. Differential count before operation:—Polys, 30; total leucocytes, 5000; large mono and trans., 14; lympho., 56. After operation (10 hours)—polys, 30; total leucocytes, 16500; large mono- and trans., 17; lymph, 53.

Case 2. H. D., aged 45 years, entered Harlem Hospital, January 12; died, January 15, 1911. Patient has been sick for a week with headaches and general abdominal pain. She worked at housework up to yesterday. Last night she had severe and recurring attacks of vomiting with pain in the abdomen. She now complains of severe headaches and severe abdominal pains, especially in the upper portion of the abdomen. She was admitted as a non-urgent case, probably gall-stones.

Physical:—Muscular female, dusky countenance; conscious, but somewhat irrational; pupils equal, react to light and accommodation; pulse, 120, full volume, tension increased; temperature, 103°; respiration, 30. Abdomen, somewhat tender but nothing localized. Kernig and Babinski absent.

Differential:—W. B. C., 31800; l. lymph, 4; s. lymph, 9; mast cells, 2; polys, 85; January 13, the next day: W. B. C., 33200; polys, 89; l. lymph, 8; s. lymph, 3; Widal negative.

Spinal puncture gave 15 ccm, of turbid fluid under pressure. Laboratory examination:—No blood. Pus cells, large number. Micrococcus lanceolatus, positive. Kernig and Babinski both present.

On January 14, patient was more lethargic. Urine passed involuntarily. Pupils contracted and eyes deviate to left. No convulsions but general spasticity. Cervical muscles especially contracted. She was being transferred to the medical ward by my assistant when I saw the case and ordered her up for operation.

Operation:—Dr. Haynes, assisted by Dr. Boynton and the Hospital Staff. Anesthetic, ether, administered by Dr. Lumbard, hospital anesthetist, by means of the nasal tubes. Time of operation, 25 minutes. Total anesthesia, 35 minutes. Anesthetic well taken. Position on table, on face with head over the edge, as in a reversed Rose-position. Steadied in this position by one of staff.

The occipital bone was exposed by the vertical incision and bared from the inion to the margin of the foramen magnum. Not having a small trephine in working order, a larger one with a diameter of one inch was used, without any trouble, to remove a button of bone from the midline region and midway between the inion and margin of the foramen magnum, from the center of the exposed area.

The bone between the trephine hole and the margin of the foramen magnum was removed with a rongeur, opening up a space an inch wide and an inch and a half vertically.

The dura bulged from the intra-cranial pressure. It was punctured with a small knife, an opening less than an eighth of an inch being made and through this the cerebro-spinal fluid spurted to a distance of six inches or more. A careful watch was kept of the heart and respirations and the flow was checked once or twice by gentle pressure of the finger, although no untoward symptoms had appeared. The wound was then drained with iodoform gauze and the muscles brought together with two or three plain gut No. 2 sutures. The skin closed with silkworm-gut.

Comments on the operation:—I did not open the dura widely in this case, inasmuch as the fluid seemed to escape so freely from the small incision. I think that this might have been done, without adding any danger to the patient or any benefit as the sequel showed.

On return to ward, patient had a general convulsion, but this was the only one she had. Within an hour the pupils reacted to light, the spasticity was less and the wound drained so freely as to soak the dressings.

Four hours later, there was a general improvement in her condition. The pupils were active and there was no deviation of eyes as there had been at a previous examination. Pulse was full and fair quality and running at 150. Respiration, 40; temperature, 102°. Morning of January 15, condition much the same. Kernig and Babinski absent. Wound draining profusely. There is a very free secretion of mucus from the nose and throat—due to nasal anesthesia. Spasticity of muscles much less, especially of the neck. Patient gradually failed and died at midnight, 32 hours after the operation. No autopsy permitted.

Case 3. Admitted to the Red Cross Hospital, April 24, 1911. Died, April 25, 1911. Referred by Dr. L. K. Neff. Baby O'C., 11 months old; breast-fed. The infant had been sick for one week with acute meningitis in which lumbar puncture had been used several times for therapeutic purposes and by which the infecting

organism was shown to be the pneumococcus. On admission, the baby had a temperature, by rectum, of 106° , pulse, 180; respiration, 40. Was in a state of coma with pupils dilated and fixed, head strongly retracted. No record of Kernig or Babinski. Blood-pressure (Dr. Imperatori) 80 mm. Hg. (Janeway's cardiac sphygmomanometer).

