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THE EVOLVEMENT OF THE PRESENT DAY TREATMENT OF HYDROCEPHALUS

Howard E. Hansen

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INTRODUCTION

"'That child has water on the brain says the layman; that child is hydrocephalic, gravely says the physician, repeating literally by a Greek word what the layman says in his own language. But what is this water? Where does it come from? That is what the doctor should try to discover.'" These queries of Francois Magendie in 1842 (Davis 1942) inspired the discovery of the foramen of Magendie which proved to be the opening wedge in unfolding the exact nature of the "third circulation" which had been cloaked in mystery since Hippocrates' time. The uncertainty of the nature of this "third circulation" prompted the numerous, empirical theories of treatment advanced from time to time through the ages. With the rationale and the discussion of these theories I will attempt to evolve the basis of our present day treatment for this age-old affliction.

TREATMENTS OF THE PRE-LISTERIAN ERA

Hippocrates, 360 B.C., (Davidoff 1929, Ballance, 1922) is probably the first of the ancients to write down his observations on what we can term interval hydrocephalus. In some cases he proposed to "'slacken the tightness of the head'" by trephining the skull and effecting drainage and decompression. (Ballance 1922) Galen in about 230 A.D. described external hydrocephalus in his prolific writings. Vesalius and Mercuialis in the sixteenth century recognized the condition and recommended such empirical treatment as purgation, cold, and heat. (Davidoff, 1929) Boerhaave proposed the word hydrocephalus.

Whytt, in 1768, commenting on the treatment in later stages when "'so much water is accumulated as, by its pressure on the sides of the ventricles, to disturb the action of the brain, we have little to hope from medicine,'" a dogma which remains unchallenged today. Purges, diuretics, friction, venesection, cupping, leeching, and blistering, were used in "dropsies of the head" on the strength of their efficacy in the treatment of dropsies in other cavities of the body. (Cooke 1824) As late as 1843 Professor Bennett in London delivered a prize essay on hydrocephalus saying that "'in the strictly acute inflammatory forms there can be little doubt that blood letting is our sheet anchor.'" (Davidoff 1929)

The medicines of internal use in vogue in Whytt's time and until the middle 1800's included digitalis, narcotics, and "large amounts" of mercury to stimulate salivation. (Cooke 1824)

To quote an honest practitioner of this era best summarizes the then accepted treatment -- "'I purged, I puked, I bled'em, and if they died, I let 'em!'" (Davidoff, 1929) Brainard in 1825 offered two most unjustifiable procedures which, fortunately, received exiguous acceptance. The first of these suggested the compression of the enlarging head by tight bandaging and the second advocated the injection of strong iodine into the ventricles to destroy the secreting epithelium. (Davidoff, 1929)

TREATMENT SUBSEQUENT TO ADVENT OF ANTISEPSIS

Puncture of the lateral ventricles was used long before Lister's revolutionizing achievement in 1867, but this advent of antisepsis marked logical acceptance of surgical procedures. Where ventricular puncture formerly always had fatal results, this procedure now is a moderately safe method for the temporary relief of intracranial pressure. Quinke, 1891, reported cures after effecting, one, two, or three lumbar subarachnoid drainages, but these cures probably were dependent on the very slight disturbance of equilibrium so that simple draining of the excess spinal fluid restored the equilibrium. (Davidoff, 1929)

Continuous external ventricular drainage was suggested by Wernicke in 1881, Zenner in 1886, and Keen in 1888, but these cases usually ended in failures. Continuous ventricular drainage into the subarachnoid and subcutaneous spaces, while it did reduce the chance of infection and permitted slower drainage, generally met with failure regardless of whether the drain used was the glass wool nail proposed by Miculicz, 1893; catgut; gold tubes; vein transplants; or silver tubes in a vein transplant, proposed by Krause in 1908.

