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IN THIS paper I shall confine my remarks for the most part to the *treatment* of brain abscesses secondary to infection of the middle ear, mastoid and accessory nasal sinuses, as well as those of traumatic origin. The subject of metastatic brain abscess will not be considered. The etiology, pathology and diagnosis of brain abscess have been adequately covered by Macewen,[21] Eagleton,[14] Evans,[15] Atkinson,[2] Adson and Craig[1] and various other writers.

Otogenic abscesses resulting from otitis media and mastoiditis are in the majority, and extension of infection from these sources most frequently involves the temporosphenoidal lobe and the cerebellum. Evans[15] states that 83.2 per cent of brain abscesses are due to spread of infection from otitis media and mastoiditis, and that 9.1 per cent result from infections of the nasal cavity and its accessory sinuses. Only 7.7 per cent arise from all other sources. Therefore, 93.2 per cent of all brain abscesses are actually due to extension of infection from the nasopharynx. He further states that the spread of infection to the brain substance from the middle ear and mastoiditis, by *direct extension*, is through purulent thrombosis of the lateral sinus, osteomyelitis of the tympanic wall, along the adventitial spaces of perforating blood vessels, and through the internal auditory meatus. The spread of infection from the nasal cavity and its accessory sinuses by direct extension is due to osteomyelitis of the sinus wall, along the perineural spaces, and along and through the veins. In addition, the involvement of the brain by direct extension follows trauma of the skull and invasion of the brain by malignant growths.

Regardless of the mode of infection, according to Evans, a brain abscess commences with an inflammatory leukocytic infiltration and softening of the brain substance, and terminates by the conversion of a portion of the brain into a cavity containing pus. In the *acute* form, the abscess has no definite wall. It consists of a broken-down area of brain tissue, which might be termed acute suppurative encephalitis, with a central area containing pus and brain detritus. The wall, if it exists at all, is irregular and ill defined and consists of brain tissue with a shaggy surface, surrounded by an area of edematous brain substance. Should the patient be fortunate, this process becomes *chronic* in that a well defined wall or "capsule" is established, and the abscess then truly follows the old surgical description of any abscess as being "a circumscribed cavity containing pus" (Fig. 1). The wall of the abscess consists of an internal layer composed of purulent tissue, the so called pyogenic membrane, and an external layer of granulation tissue composed of various proportions of fibrous macroglia and all fibrous tissue derived from the vascular adventitia and, in some instances, from the leptomeninges. The granulation tissue is infiltrated with plasma cells, lymphocytes, and a few eosinophile

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leukocytes. The infiltration is continued in the adventitia of the vessels for a considerable distance into the brain (Evans). Bagley,[3] in 1922, described the formation and pathology of a brain abscess and its wall.

It has not been determined accurately how long it takes for a definite wall or capsule to form. Penfield[23] stated that the wall of an abscess begins to form in the first week, but that it does not offer resistance to a brain cannula till after two or three weeks. Grant[17] stated that a definite capsule or firm wall is

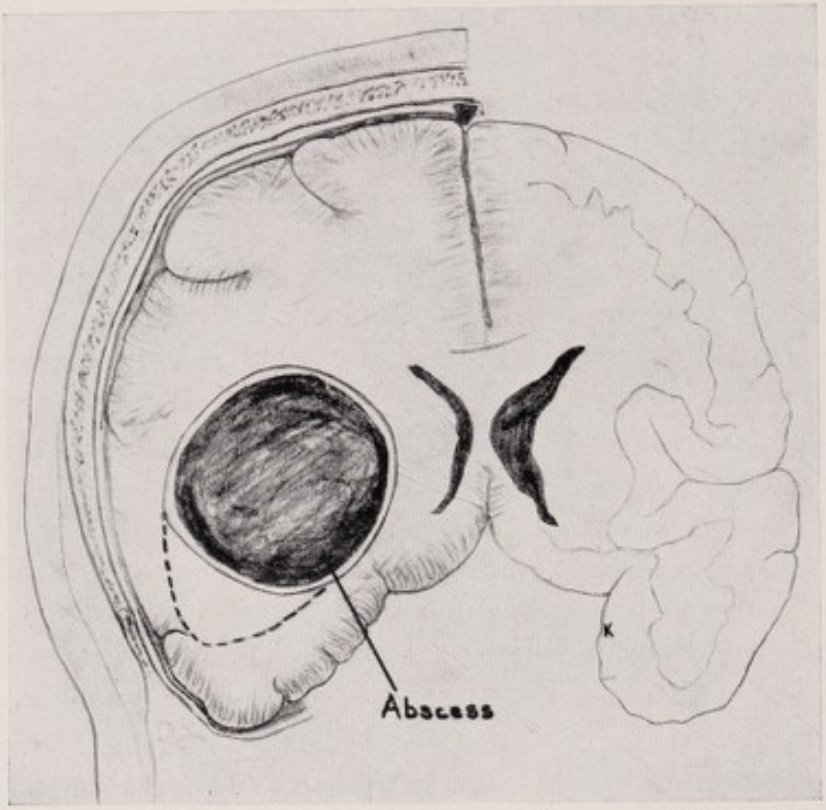

FIG. 1.—Chronic encapsulated abscess of the temporal lobe. The hemisphere which contains the abscess is larger than its mate. The ventricles are markedly compressed. The adjacent ventricle may be completely collapsed. The structures are shifted to the opposite side. The broken line indicates that the proximal pole may extend downward and outward and may form a definite "stalk" fixed to the dura.

well established in the interval between the fourth and sixth weeks, and Bagley showed a section of an abscess wall which formed in three to four weeks. The latter also stated that the thickness and firmness of the abscess wall will be determined by the relative amount of mesoblastic and gliablastic fibrous tissue present, the amount of glial tissue in the wall, and the length of time the abscess has existed.

PRELIMINARY MANAGEMENT.—When a brain abscess is suspected, *stereoroentgenographic* examination should be made in order to determine the degree of involvement of the mastoids, ethmoids, frontal sinuses, sphenoidal cells and antra. This may throw considerable light on the neurologic picture. Should infection of the sphenoid coexist with the involvement of the ethmoids and the frontal sinus, and a frontal lobe abscess is properly treated, a subsequent unsuspected abscess in the temporosphenoidal lobe due to sphenoidal infection may develop. The lack of attention paid by many writers to the

eradication of the source or focus of the infection in the middle ear, mastoid, or the nasal accessory sinuses is rather remarkable. Except in a case of emergency, the infectious process or processes in the sites of *extracranial* origin should first be eliminated before the intracranial suppurative process is attacked. Otherwise, following the proper handling of a subcortical abscess, another abscess may develop from the same source. Furthermore, an extradural lesion which may simulate a subdural one may be eliminated without a subdural exploration. In most instances of brain abscess, the drainage of the abscess can be accomplished immediately following the extracranial procedure. In some critical, comatose cases accompanied by marked slowing of the pulse, it may be advisable to evacuate the abscess first and perform the extracranial operation at a later date.

Types of Operation.—In a general way the types of operative procedures which have been described may be classified as follows: (1) The closed method. (2) The open method. (3) Extirpation of the abscess *in toto*. (4) Tapping.