Blood-count: White blood cells, 8000; polys, 17; lymph, 61; large mono- and trans., 22. Operation as a last resort. It was completed within 15 minutes. Dr. Haynes, assisted by Drs. Kopetzky and Imperatori, and House Surgeon, Dr. Neff present. Slightest amount of ether used. The operation as detailed in the previous cases was performed. No difficulty in removing the bone or in opening the dura and arachnoid. The opening was made by an ordinary scalpel and was made easily and wider than intended, allowing of rapid escape of the cerebro-spinal fluid. No bad effects were noticed. Clear fluid escaped in considerable quantity. No exudate visible in cisterna magna. The operation was performed at 11:30 a. m.

On return to bed the pulse had dropped to 168, was of good quality. The Murphy drip was started. At 6 p. m., pulse, 170; respiration, 32; temperature (by axilla) 101° . At 6:33 p. m., apparently had a convulsion which lasted 3 minutes. At 8 p. m., blood-pressure, 80 mm. Hg. Four ccm. maternal serum was injected into the flank. At 11:30, temperature (axilla) 102° ; pulse, 168; respiration, 36. Patient unconscious. Child died at 1 a. m., without regaining consciousness. Permission could not be obtained for a post-mortem examination.

Comments:—These three cases were in the last stages of septic meningitis. The time for operating had long passed. The operations were performed as a last resort, to offer the only possible chance in a certainly fatal disease. We did not expect to save any of them. However, the demonstration of the rapidity, the ease, the freedom from any disadvantages as an operative proposition was absolute. The cisterna magna was reached, opened, drained and the wound closed within fifteen minutes in the two children and thirty minutes in the adult. Drainage was free, profuse and continuous in all. All the symptoms were ameliorated and death came peacefully.

Operations in such extreme cases are not advocated. They accomplish nothing but an easy death and invite adverse criticism. However, as no one can as yet say absolutely when every case is

beyond assistance, even in these moribund patients I advise interference; possibly one may be saved.

These cases merely emphasize the contention of this paper that this operation must be done *early*. The co-operation of the family physician must be secured. He must learn that the time to operate is just as soon as the diagnosis has been confirmed by lumbar puncture. Delay invariably brings disaster. The argument that because operations in the past have accomplished almost nothing proves nothing except that there must be a change in the time, place and method of operating.

Note:—I would like to express my thanks to Dr. Emil Altman and to Dr. Lewis K. Neff for the opportunity of operating upon Cases 1 and 3.

Case 4. Acute mastoiditis, acute purulent labyrinthitis and streptococcic meningitis. In the service of Dr. Wendell C. Phillips at the Manhattan Eye, Ear and Throat Hospital, New York.

J. H., a Greek, aged 20 years. Came under observation March 19, 1912, giving the following history: There was pain in the left ear, beginning one month ago, followed one week later by spontaneous discharge from that ear. A week before coming to the hospital paracentesis of the membrana tympani was performed. There has been no previous illness.

On admission to the hospital, March 19, he presented all the clinical signs of acute mastoiditis of the left side with infection into the soft tissues behind and below the mastoid process. The discharge from the ear was profuse, yellowish. The temperature at 3 p. m. was 102.4°; pulse, 100; respiration, 26. Eyes reacted to light, patient fully conscious. Tests of the labyrinth showed that it was not functioning, total deafness, absence of caloric and rotation-test reactions, spontaneous nystagmus present. At 9:30 p. m., incision into swelling below and behind mastoid did not evacuate pus. Blood pressure (Janeway) 128 mm. Hg. March 20, 9 a. m., temperature, 102°; pulse, 112; respiration, 24. Complains of intense headache. At 2 p. m., temperature 102.8°; pulse, 80; respiration, 26. Intense headache. Blood-pressure, 146 mm. Hg. (Janeway)...

Lumbar puncture performed. The chemical examination of the spinal fluid showed meningitis present, although complete examination was not made (Kopetzky's test).

The fluid, while almost water-clear, showed pus cells upon cyto-diagnosis (Strong's examination), and on the next day was reported showing streptococcus present (Strong).