Similar attempts at drainage directly into the blood stream were attempted by Payr, 1910, using a vein transplant, i.e., connecting the ventricles to the longitudinal sinus, jugular, or (Fig. 1) common facial veins. In six cases of failure Payr concluded that the vein transplants had collapsed and so in 1911 he tried using

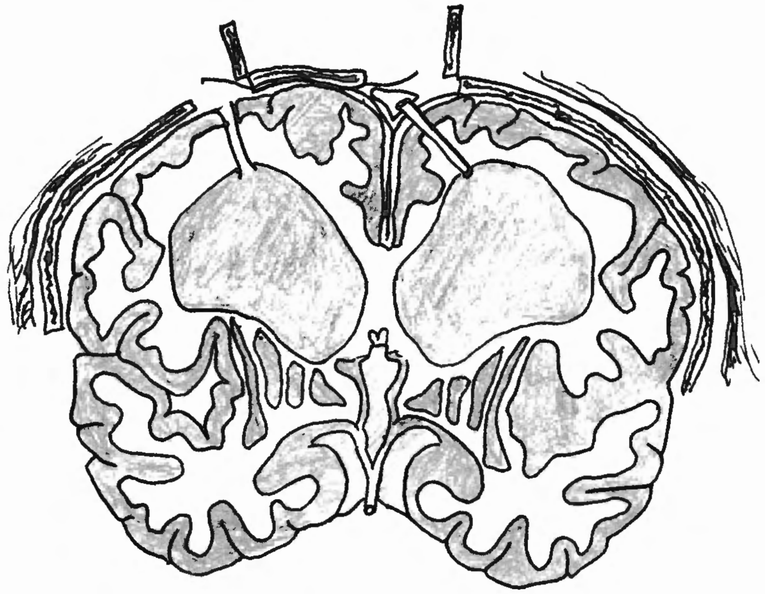

Figure 1. Drainage of the ventricles into the longitudinal sinus (right) or the subarachnoid space (left) by means of a transplanted vein. (After Payr 1908 from Davidoff 1929)

hardened calves arteries within a venous sheath. He claimed that four out of fifteen cases showed some improvement. Enderlen, 1911, transplanted a section from the fresh anterior tibial artery between the ventricles and the superficial temporal vein and, though the channel worked for several months, it finally became blocked and symptoms of increasing intracranial pressure returned. McClure in 1909 anastomosed the subarachnoid space with the jugular vein by means of a vein transplant and although the procedure was successful in five attempts in dogs, the only human case he attempted died post-operatively from hyperthermia. Cushing, 1926, placed a silver tube connecting the ventricle and the longitudinal sinus, but the results were considered inclusive. Haynes in 1913 reasoned that the cerebrospinal fluid in a communicating hydrocephalus could be shunted directly from the cisterna magna into the longitudinal sinus but his results also did not lend favorable support to this theory of treatment.

For communicating types of hydrocephalus, continuous drainage of the spinal subarachnoid space was attempted by Quinkè, 1891, and Framowicz, 1912, by slitting the dura and allowing the excess cerebrospinal fluid to escape, by seepage, into the subcutaneous tissues. Ferguson in 1898, removed the spinous process of the fifth lumbar vertebrae and drilled a hole anteriorly through the body of the vertebrae attempting to establish drainage into the peritoneum. One of his two cases died post-operatively and the other lived for several months before succumbing to bronchopneumonia. Cushing in 1905 operated on six selected cases attempting to anastomose the spinal subarachnoid space with the peritoneal space. He reported that three cases looked encouraging but he abandoned this technique in 1908 presumably in pursuit of more efficacious therapy. Fowler tried the Cushing technique in 1909 reporting inconclusive but encouraging results in a fourteen month old infant, six months post-operatively. A German surgeon, B. Heile, quite persistently tried numerous related techniques in attempting to establish drainage from the spinal canal. His techniques included, attaching the serous surface of the small intestine to an incised defect in the dura (1910), placing silk threads from the dural defect into peritoneum (Fig. 2), using a vein transplant