Closed Method.—In the closed method, usually a small opening is made in the skull. Some type of drainage tube, *e.g.*, a small rubber tube or a small rubber catheter, is inserted into the abscess cavity without inspection of the cavity, the tube is allowed to remain in place for a considerable period of time, and is slowly removed without any, or but a small, degree of herniation. Coleman,[8, 9] Grant,[17] Dowman,[13] Sachs,[24] Bagley, McKenzie,[22] Atkinson, Davidoff[12] and others have advocated this method with some few changes or special details in the technic being recommended by them. In this method one first locates the "capsule" of the abscess and introduces the drainage material, catheter or tube, into the abscess cavity without intentional leakage of pus into the surrounding brain substance. For this purpose various ingenious devices in the form of guides, directors, encephaloscopes and searchers have been used. Among these is the encephaloscope devised by Whiting, its modification described by Eagleton,[14] and the cannula, sleeve and tube by Grant. Both Grant and Coleman have reported rather large series of recoveries following operation by the closed method. Macewen's use of the decalcified chicken bone drain is well known.

It is difficult to understand how an abscess with secondary extensions, loculations, or of an irregular shape could be properly drained by this method. Moreover, it is believed that the capsule, in the cases of so called recoveries, collapses about the drain as it is slowly removed, leaving a partially obliterated tract with a thick fibrous wall which remains as a potential source of infection. Such an instance was observed in 1919 after an abscess had been drained in this manner. Deep or centrally situated abscesses, however, can be drained only by this method, or by the use of a cannula or searcher.

Open Method.—In 1924,[19] the author advocated a rather wide open approach to the abscess, removal of the overlying cortex and a portion of the presenting capsule, evacuation and irrigation of the abscess cavity, thorough inspection of the cavity, and eventual obliteration of the cavity by its tem-

porary eversion and herniation. This method was advocated following the recovery of a patient in 1920 and of two other patients in 1923 who were operated upon in this manner. Previous to this time drainage tubes had not proven satisfactory for one reason or another, and in the method described they were completely discarded. The principles set forth at that time are still adhered to in general, with some modifications which will be dealt with later in this paper.

In 1925, Cahill[4] reported a series of cases treated by the use of the Mosher drain which was first considered by Mosher in 1915. The abscess was operated upon in two stages and was entered, in the majority of cases, by the mastoid route. Subsequently, in papers presented in 1929 and 1933, Cahill[5, 6] advocated a more extensive removal of the brain cortex and capsule of the abscess, so that the drain could be more accurately placed into the abscess cavity. He stated that "the formation of a fistulous tract about the drain to the abscess cavity in part makes the capsule extend to the surface of the brain," which approaches in some degree the method described by the author. In a personal communication, Cahill[7] described the formation of a small hernia or "nubbin" at the site from which the drain was finally removed in the cases operated on according to his modified method. It is believed that this small hernia represents the remnants of the contracted abscess cavity which has found its way to the surface. Cahill described the use of the Mosher drain in cases of otitic abscess and advocated its use in cases treated by the otologic surgeon.

Horrax,[18] in 1934, described a procedure first advocated by Dr. Cushing 10 or 12 years earlier for certain chronic encapsulated brain abscesses. He termed it "marsupialization." It decidedly belongs to the open method. Horrax made an opening in the skull about the size of a half dollar, a similar opening in the dura, removed the overlying cortex, removed a portion of the presenting abscess wall after partial evacuation of the abscess, fixed the cut edges of the capsule to the galea with sutures, and filled the abscess cavity with gauze lightly packed over a thin layer of gutta percha. Over this packing of gauze another layer of perforated gutta percha was placed and the entire area was covered with dry dressing and bandage. Subsequently the gauze and gutta percha were gradually extruded by herniation of the abscess cavity outward and were finally removed. A hernia cerebri may have developed, but this subsided. The area became covered with granulation and epithelialized. In this procedure thorough removal of the contents of the abscess cavity and inspection of the cavity can be accomplished. With the exception of suturing the edges of the capsule to the galea, this procedure, in general principles, is quite similar to the one proposed by the author. Horrax reports only one death in a series of eight cases operated upon by him according to the marsupialization method. Sachs reported a successful case operated upon by this method.

In 1932, the author[20] operated upon a case of temporosphenoidal abscess which had spontaneously ruptured through the mastoid wound. The capsule

of the abscess was almost completely empty, was contracted to about the size of a malaga grape, and was surrounded by a considerable area of necrotic and suppurative brain substance. In this instance the pericapsular necrotic brain was removed by suction, and inasmuch as the small contracted capsule could not be utilized in any manner, it was removed. The central portion of two layers of iodoform gauze was inserted into the resulting excavation in the temporosphenoidal lobe, and strips of soft iodoform gauze were packed into the cavity against the two layers of iodoform gauze, in the manner of a Mickulicz tampon, until the entire excavation was gently but snugly filled. Dakinization of the wound was carried out and the superficial dressings were changed daily after the first 48 hours. The iodoform gauze packing was slowly pushed out by the gradual herniation of the excavated brain surface and a portion of it was removed each day until none remained. The two layers of iodoform gauze were carefully removed from the brain surface which had herniated to the level of the skull. The area granulated over and healed. Later excision of the scar with approximation of the scalp edges was accomplished.

Since this time iodoform gauze has been used in a similar manner both in encapsulated and non-encapsulated abscesses, and in one instance in which there was a considerable amount of pericapsular brain suppuration and necrosis similar to the case described above.

Adson and Craig, in 1935, described a procedure somewhat similar to those advocated by Horrax and the author. They made an opening in the skull about 3 cm. in diameter, sutured the meninges and the cortex together, to prevent separation of the cortex from the dura, opened the dura by a crucial incision, so as to expose an area of cortex about 2 cm. in diameter, and then sealed the meninges to the cortex by electrocoagulation. After aspiration of pus from the abscess cavity, followed by gentle irrigation with saline solution, the capsule of the abscess was opened with the electrosurgical needle. This allowed of inspection of the abscess cavity aided by an illuminated retractor. Two rubber tubes, sections of a No. 18 F. catheter, were inserted into the cavity and about these strips of iodoform gauze were loosely packed. These strips of gauze were shortened and removed by the tenth day, leaving the two tubes in position. One of these tubes was shortened every other day, while the other one was removed gradually as the sinus closed in and forced it out. The time required from four to six weeks. They stated that there was but one death in 15 consecutive cases of supratentorial abscesses and one death in three cases of cerebellar abscesses. One may judge from the description of their procedure that the approach to, and inspection of, the abscess cavity classify it as an open method, while the use of drainage tubes with the formation of a sinus might place it in the category of the closed method.

It may be deduced that the operative procedures proposed or devised by Cahill, Horrax, Adson and Craig and the author have many similarities in principles though they may differ in details of technic.

Extirpation.—Various writers have reported an occasional case in which an old chronic abscess has been completely extirpated. Most of these were probably removed after an osteoplastic flap had been turned down in exploration for a tumor. Adson and Cairns report such instances. I am not acquainted with anyone who advocates routine extirpation of diagnosed abscesses, although one of the French surgeons stated that he did. When the abscess is of long standing, has a very thick wall, is calcified or contains thick inspissated pus, extirpation without opening the abscess might be considered. Or in a case of spontaneous evacuation of an abscess cavity, which is surrounded by suppurative necrotic brain tissue (as in the case which I have reported above), extirpation would then have to be done for the reason that it cannot be utilized.

In the instances of large abscesses which closely approach the ventricle, extirpation would surely be followed either by rupture into the ventricle, or rupture from the ventricle outward due to the increasing intraventricular pressure. I feel that the major and inner portion of the capsule should be preserved as a barrier and serve to prevent such a catastrophe.