March 21, 3 p. m. Because of advancing signs of meningeal irritation, operation was decided upon. A radical mastoid and labyrinthine exenteration was performed by Dr. Wendell C. Phillips in the usual way and pus and detritus found, but no fistula into the labyrinthine channels was demonstrated. This was followed by *drainage* of the *cisterna magna*, by Dr. S. J. Kopetzky, assisted by Dr. Fresner, who held the patient's head and Dr. McQuade, the House Surgeon. The occipital bone was exposed by a median incision and the parts retracted. A three-eighths inch trephine opening made in the middle line above the foramen magnum and the wedge of bone removed by a chisel and mallet. The dura was exposed and incised. About 40 ccm. of cerebro-spinal fluid was allowed to slowly escape, its flow being controlled by pressure on the edges of the dural incision. The wound was drained by a strip of iodoform gauze and the soft parts loosely closed about the drain by four interrupted sutures. A moist dressing applied and the patient returned to the ward, no stimulation being needed. Patient was reported as comfortable, but not sleeping.

March 22, 10:45 a. m. Blood-pressure, 120-125 mm. Hg. Patient conscious, has no headache. Spontaneous nystagmus still present. (Kopetzky). 3 p. m. Blood-pressure, 130-140 (K.) Urotropin, gr. V and sodii benzoate gr. VIII, ordered. Temperature ranged from 99.2° to 101.4°; pulse, 74-90; respirations, 22-24. He slept during the following night but became restless towards morning.

March 23, 11 a. m. Blood-pressure, 148 mm. Hg. At 3 p. m., temperature, 104°; pulse, 92; respiration, 20. Blood culture taken but later report showed it to have been contaminated. Murphy drip started and continued. Patient was reported as comfortable during the night.

March 24, 1912, noon. Blood-pressure, 132 (K.). Patient had a slight nose-bleed. He was conscious. During the afternoon he became somewhat restless. His eye-grounds were examined, but no signs of pressure reported. Was restless during the night. Temperature, 103.6°; pulse, 86; respiration, 24.

March 25, 6 a. m. Temperature, 101°; pulse, 84; respiration, 24. 1:30 p. m. Patient complained of headache, but no dizziness. Nystagmus gone. Blood-pressure, 140 mm. Hg. Wound dressed by Dr. Kopetzky as drainage seemed to have stopped. One stitch was removed and the gauze drain withdrawn, followed by a spurt of clear cerebro-spinal fluid. Patient complained of intense pain in his head during this procedure. The edges of the wound were

grasped and the flow controlled. The pulse dropped from 90 to 72. A rubber tissue drain was inserted.

Blood-pressure at the conclusion of the dressing was, 118-120 mm. Hg. Patient was left without any headache but still dizzy. At 2:30, an ophthalmoscopic examination showed that the fundus was normal, nerve not swollen, questionable enlargement of veins, very fine nystagmus (Dr. Oatman). He had a comfortable night.

March 26, 2:45 p. m. Blood-pressure, 125 (K.). Hypodermic injection given of 1 ccm. of the combined bacterial vaccines (450 million). At 5:30 he complained of very severe pain in his head, was very restless. One-fourth grain morphin given. Patient rested easily until 5:30 a. m. of March 27. Again became restless and complained of pain in his head. At 11 a. m., blood-pressure, 130 (K.); pulse was soft. Blood culture gave staphylococci (probably agonal, Dr. Callison). During the night patient required one-eighth grain of morphin to control his restlessness. He died during the forenoon of March 28. *perfectly conscious up to the end*. No autopsy was permitted.

Comments:—In addition to this patient's mastoid and labyrinth disease he had a streptococcic meningitis. The *early diagnosis* of meningitis was shown by the rising blood-pressure and by the definite chemical reaction of the cerebro-spinal fluid (the absence of the carbo-hydrate-sugar (Kopetzky), with beginning meningeal irritation. There were none of the usual signs and symptoms of meningitis. His mind was clear, his eye-grounds were normal. His pulse and temperature only reacted to the septic infection. The patient died of septic meningitis without the usual signs of meningitis. Only at the last did he become restless and noisy. There was no stupor, slowed pulse, irregular respirations, or choked-disc invariably found accompanying the usual exitus from meningitis.

The operation distinctly relieved the patient. It did not cure because the infection was too extensive. It demonstrated, however, its value in these otherwise hopeless cases and its use is thereby justified. Some cases will be saved. It is only a question of diagnosis and early operation.

CHAPTER VII.—CONCLUSIONS.

Meningitis kills. The least deadly and after the best treatment 10 per cent to 25 per cent, the other varieties, 100 per cent of cases.

Meningitis kills by producing intra-cranial pressure, anemia of the "vital centers" and their paralysis.

Intra-cranial pressure is assisted in its effects by the constitutional results of infection—septicemia and bacteremia.