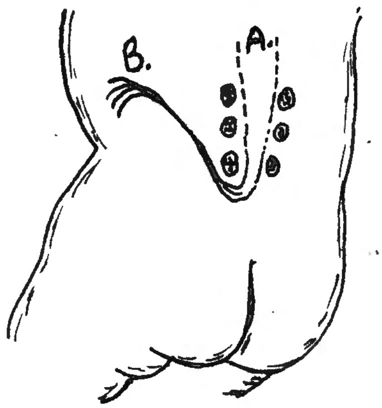

Figure 2. Silk threads (A to B) used to conduct the cerebrospinal fluid stream from the end of the meningocele sac into the peritoneum (after Heile from Davidoff 1929)

or rubber tube, and advancing a very radical theory in 1925 proposing to do a unilateral nephrectomy and subsequently to connect the renal pelvis to the spinal subarachnoid space, draining the excess spinal fluid via the ureter to the bladder for excretion. Drachter, however, claimed that he had already tried this in 1917 on an infant six months old who died from an undeterminable cause in forty-eight hours. Heile carried out this dura-ureter anastomosis on four children and reported three were doing well in 1927. Another surgical procedure advanced by Davidoff in 1929 proposed to transplant a strip of skin into the rectus muscle. After four weeks the transplant theoretically should have formed an autogenous epithelialized tube which could be subsequently used as an anastamosis between the cerebral or spinal subarachnoid space and one of the body cavities. (Davidoff 1929) The article proposing this procedure stated that it worked on dogs but as yet hadn't been attempted in humans. (1929) In collecting the material for this thesis, the results of an application of Davidoff's theory has not been found in any of the references.

It should be mentioned before going on with this review that the probable reason for failure in all the anastomosing procedures can be explained by several well accepted facts; (1) veins are thin walled structures and therefore ineffective as anastomotic channels because of their proness to collapse, (2) the human body reacts to foreign bodies by expulsion or chemical reaction, (3) incised openings or slits in the dura have a tendency to heal over shortly after their formation, (4) subcutaneous tissue rapidly loses its absorptive function due to chemical reactions on the membrane of the cells, and (5) the dura-ureter anastomosis is attendant with danger from ascending urinary infections.

If it were possible to remove all the choroid plexus within the brain, hydrocephalus would be curable. (Dandy-Lewis, 1946) Extirpation of the choroid plexus in the treatment of non-obstructive (communicative) hydrocephalus was first attempted by Dandy in 1918. The technique was that of an open operation in which the cerebrospinal fluid was first aspirated to permit a dry field for the direct visual extirpation of the choroid plexuses. Post-operatively, the ventricles collapsed producing a severe ventricular shock which terminated in death. (Dandy 1918) Dandy in 1922 is also credited with doing the first closed operation for the extirpation of the choroid plexuses using an ordinary operating endoscope. (Scarff 1936) Davis however refutes this claim ascribing the first operation on the choroid plexuses by means of an endoscope to Lespinasse in 1910. (Davis 1942) Mixter, 1923, also used an endoscope. Not until 1934 did Putman describe the ventriculoscope, a new instrument he had perfected for ventricular surgery. He reported its use in nine operations on five patients with encouraging results, the technique being the unilateral extirpation of one ventricle at the first operation, followed by a second operation if symptoms of increased intraventricular pressure reappear. Scarff reported favorable results using Putman's ventriculoscope in fulguration of the choroid plexuses.

A miscellany of other theories of treatment have been profferred in addition to the foregoing. The most significant of these are the use of thyroid extract which is known to depress the production of cerebrospinal fluid by the choroid plexuses. Another chemical of more current acceptance is theobromine sodiosalicylate. Certain cases of edema result from decreased surface tension in the blood, allowing fluid loss. Thus, the use of theobromine sodiosalicylate, which increases the surface tension of the blood, has been reported to have favorable results in some cases. Somma in 1886 treated five patients by exposing their heads to sunlight with reported improvement. Sgalitzer and Spiegel, 1926, attempted to depress the secretion of the choroid plexuses by exposure of the head to roentgen radiation. Another interesting theory was the ligation of the carotid arteries first propounded by Chisholm in 1796 while still a student at the University of Pennsylvania. Stiles 1898, Frazer and Dott 1922, and Fuller 1927, reported favorable results with this technique. Other theories still in acceptance will be discussed in the next section.