Tapping.—Dandy,[10, 11] in 1926, and again in 1932, advocated tapping only in cases of chronic abscesses. He introduced a ventricular needle through a small trephine opening and a tiny nick in the dura into the abscess cavity and left the needle in place until the pus ceased to drip. He neither aspirated nor irrigated the cavity, but withdrew the needle and closed the scalp incision tight. He stated that "many times a single release of pus has been necessary; on fewer occasions two or more taps have been required."

I have had no experience with this method. The fact that it is not used by many authors who have reported a fairly large number of recoveries would seem to indicate that tapping is not generally used. Recently I saw sections of three brains which had been removed from patients who had been operated upon consecutively by one of my colleagues according to this method. He told me of the autopsy findings in a fourth case. He has given up the use of this type of operation. In passing, it might be said that the use of the osteoplastic flap in connection with the operation for brain abscess in general is not used and should not be advised.

It will thus be seen that there is wide divergence of opinion regarding the proper approach to, and the method of drainage of, an abscess of the brain, although most writers agree that the operation should be done after the abscess has developed a substantial wall or capsule. It is believed that no single procedure or combination of operations will result in 100 per cent recoveries. All abscesses are not alike; therefore, no one procedure will suffice in all cases.

Surgical Technic.—*Anesthesia.*—Local anesthesia, novocain 1 or ½ per cent solution with suprarenin alone or combined with avertin, is preferred. With adults, especially those who are stuporous or semicomatose, local anesthesia alone will suffice. With children the combination of avertin and novocain is more satisfactory. The use of ether is not advised for the

reason that it increases intracranial pressure while avertin decreases it. Vomiting following ether administration may produce damage to the abscess wall or result in rupture of the abscess into the ventricle. Ether also increases bleeding.

Procedure.—The vast majority of all cerebral abscesses in my experience have approached the dura at a point where it can be attacked at a depth which varies from ½ to about 3 cm. Inspection of museum specimens shows similar findings. Therefore, the approach to the abscess, as advocated in my original paper, with the modifications in technic to be described, will allow of adequate drainage of the majority of cerebral abscesses, whether the source of infection originates from the mastoid region and middle ear, the nasal cavity and accessory sinuses, or trauma. As stated above, the source of the intracranial infection should be eliminated before operation for the abscess, except in traumatic and in certain critical or extremely grave cases.

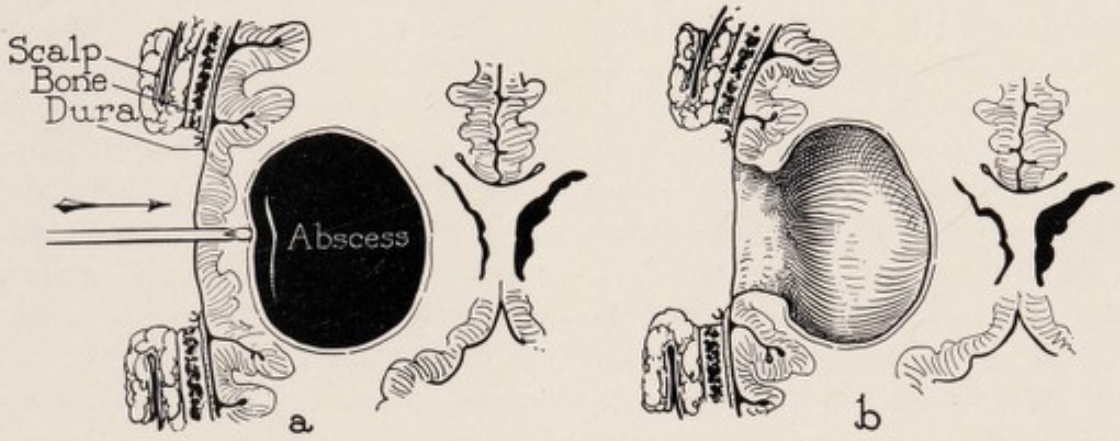

FIG. 2.—(a)—A cranial and a dural opening have been made directly over the abscess. The dural margins are fixed to the meninges and cortex by electrocoagulation and interrupted fine catgut sutures. The cannula inserted into the brain substance meets with resistance not unlike that of a thin rubber ball. (b)—The overlying cortex and a portion of the wall of the abscess have been removed. The cavity can be inspected thoroughly. Fixation of the dura to the meninges and cortex prevents spreading of infection into the meninges.

In a case of temporosphenoidal lobe abscess, a short, straight, slightly oblique incision about one and one-half inches is made through all the soft parts down to the outer table of the skull. An opening with a bone drill is made at a point about one inch posterior to and about one and one-half inches above the external auditory meatus. A small self-retaining retractor gives adequate exposure and controls bleeding. A small nick is made in the dura and a specially devised blunt cannula of small caliber is introduced and passed directly inward and slightly downward. When the end of the cannula comes in contact with the wall or capsule of the abscess (Fig. 2-a), resistance similar to that offered by a thin-walled rubber ball is encountered. It is preferred that the cannula should not enter the abscess cavity. It is not necessary, and spreading of infection is obviated while preparation for drainage of the abscess is being made. When the wall of the abscess cavity is located, slow tangential insertions of the cannula will help to ascertain the location and approximate size. By means of the cannula it can be determined whether the abscess is situated more anterior, superior, posterior or inferior to the

opening in the skull. When the position of the abscess is determined, the mastoid incision is extended upward over the ear at a distance of about half an inch from its attachment. The oblique straight incision is connected with it and the three scalp flaps thus defined are dissected up from the pericranium and held with self-retaining retractors. The anterior flap carries the ear downward and forward out of the way. This exposes an area of pericranium about 3 or 4 cm. in diameter depending upon the size of the abscess. The bony opening in the skull is enlarged in a circular manner to about the size of a silver dollar and in the direction necessary to place it directly *over* the abscess. The pericranium is removed from the outer table of the skull only sufficiently to permit making the proper sized opening in the bone, and is not stripped off from the outer table of the skull for any distance beyond the bony opening. In some cases where the abscess extends low into the temporosphenoidal lobe it may be necessary to remove the bone downward into the mastoid wound. The dura is incised in stellate manner to within about one-quarter of an inch of the bony margin of the defect and the dural flaps are excised. This leaves a circular opening in the dura slightly smaller than the bony opening into which the cortex bulges. The cortex is fixed to the dura by means of interrupted sutures of fine plain catgut as suggested by Adson, and the dural margin, meninges and cortex are fused by means of electrocoagulation. The three narrow strips of iodoform gauze which were formerly inserted beneath the dura, between it and the cortex, to prevent spread of infection into the subdural space, are no longer used in this manner but are placed in a tangential position about the bony opening to cover over the edges of the bone and dura. The subsequent oozing of blood into this gauze followed by clotting of the blood fixes the gauze to the bony and dural margins and forms a mechanical barrier against the spread of infection. The overlying brain substance is removed by means of the electrosurgical unit and suction to expose an area of the wall of the abscess about the size of a quarter or a two-franc piece, depending upon the size of the abscess. Should pericapsular necrotic and suppurative brain substance be present it can readily be removed by suction. This necrotic brain material if encountered is usually external to that portion of the capsule which is exposed, but it may extend laterally about the capsule. As the overlying brain substance is removed, the capsule comes into view and presents itself like the end of an egg. An aspirating needle is inserted into it and a small amount of the pus is removed in order to lessen the intracapsular tension and is preserved for laboratory examination. The capsule is then opened with the electrosurgical needle and the pus is removed by suction. The outer presenting portion of the capsule is next removed in a circular manner so that the complete interior of the abscess cavity can be inspected (Fig. 2-b). Should an opening into an extension of the abscess be found, a sufficient portion of the capsule is removed to convert both into one cavity. After the pus has been removed and the cavity cleaned the inner wall will appear rather smooth, but may have thin flakes of inspissated pus loosely attached to it. These can

be easily removed under direct inspection. By this time it will be observed that the depth of the cavity is not so great as when the cavity was first entered. The floor of the cavity will have progressed upward toward the operator or outward toward the opening in the skull. This lessening in depth varies from about one-quarter to one-half inch in the cases which have been observed. This elevation or outward progression of the floor of the abscess after the outer portion of the capsule has been removed is due to release of pressure from within the abscess, followed by increase in the size of the compressed ventricles.