The presence of infection is early demonstrated in the cerebro-spinal fluid drawn by lumbar puncture and by the clinical effects of intra-cranial pressure, as recorded by the changes in blood pressure, fundus of the eye, pulse, respirations and state of the sensorium.

These early evidences of meningeal infection are clearly shown by: 1. Progressive increase in blood-pressure; 2. absence of carbohydrates from the cerebro-spinal fluid; 3. edema of the papilla (not "choked disc"); 4. a clouding or irritable sensorium.

Such findings absolutely prove infection is present. If they are present, the diagnosis is certain and the end is sure.

It takes some hours or days for death to occur.

No present therapeutic measures save more than 75 per cent to 90 per cent of diplococcic infections and practically none of all other varieties.

The only relief is by early, free, and continuous removal of the rapidly forming cerebro-spinal fluid, thus preventing cerebral compression, bulbar anemia and paralysis and death.

Anatomy, physiology, pathology and surgery show the cisterna magna the place best suited for such a purpose.

The operation which reaches this in the minimum of time, with the least structural disturbance, with freedom from hemorrhage, with maximum access to the region without cerebellar hernia, with provision for adequate and sustained drainage, with opportunity to explore and treat adjacent parts and prevent complications and with the greatest safety to the patient is the preferable one.

The operative procedure here submitted for draining the cisterna magna fulfills these requirements more completely than any heretofore proposed or performed; therefore, it should be the operation of choice for the treatment of meningitis.

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Figures 1, 2, 3. Dissections by the Writer.
 Drawn by Mr. Bosse, reduced.
 Veins injected to make them more prominent.
 Figure 1. Dissection of the post-cervical region superficial to the trapezius muscle. A small anastomotic vein is shown crossing the line of the incision.

Figure 2. Structures superficial to the complexus muscle.

Figure 3. The deeper structures. The small anastomotic veins which cross the line of the incision.

Figure 4. Saggital section of the head and neck of a child. The subject had been hardened in formaldehyde and sectioned by the writer; (slightly reduced).

Note:—Vertical position of brain stem. Its relation to the foramen magnum. The ease with which "corking" this foramen could occur.

The large cisterna magna, its relations to the other subarachnoid spaces and especially to the occipital bone near the foramen magnum. Also the very narrow space between the foramen magnum and the arch of the atlas.

The distance of the skin from the occipito-vertebral angle is greatly diminished by flexion of the head and spine.

Figures 5 to 12. Illustrate the steps in the operation of "Draining the Cisterna Magna."

Preparations by the writer upon an adult male subject. Figures 5 to 8 are slightly reduced. The remaining, on a scale twice that size.

Figure 5. The incision.

Figure 6. The incision has been carried down to the occipital bone and posterior arch of the atlas. The pericranium with the muscles has been reflected from the occipital bone. The field is fully exposed by the aid of the self-retaining retractor.

Figure 7. The trephine opening has been made and grooves have been cut into the foramen magnum.

Figure 8. The wedge of bone has been removed. In this cadaver the occipital sinus was double, as shown in the illustration, and both clearly visible.

Figure 9. This figure and the two following have been drawn twice the natural size to render the structures more distinct. The dura has been opened between the double occipital sinus and the arachnoid is presenting.

Figure 10. The arachnoid had been divided and the cisterna magna opened. Note the space between the lobes of the cerebellum and the medulla.

Figure 11. The sinuses have been ligated and the dura and arachnoid widely reflected. The two arteries shown curving around the poles of the cerebellum are the posterior inferior cerebellar. They seem to be in close relation with the medulla. They are not. It is impossible to represent, in an illustration, the real depth of the cistern at the bottom of which lies the medulla.

Figure 12. The instruments which will be found useful in performing this operation. It will be noted that the most of them are "stock" instruments, found everywhere, and do not require even mention.

Attention is called to the self-retaining retractor which is of great assistance in maintaining the wound fully exposed. Also, to a bone cutter, which has a reversible cutting end that may be used in four different positions. Further, to the cerebellar "spoons or pushers" with which the lobes of the cerebellum may be gently pushed upward and apart.

Figure 13. Detached portions of the head-rest shown.

Figure 14. The head-rest assembled. The table should be horizontal. It was inclined by the photographer.

Figure 15. Shows the position of a patient with the head rest in use. In practice fixation of the head is secured by placing towels in the head piece until a tight fit is obtained for the head.

Figure 16. The author's head-rest attached to a common kitchen table by a webbing trunk strap.