PHYSIOLOGICAL BASIS OF A MORE SCIENTIFIC APPROACH TO THE PROBLEM OF HYDROCEPHALUS

To understand the mechanism of the production of hydrocephalus one must recall the normal physiology of the cerebrospinal fluid. We are indebted to Dandy, Blackfan, Weed, Cushing, and their associates for our extensive knowledge of the third vascular system. (Bucy - Brenneman 1946) The circulatory system for cerebrospinal fluid is divided into two parts: (1)the ventricular system and (2) the subarachnoid spaces. From precise experiments the above mentioned investigators have shown that cerebrospinal fluid forms in the ventricular system but must pass to the subarachnoid space for absorption.

The ventricular system is composed of four ventricles (Fig. 3), two (paired) lateral, the third, and the fourth ventricles, all which are normally in free communication with each other through well defined openings. Each lateral ventricle contained within a cerebral hemisphere communicates with the mesially placed third ventricle (between the basal ganglia) by a single opening, the <u>interventricular foramen</u> or <u>foramen of Monro</u>. This foramen, though located in the anterior horn of the lateral ventricle, is the only means of exit for the entire lateral ventricle, a fact which has been occasionally disputed but has been proven to be true.

The third ventricle has but one other opening, the <u>aqueduct of Sylvius</u>, a narrow channel about two centimeters in length and approximately the diameter of the lead in a pencil. This channel passes through the mid brain to enter the anterior part of the fourth ventricle. From the pathological standpoint, the aqueduct of Sylvius