The central portion of two layers of iodoform gauze, about six inches square, is introduced into the abscess cavity (Fig. 3-c), and strips of *soft* iodoform gauze are gently but rather snugly packed against the two layers of iodoform gauze so that the two layers of gauze come in intimate contact with the wall of the entire cavity (Fig. 3-d). The packing is continued until the

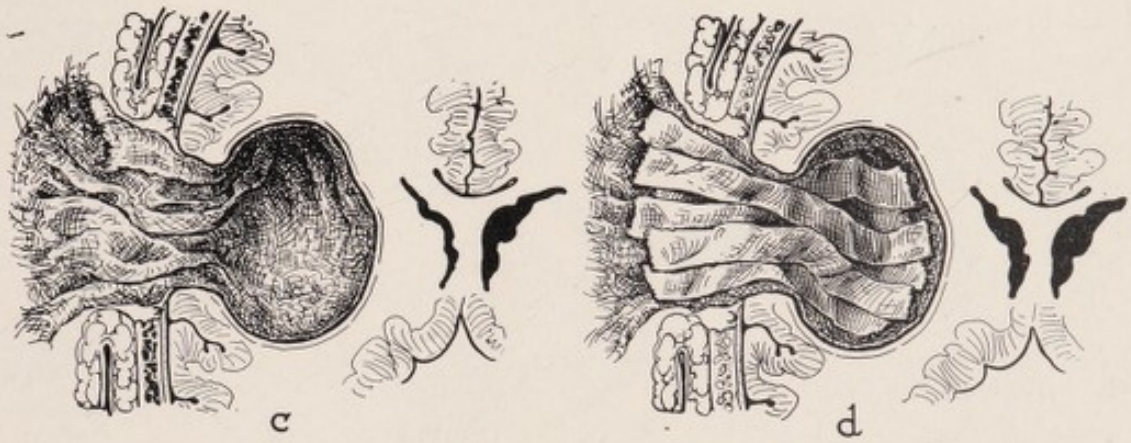

FIG. 3.—(c)—The central portion of a pack consisting of two layers of iodoform gauze have been inserted into the abscess cavity and the free edges have been brought out through the openings in the dura and skull. (d)—Narrow strips of soft iodoform gauze have been gently packed into the soft pack so as to bring the two layers of gauze into opposition with the inner walls of the cavity and the tract through the cortex.

tract is completely filled to the level of the skull, and the loose margins are folded over the packing. The self-retaining retractors are removed, bleeding points are controlled by electrocoagulation or suture ligature if necessary, and fluffed iodoform gauze is loosely stuffed beneath the flaps. The open end of a small rubber irrigating tube is carried within the overlying gauze, and a wet azochloramid gauze dressing is applied and held with a bandage which includes the lower jaw so as to prevent displacement of the dressing.

AFTER TREATMENT.—*Dressings.*—The first dressing is done after 48 hours. All the dressing down to the incision is removed and replaced. Meanwhile instillation of azochloramid solution into the superficial dressing in the wound is made every two hours. (Azochloramid solution is used now in place of Dakin solution for the reason that it is more prolonged in action, does not irritate the scalp so much as Dakin solution, and is readily obtainable and easily prepared.) On the third day the iodoform gauze packings in the external portion of the wound beneath the flaps are loosened and wet with the solution. This allows of slight progression outward of the iodoform

gauze in the brain abscess cavity proper. At daily dressings the narrow gauze strips are gradually removed from the operative wound and from within the iodoform packing lining the abscess cavity (Fig. 4-e). On the fifth day the iodoform gauze strips are removed from about the bony margin. By the tenth day the floor of the abscess cavity will have become elevated sufficiently to extrude and allow complete removal of the gauze within the cavity. The last two layers of iodoform gauze are slowly and carefully removed. While doing this it is well to use a rubber ear syringe with a soft tip and hydrogen peroxide. Where the wall is but weakly encapsulated the gauze will have become firmly adherent to the floor of the abscess, and must be very slowly and carefully removed, otherwise the surface of the brain will be torn. This is not the case when the abscess is well encapsulated.

Rapid herniation of the abscess cavity is no longer advised nor permitted. It is necessary only to allow the floor of the abscess to reach the level of the

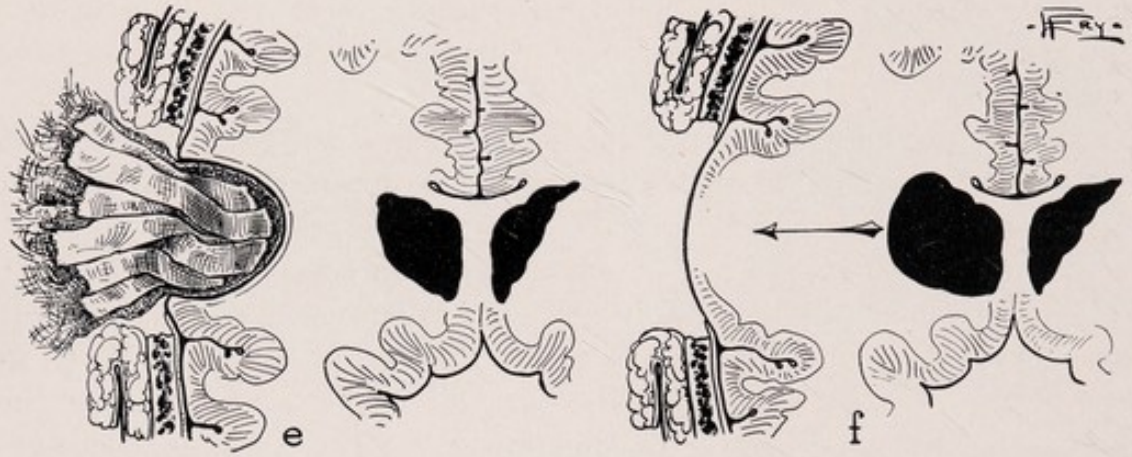

FIG. 4.—(e)—The gauze strips have been slowly shortened at successive dressings accompanying slow and gradual elevation of the floor of the cavity. This controlled herniation outward is due to accumulation of fluid in the ventricles with slow removal of the gauze. (f)—The floor of the cavity is maintained at the level of the skull by lumbar punctures, should they be necessary. The remnants of the abscess wall become a part of the scar tissue at the operative site. The margins of the bony defect become covered with granulation tissue and the scalp flaps are allowed to fall over and become adherent to the area. Development of an actual hernia cerebri is *not* allowed.

skull or near the level of the skull (Fig. 4-f). This slower outward progression of the floor of the abscess which reaches completion by the tenth day is controlled by lumbar punctures done as often as is necessary. It is also due in a considerable degree to the fact that the gauze is maintained in position in the cavity. Iodoform gauze for this purpose has proved to be of greater value than the rubber dam formerly used. Meanwhile, the scalp flaps have been allowed to fall back into position and become attached to the underlying tissues.