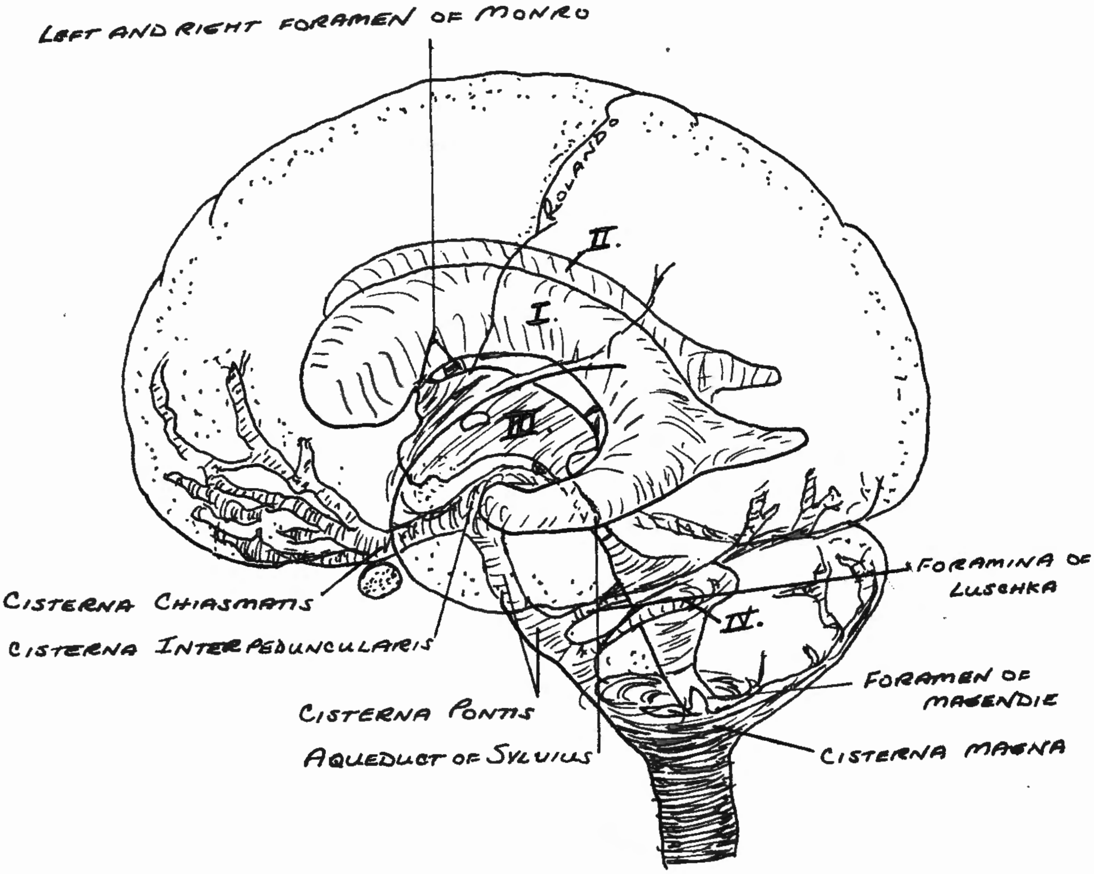

Figure 3. System of spaces through which cerebrospinal fluid circulates. See the text for a description of the circulation. (Dandy - Lewis 1946)

has been termed the weakest link in the entire cerebrospinal circulatory system due to its small size and its extreme importance as the only exit for cerebrospinal fluid formed in ventricles I, II, and III.

The fourth ventricle situated entirely in the posterior cranial fossa, is bounded by the cerebellum above (roof) and the medulla and pons below (floor). Three openings connect the fourth ventricle with the subarachnoid space. The mesially located foramen of Magendie opens into the cisterna magna and the paired lateral foramina of Luschka into the cisterna lateralis. These are the only communications between the ventricular system and subarchnoid space.

Proof that openings from the fourth ventricle do exist is evident from two very simple experiments; (1) if 1.0 cc of phenosulfonphthalein is injected into a cerebral ventricle, the dye will appear in the spinal canal in two minutes, later to be excreted in the urine; (2) if air is injected into the spinal canal it will appear almost instantly in the ventricular system.

The cerebrospinal fluid is known to be formed only by the choroid plexuses of the lateral, third, and fourth ventricles. The ependymal lining of the ventricles is no longer considered contributory to its formation.

Absorption of the cerebrospinal fluid does not take place in the ventricular system so it must be absorbed in the subarachnoid space. Beneath the brain stem is a broad conduit (the cisterna) which carries cerebrospinal fluid from the cisterna magna, where it leaves the ventricular system, to the cisternae interpeduncularis and chiasmatis. Branches of the subarachnoid space radiate over both cerebral hemispheres, following the cerebral sulci, thus filling all the external cerebral depressions. Similar but smaller branches pass over the cerebellum from the cisternae magna and lateralis. Cerebrospinal fluid also passes down the spinal subarachnoid space from the cisternae magna and lateralis. The theories of absorption (1) directly through the pacchionion granulations into the longitudinal sinus or (2) via the microscopic stomatas suggested by Weed to exist between the subarachnoid space and longitudinal sinus, have been proven false by experimental methods. Cerebrospinal fluid passes directly into the capillaries which extend into every part of the subarachnoid space.

The chief function of the cerebrospinal fluid is that of space compensation in the cranial vault. Its mechanical function as a buffer against injury is a controversial question. (Dandy - Lewis 1946)

Types - It is important at the outset to distinguish between the two descriptive types of hydrocephalus; (1) increased volume of cerebrospinal fluid with normal pressure -- compensatory hydrocephalus and (2) increased volume of cerebrospinal fluid with increased pressure -- hypertensive hydrocephalus. (Brain 1940) Compensatory hydrocephalus is of no clinical importance with regard to treatment because the excess of fluid is compensatory to atrophy of the brain such as may be observed in cases of congenital cerebral hypoplasia and of acquired cerebral atrophy due to diffuse sclerosis, general paralysis, and senile or presenile degenerative changes.