The iodoform gauze which was placed in the mastoid wound is removed on the sixth day and thereafter changed every other day. In the case where a mastoidectomy has been done simultaneously with evacuation of the abscess, the removal of the squamous portion of the temporal bone between the site of the operation for the abscess and the mastoid process is usually done, for the reason that this bone is frequently involved. The dura in this region is

kept intact. Since overherniation or development of a hernia cerebri at the site of operation is not allowed, the difficulty formerly offered by the overhanging hernia into the mastoid wound does not exist. The area now becomes rapidly covered with healthy granulations followed by epithelialization. In order to permit more rapid spread of epithelium across the surface, the scalp about the wound is kept well shaved and the granulating area is covered with strips of perforated adhesive placed across from one scalp flap to another. After the area has been covered with adhesive strips, irrigation of the wound is discontinued and a dressing of wet azochloramid gauze is applied.

In this type of abscess the patient should be out of bed after about 16 days, should be able to leave the hospital about the end of the third week, and the wound should be completely covered with epithelium within four or five weeks. After about six months to a year I have usually performed a scalp plastic in order to cover the area more securely with normal scalp. This affords better protection and prevents excoriation of the scar, especially in summer. Most of the scar following the plastic procedure is in the hairline, and that portion behind the ear over the mastoid region is rendered less conspicuous.

Usually the postoperative temperature reaches its highest point, about 101.5° or 102° F., on the first or second day postoperative, and after a few days recedes to normal.

Lumbar Punctures.—Lumbar punctures can safely be done on the third or fourth postoperative day, and thereafter as often as is necessary to prevent elevation of the floor of the abscess beyond the level of the skull. When the abscess is very large it may be necessary to resort to a lumbar puncture daily. In one instance where the abscess cavity contained more than seven ounces of pus and in which later ventricular distention was rapid and considerable, daily lumbar puncture was done with removal of from one and one-half to two ounces of fluid. Removal of too much fluid will produce a negative pressure in the ventricle with resultant headache, while removal of too small an amount will result in bulging of the floor of the cavity. It should be remembered that recession of the floor continues to some extent after removal of the fluid; therefore the needle should be withdrawn when the floor of the cavity is at the level of the skull. Headache will thus be obviated.

General Care.—The head of the patient is kept elevated, at first on one or two pillows. On the third day the patient is placed in a semisitting position. Fluids are readily taken after the patient has recovered from the anesthetic. It has not been necessary to give tubal feeding, and intravenous administration of glucose is not necessary. It is important that the bowels should move well daily. An enema is given every morning, and a mild saline laxative or cathartic at night should this be necessary. When the bowels have not moved well, it will be noticed that the brain surface tends to bulge, while the reverse is true if the bowels have been properly evacuated. Usually the patient complains of very little pain. For restlessness hypodermic administra-

tion of sodium luminal, or administration of chloral hydrate by rectal instillation, is advised.

Advantages of the Procedure.—(1) It allows direct approach to the abscess with some spillage or leakage of pus *on to* but not *into* brain substance, with avoidance of secondary suppurative encephalitis. With the wide open wound containing iodoform gauze kept wet either with Dakin or azochloramid solution, necrosis of the brain accompanied by suppuration does not occur. In fact, no actual pus is seen after complete evacuation of the abscess.

(2) Removal of the outer wall of the abscess allows complete inspection and cleansing of the abscess cavity so that a secondary pocket or an extension, should it exist, can be properly dealt with and drained.

(3) Cerebral and medullary compression are relieved by direct evacuation of the abscess, and recession of edema of the brain due to the open drainage avenue. Slow herniation, or progression of the floor of the abscess outward carrying the iodoform gauze with it, prevents compression during the time of rapid intraventricular accumulation of fluid.

(4) Should pericapsular brain necrosis coexist, it can easily be seen and the necrotic brain substance can be removed by suction.

(5) Meningitis does not occur (unless it already exists) by infection spreading to the meninges, for the reason that the meningeal spaces about the wound have been sealed off before the pus is evacuated.

(6) The disastrous results from ventricular perforation by a drainage tube, or dislodgment of the tube are avoided, because no tubes are used.

(7) When iodoform gauze is kept in contact with the inner surface of a non-encapsulated, or a weakly encapsulated abscess for a period of ten days, a definite protective fibrous layer develops on the surface or wall.

(8) Secondary pockets do not occur inasmuch as the remainder of the abscess is carried outward to, or about, the level of the skull, at which level it is maintained by lumbar puncture. The entire infected area is brought to the surface and is maintained at this level (Fig. 5). Multiple operations are obviated. The remaining portion of the capsule becomes a part of the scar tissue area at the operative site. Therefore, no scar tissue tract or closed sinus, with thick wall which might later act as a focus for recurrence, remains within the brain substance.

(9) Rupture of the ventricle from within outward, and overherniation are prevented by lumbar puncture. By inspection of the area under direct vision, one can determine the proper amount of fluid to be removed.

(10) The stuporous, semicomatose or comatose condition of the patient is relieved almost immediately and it does not recur. Therefore, early giving of fluids and food without having to resort to tubal feeding is carried out. This prevents choking and coughing which otherwise attend taking of food by a stuporous patient in the absence of tubal feeding.

(11) The procedure can be utilized in the majority of cerebral abscesses, and not only in small superficial abscesses as may be inferred from an illustration in my original paper.

These advantages are likewise obtained in the operation described by Horrax in those cases where it can be used. It can be used only in cases where there is a definite chronic abscess wall, and where the edges of the capsule can be brought out sufficiently to permit of suture to the galea.

CRITIQUE OF THE PROCEDURE.—(1) It cannot be utilized in cases of small, deep, and centrally placed abscesses. This is self-evident. One should be highly gratified if such an abscess could possibly be located, and still more so if it could be drained by any means. A small catheter introduced through the apparatus devised by Grant would be probably the method of choice.

(2) It should not be used in cases of cerebellar abscess except in those

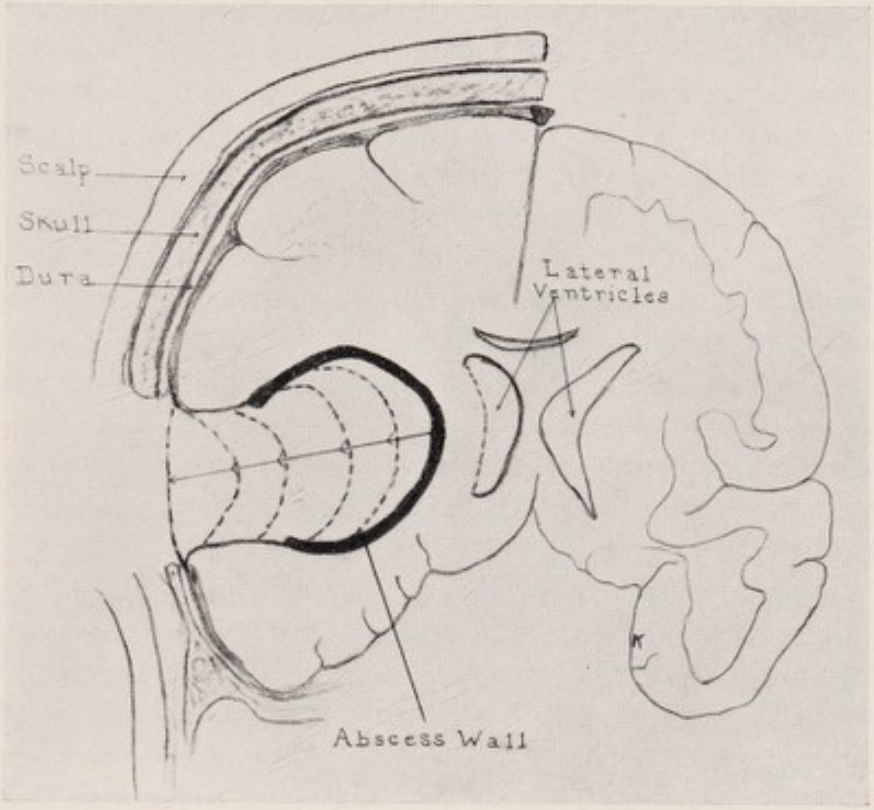

FIG. 5.—Illustration shows the gradual outward progress of the floor of the abscess cavity to the level of the skull, where it is maintained. One or more lumbar punctures may be necessary. The adjacent ventricle becomes markedly dilated, the opposite ventricle becomes moderately dilated. Shifting to the opposite side ceases and regression takes place.

in which the abscess is located completely within the cerebellar lobe, without being fixed to the petrus or dura.

(3) Objections have been made to the removal of a portion of the cortex overlying the abscess. There has been no instance of *production* of aphasia, mental deterioration, epileptiform attacks, or paralysis.

(4) Objection to the overherniation advocated in my original paper is proper. Not only was it unnecessary, but it required a longer period of time for eventual subsidence of the hernia and healing of the wound. Marked herniation is not allowed. When the floor of the cavity has reached the level of the skull, everything desired from herniation has been accomplished.

Frontal Lobe Abscess.—In the vast majority of cases abscesses of the frontal lobe follow infections of the nasal cavity and the accessory sinuses, with or without osteomyelitis of the frontal bone. They are usually ovoid in shape with the smaller end directed forward when the source of infection is the ethmoids or the frontal sinus. Most of them have but a small area of brain substance intervening between the anterior portion of the abscess wall and the inner table of the skull (posterior wall of the frontal sinus or ethmoids), and some may have perforated and drained into the nasal cavity. Those which develop secondary to osteomyelitis of the frontal bone are more likely to be spheroid. Eradication of the extracranial source of infection should be accomplished in all cases where the general condition of the patient will permit. Provided a definite diagnosis and localization of a frontal lobe abscess has been made, operation upon the frontal sinus and ethmoids, if necessary, should be done by the rhinologic surgeon and followed immediately by operation upon the abscess. If osteomyelitis of the frontal bone coexists, the complete operation for this condition according to a modified Furstenberg[16] procedure should be carried out. After removal of the involved frontal bone, an extradural pus pocket may be found. An opening through the dura leading into a subdural or subcortical abscess may be seen. If so, the abscess should be opened immediately. Otherwise, opening of an intact dura is better deferred unless one is certain that a subcortical abscess is present.

The incision begins in the outer extremity of the eyebrow, extends inward through the eyebrow to its inner extremity obliquely upward and inward to the midline of the forehead at the root of the nose, from which point it is carried vertically in the midline to within the hairline and thence downward for about two or two and one-half inches toward the temporal region. The flap consisting of all soft parts, except the pericranium, is turned down. The pericranium is included in the flap in cases of osteomyelitis of the frontal bone. This incision allows one to clean out the frontal sinus with preservation of the supra-orbital ridge, and to evacuate the frontal lobe abscess. Should it be necessary to exenterate the ethmoids, a short curved incision extending from the inner inferior angle of the incision is carried downward over the ethmoid region. The free end of the flap is turned underneath, thus folding the flap on itself, and is sutured loosely with the denuded surfaces approximated. This keeps the flap out of the way, controls bleeding from it, and prevents it from shriveling, as otherwise it would do if left free. After the floor of the abscess has herniated to the surface of the skull, it is maintained at this level by lumbar punctures, should they be necessary. When the surface has become firm and well granulated or covered with epithelium, the flap is unrolled and replaced in position. After healing, the only portion of the scar which can be seen is that in the midline. This is scarcely noticeable and may be altogether lost in the vertical wrinkles of the forehead. The other portions of the scar are within the eyebrow and the hairline and are not seen.

Should osteomyelitis of the frontal bone be present, the infected bone is removed according to a modified Furstenberg method through the same incision carried farther back of the hairline. Operation upon the frontal sinus and the ethmoids is done should it be necessary.

Most frontal lobe abscesses are fairly large, ovoid in shape, with the smaller pole directed forward and the larger backward. The wall of the abscess is thickest and toughest about its anterior pole where it approaches the cortex and dura. It is thinnest at the posterior pole which represents that portion of the abscess in its farther progress backward into the white substance of the brain. Should the abscess lie in the medial inferior portion of the frontal lobe, internal to the anterior horn of the lateral ventricle, it will collapse almost immediately after evacuation to such an extent that it is difficult to insert anything into the cavity without injuring its wall. In such instances, a fine meshed silver wire basket covered with a perforated rubber glove finger inserted into the cavity will serve to lead or guide the floor of the cavity to the surface and prevent collapse and subsequent pocketing. Herniation in this type of abscess will be marked if not controlled by lumbar puncture done after 48 hours. If the abscess is located in the outer upper portion of the frontal lobe external to and above the anterior horn of the lateral ventricle, it will not collapse readily. It is treated in the manner similar to that described for temporosphenoidal lobe abscess.

Although diagnosis of brain abscess is not discussed in this paper, the paralysis or paresis produced by frontal lobe abscess will be briefly considered. A large abscess situated in the outer upper portion of the lobe external to the anterior horn of the lateral sinus produces in its progress backward (if not operated upon) contralateral *paresis* of the upper extremity, then the lower extremity, and lastly the face. Such an abscess *per se* seldom produces paralysis for the reason that it is usually evacuated before this can occur, or it spontaneously ruptures into the ventricle. A sudden flaccid contralateral hemiplegia in which the patient's mental condition is not changed may be due to perforation of the posterior wall of the frontal sinus through the dura with extension of the infection upward and backward over the cortex along a narrow tract with formation of a well walled off subdural collection or pocket of pus over the motor area. In such an instance the spinal fluid cell count may be only six or eight. This paralysis clears up in about 48 hours after drainage of the walled off pocket of pus. In a case of suspected abscess, a sudden adverse change in the patient's mental condition either to stupor or coma, accompanied by high elevation of temperature and hemiplegia which develops rather rapidly and completely, is most likely due to rupture into the meninges with rapid spreading of pus over the cortex (massive suppurative leptomeningitis). A small superficial abscess situated in the anterior pole of the frontal lobe will more likely rupture and produce such a picture than a larger abscess which has progressed backward into the white substance of the brain.

Cerebellar Abscess.—A ventricular puncture should be made before an operation is performed for cerebellar abscess in order to lessen the intraventricular pressure, decrease the likelihood of jamming the conus into the foramen after evacuation of the abscess, and allow one to control the intraventricular pressure during convalescence. This puncture is advisedly made over the anterior horn of the right side for the reason that it gives good access for subsequent tappings of the ventricle and places the site of puncture away from the likelihood of infection.

In instances where a mastoid wound is not present, the approach to the abscess is made behind the lateral sinus. This allows clean exploration in case of negative findings. It also gives adequate exposure of the abscess if found. In the event that the lateral sinus has been opened for an infected thrombosis, or the abscess has perforated through the mastoid antrum or the lateral sinus, approach through the infected area would then be advisable. The procedure which I have described for cerebral abscess is advocated in the cases where the abscess is located centrally within the cerebellar lobe and is not fixed anteriorly to the petrus or dura. Such abscesses are more or less globular in shape and are in the minority.

Most cerebellar abscesses are located on the anterior inferior surface of the cerebellum and project into the lobe. They are usually quite ovoid in shape and resemble an elongated bird's egg. The smaller thickened pole of the capsule is attached to the dura or the petrus and is so fixed that no herniation can occur. In this type abscess the posterior pole of the wall or capsule of the abscess is exposed after the dura has been fixed to the cerebellum by sutures and electrocoagulation and removal of the overlying cortex by suction. A portion of the capsule about the size of a dime is removed with the electrosurgical needle, the cavity is washed out and inspected and two small rubber drainage tubes (Dakin tube size with a lateral perforation near the distal end) are inserted into the cavity to the full extent. The ends of the two tubes will completely fill the pointed distal extremity of the abscess cavity, while the remaining portion of the capsule will collapse about the tubes. No secondary pocket will develop. The opposite is the case when drainage tubes are placed in a frontal or temporosphenoidal lobe abscess cavity for the reason that the smaller pole or portion of the cavity is directed toward the operator and the larger pole of the abscess is toward the ventricle. The cavity may not collapse equally about the drainage tube, and a secondary pocket is likely to develop.

The incision in the scalp is closed at either extremity. The two tubes are brought out through the middle portion of the incision and about these the wound is loosely packed with iodoform gauze within the bony opening. The two tubes are fixed to the scalp to prevent displacement. In this type abscess there is no danger of perforation by the tubes. In subsequent dressings the tubes are irrigated with azochloramid solution, are allowed to remain in position for about three weeks, and then are gradually shortened until they are completely removed.

Traumatic Abscess.—In cases of traumatic abscess, especially those secondary to compound, depressed fracture of the skull, the meninges have already become adherent and fused so that entry to the abscess cavity can be done without transgression of the meningeal spaces. Approach should be made through the scar tissue overlying the abscess where these spaces are obliterated without entering the free subdural or subarachnoid space. By so doing spreading of infection to these spaces and retraction of the cortex after evacuation of the abscess are not likely to occur. Should a foreign body be present within the cavity it is removed. Other foreign bodies lying without the abscess cavity in the brain had better be left unmolested at this time for fear of producing suppurative encephalitis. Should the abscess extend from the vertex downward to a depth below the level of the lateral ventricle, it will rapidly collapse after evacuation, so much so that it will be difficult to introduce any type of drain. Inasmuch as the cortex has already become firmly fixed to the dura, however, lumbar puncture may safely be done at the time of operation. As the cerebrospinal fluid is gradually removed through the lumbar puncture needle, one will observe that the abscess cavity enlarges again so that it can be thoroughly inspected. After this is done, iodoform gauze or plain gauze dipped in azochloramid oil is packed loosely into the cavity in the manner described. Intraventricular pressure is controlled by lumbar punctures, and the floor of the abscess cavity is allowed to progress slowly outward until it appears as a small dimple in the wound. This area granulates over and heals. In these cases the opening in the abscess may not be made as large as in the cerebral abscesses due to infections from the mastoid region or the nasal cavity and its accessory sinuses, for the reason that one desires to limit the size of the opening to the definitely sealed off region of the meninges. Although the duration of convalescence may be more prolonged, these cases can be gotten out of bed sooner than those with the usual type of abscess.

RESULTS

The rather numerous cases of fistulae and sinuses in the brain and traumatic abscesses developing about foreign bodies which were observed in military service in both Germany and the United States will be excluded.

Although a case was operated upon unintentionally in the manner described, in 1920, the procedure was not actually advocated until 1923. Nevertheless, all cases operated upon or seen by the author since 1920, with the exception of several cases of metastatic abscess, will be reported.

Thirty-two cases have been seen. Death resulted in the following groups of cases:

Three of the early cases in which a drainage tube was used; in one of which the tube perforated into the ventricle; in one the tube was dislodged and was replaced by an assistant into brain substance instead of into the tract; and in the third a secondary pocket ruptured into the ventricle.

One case in which a Mosher drain was used; cerebellar.

One case of acute abscess which was aspirated. The patient was moribund when seen; no drainage used.

Four cases of multiple abscess in which the second abscess was not located after operation upon one abscess, or in which a subcortical abscess was associated with a drained subdural pocket of pus.

One case of acute abscess associated with sinus thrombosis and blood stream infection.

Two cases operated upon for extensive suppurative leptomeningitis in which the presence or location of abscess was not determined.

One case of extensive suppurative leptomeningitis in which the presence and location of abscess was known before operation, but permission for operation at the time was not given. Moribund when explored.

One case of coexisting insufflation pneumonia following taking of food in a semicomatose condition. Moribund when explored.

One case in which the patient tore off the dressing and lacerated the hernia cerebri with her finger nails. Followed by infection of the brain.

One case, a child, of postoperative pneumonia.

Two cases without operation: one a few moments after being seen; cerebellar: the other 15 minutes before being seen due to spontaneous rupture of frontal lobe abscess into the ventricle.

Five of the fatal cases probably would have survived had proper management been carried out. The patient who removed the dressing was not under the operator's supervision, having been operated upon in a distant hospital. The child who developed pneumonia did so as a result of being dakinized and left by an open window. One child should have had a good chance of recovery had he been operated upon when the diagnosis was made, but permission was refused by both parents and physicians. The abscesses in two cases, associated with a subdural pocket of pus and a subcortical abscess respectively, which had previously been operated upon, probably could have been well localized and drained had ventriculograms been made.

Only three of the 18 cases enumerated above, in which a single abscess was present, were operated upon by the method advocated. All three were readily located, were well encapsulated, and were acceptably operated upon. One of these had insufflation pneumonia and was moribund when seen. Another is the patient who tore off her dressing, and the third is the child who died of pneumonia.

Three of the 17 cases in which the abscess was single, and who were operated upon by the method advocated, died, making a mortality rate of 17.5 per cent for this procedure. There was only one death in the last ten cases of this type consecutively operated upon.

Of the 14 cases which survived (Table I), the largest abscess contained more than seven ounces, and the smallest single abscess was about the size of a golf ball. The average size was about that of a lime or small tangerine. Five of the cases were either comatose or semicomatose at the time of opera-

tion. Four cases developed cerebrospinal leakage through the hernia cerebri, but with dakinization meningitis did not develop. None of these cases developed epilepsy following operation. One case, that of traumatic abscess in the parietal region, had epileptic attacks both before and following operation. No case had a permanent paresis or a hemi- or monoplegia following operation. Four cases operated upon by a colleague according to the principles set forth in this paper recovered; these cases are not included in this series.

TABLE I

RECOVERED CASES OF BRAIN ABSCESS *

Case	Age	Sex	Source of Infection	Location	Pericapsular Brain Necrosis	Infection	Approximate Size
M. L.	28	M.	Mastoiditis with mastoidectomy	Left temporal lobe	None	Streptococcus	Tangerine
T. W.	46	M.	Infected C. C. F. of right frontal sinus	Right frontal lobe	None	*Streptococcus hemolyticus*	Duck egg
C. D.	26	M.	Mastoiditis with mastoidectomy	Left temporal lobe	Fairly well marked	*Staphylococcus aureus*	Tangerine
A. S.	22	M.	Infected C. C. F. of skull (gunshot)	Right parietal region	None	*Staphylococcus aureus*	Golf ball
G. F.	20	M.	Frontal sinusitis left	Right frontal lobe	None	*Staphylococcus aureus*	Large hen's egg
H. W.	19	F.	Mastoiditis with mastoidectomy and previous operation for brain abscess	Left temporal lobe	Mild	Not recorded (mixed infection from drainage tract)	Multiple (2) each size of malaga grape
C. B.	15	F.	Frontal sinusitis, bilateral; radical operation. Osteomyelitis of skull; operation	Right frontal lobe	Mild	Nonhemolytic streptococcus	Long-drawn-out hen's egg
P. M.	28	M.	Mastoiditis	Left temporal lobe	None	*Streptococcus mucosus capsulatus and B. coli communis*	Small orange
C. A.	6	F.	Mastoiditis	Left temporo-frontoparietal lobes	None	*Streptococcus hemolyticus*	Large orange, more than 7 ounces
L. N.	45	F.	Mastoiditis with mastoidectomy	Left temporal lobe	Marked	*Streptococcus hemolyticus*	Collapsed; spontaneous rupture into mastoid wound
L. B.	55	M.	Frontal sinusitis, ethmoiditis; radical frontal operation; old	Left frontal lobe	Marked	*Streptococcus hemolyticus*	Multiple (2) communicating. Small fig and butternut
F. R.	56	M.	Stab wound through old cranial defect	Left fronto-parietal lobes	None	Mixed. Discharging sinus	Elongated hen's egg
J. M.*	12	M.	Mastoiditis with mastoidectomy	Left cerebellar lobe	None	*Staphylococcus aureus*	Lime
L. A.	32	M.	Frontal sinusitis	Right frontal lobe	None	Specimen lost	Lime

* This patient was operated upon for his abscess by Dr. Daniel S. Cunning, who consulted the author regarding the patient's condition. The plastic procedure was performed by the author.

* 3 additional consecutive recoveries; 2 frontal, 1 tempo...

It is realized that this series of recovered cases is not large, but the fact that 14 out of 17 cases operated upon by this open method lived tends to make one who is accustomed to its use more confident in its efficacy. In fact, one can readily subscribe to the statement by Macewen that "One might almost conclude that in uncomplicated abscess of the brain, operated upon at a fairly early period, recovery ought to be the rule."

Until the probability or likelihood of brain abscess is suspected earlier than has been formerly the case so that diagnosis and localization can be made before a disastrous complication ensues, the mortality rate will continue to be fairly high, regardless of the type of operation used.

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DISCUSSION.—DR. CLAUDE C. COLEMAN (Richmond, Va.).—There has been some unanimity of opinion regarding the treatment of brain abscess. It is generally believed that abscess of the brain does not become operative until encapsulation takes place. In the first stage of abscess formation the condition is a diffuse, septic encephalitis which cannot be drained, and, therefore, attempts at drainage have proved to be harmful, as no effective surgical measures have been devised for the eradication of the infection. One must wait, therefore, for encapsulation before attempting to eradicate the abscess.

While brain abscess is fatal in its tendencies if not operated upon, and while a large majority of patients will die unless the abscess is eradicated, the fact remains that when a patient does die following operation, he generally dies because of the surgeon's well intended efforts to remove the abscess. In other words, fatalities following brain abscess operations are usually the result of spreading the infection into the unprotected brain tissues outside of the capsule.

For a number of years I have used one of the methods to which Doctor King referred. That is, drainage with the eye end of a soft rubber catheter. If there is much difficulty in placing the catheter into the abscess cavity, the fumbling with the catheter is likely to lead to an extravasation of pus outside the capsule and a diffuse encephalitis, with secondary abscess formation. We have been more concerned with and troubled by the small, deeply seated, densely encapsulated brain abscess than any other type of encapsulated abscess. In some cases, particularly deeply seated abscesses, in which the capsule is dense, we have first verified the presence and location of the abscess by means of a ventricular needle over which a cannula is fitted. If the capsule of a deeply seated abscess offers much resistance to the penetration of the ventricular needle, we have slipped the silver cannula into the abscess cavity as soon as the pus began to escape from the needle, and left the cannula for permanent drainage instead of using a catheter. In two of the cases treated by drainage with a soft rubber catheter, the abscess cavity, as determined by the depth of penetration of the catheter, appeared to extend across the median line. This was due to the swelling of the brain on the side of the abscess, with displacement of the falx to the opposite side.

I should like to emphasize what I believe to be a logical attitude toward the treatment of brain abscess; that there is no standardized treatment which will be applicable to all cases. In superficial abscesses with a thin layer of brain tissue between the dura and abscess cavity, I should expect excellent results from Doctor King's "unroofing" operation. In deeply seated densely encapsulated abscesses, one must rely upon simple tapping, as Dandy has advocated, or upon some method of drainage that will empty the abscess with the least disturbance of the surrounding brain. The method of drainage with the eye end of a small, soft rubber catheter or with a cannula fitted over a ventricular needle, for the deeply seated abscess (and many of them are of

this kind), has given about as satisfactory results as any method we have seen reported.

Dr. Joseph E. J. King (closing).—As I have stated before, 14 cases out of 17 which were operated upon according to the method described survived, and we have seen an autopsy performed upon only one of these 14. An old man, who was the second in the series of those who survived, and who was an habitual alcoholic, was admitted to Bellevue Hospital three or four years later in an alcoholic stupor, and died. The autopsy revealed no pathologic condition in his brain other than a dilated anterior horn of the right side beneath the site of the operation for a frontal lobe abscess.

None of the cases had epilepsy other than the fourth case who had a traumatic abscess in the right parietal region and who had epileptic attacks before operation.

I agree with Doctor Coleman that if operation can be delayed until a capsule is formed, it is safer than operating in the stage of suppurative encephalitis. In one case of metastatic abscess, which is not included in this series, we were advised by the attending neurologist to operate upon him early, and the patient was fortunate enough to survive. In a previous paper by Doctor Coleman he stated that four out of five deaths were due to leakage about the drainage tube with formation of suppurative encephalitis, which condition resulted in death.

I stated that one would be fortunate to locate a very deep seated abscess and to drain it by any means, but preferably by the small catheter as described by Coleman, or a searcher or cannula, and one would be most fortunate to be able to drain it by any method. I have never advocated the procedure described in this paper for a very deep seated small abscess. The procedure described is intended for abscesses which extend to within 3 or 4 cm. of the surface, exclusive of the basilar surface. Abscesses of this type offer the best opportunity for a successful outcome.