Hypertensive hydrocephalus is due to a disturbance of the formation, circulation, and absorption of the cerebrospinal fluid and one or more of these factors may operate in a given case. Hypertensive hydrocephalus can further be subdivided into non-communicating and communicating types. Non-communicating hydrocephalus results from a space-occupying, obstructive lesion which interferes with the circulation of the fluid either within the ventricular system or at the outlet from the fourth ventricle. Early recognition of this condition, particularly in adults, is very important in cases of operable tumors which may at this stage be removed surgically to cure the condition. Obstructions may be caused by a neoplasm compressing one or both foramina of Monro or filling the third ventricle. The aqueduct of Sylvius may be obstructed by a tumor arising in the third ventricle, in the midbrain, or in the pineal body, or it may be congenitally absent. Slight swelling of the ependymal lining of the aqueduct (ependymitis) may obstruct its narrow lumen. Sub-tentorial tumors may obstruct the fourth ventricle. The foramina of Luschka may be blocked by adhesions following meningitis or by displacement of the medulla and pons into the foramen magna by the pressure of a tumor or by herniation of the Arnold-Chiari malformation. Within the subarachnoid space, obstruction may again be due to tumor, to adhesions following trauma, inflammation or hemorrhage or due to congenital abnormalities.

The various etiological types of hydrocephalus will be classified here, but the discussion of the treatment will be included in the next section.

I. Congenital hydrocephalus.

  A. Developmental defects.

    1. Atresia of Sylvian aqueduct.

    2. Congenital absence of one or more of the ventricular foramina.

    3. Arnold-Chiari malformation usually associated

with spina bifida and platybasia.

4. Cerebral agenesis.

B. Congenital syphilis.

II. Acquired hydrocephalus.

A. External hydrocephalus.

1. Secondary to birth injuries.

2. Residual of subdural hematoma.

B. Internal hydrocephalus.

1. Intracranial tumor.

2. Acute infections.

a. Meningitis.

(1) Leptomeningitis - inflammatory exudate over hemispheres interfering with absorption.

(2) Occlusion of Sylvian aqueduct.

(3) Inflammatory adhesions in cisterna magna.

b. Toxoplasmosis (mechanism unknown).

c. Gummatous (luetic) leptomeningitis producing hydrocephalus.

3. Subarachnoid hemorrhage.

4. Otorhinogenic hydrocephalus.

a. Otitic hydrocephalus.

b. Rhinogenic (paranasal sinuses).

Another classification of importance describes hydrocephalus as (1) communicating and (2) non-communicating. In the former group the obstruction is in the cisternae or subarachnoid space, in the latter it is in the ventricular system. It is important in diagnosis of any case of hydrocephalus regardless of its etiology, to determine if possible whether it is communicating or non-communicating between the ventricular system and subarachnoid space.

TREATMENT OF HYDROCEPHALUS

Although the prognosis in infantile hydrocephalus has a very high mortality rate, spontaneous cures occasionally do occur attesting to the supposition that surgical methods are not entirely hopeless. Cushing said "'---though we may not appear to be much nearer to a cure for congenital hydrocephalus, in quest of which we started out, we have at least learned many things on the way which are essential and of practical therapeutic value'" (Davis 1942). Of prime importance to the treatment of infantile hydrocephalus is the evaluation of individual cases as to the infant's mentality and the selection for radical treatment of only those milder cases which show nearly normal mentality and have no operative contraindication. Non-operative treatment may be tried in these selected cases and, in doubtful cases, it may offer more exacting evaluation after two or three weeks trial therapy. Postural dehydration, in which the head is always maintained above the sacrum, in conjunction with a concentrated diet, can be employed in milder cases for two or three weeks if the intracranial pressure is above 150 mm water, but less than 300 mm water. (Davis 1942) If no improvement is shown within this period, appropriate surgical measures should be attempted in favorable cases. (Bancroft 1946) The treatment of marked or advanced cases is superfluous because in such cases the majority will die within the first four years regardless of treatment, and if treatment should prove effective the already marked cerebral agensis would produce an imbecile or idiot.

The choice of the operation must be made with evaluation of the causative lesion, localization of the lesion, whether the hydrocephalus is of the communicating or non-communicating type, and with due regard to prognosis. In the subsequent surgical procedures, the head must be enclosed preoperatively in a plaster cast if sutures are not united, to prevent collapse of the head at the time of operation. Any desirable size of hole can be made at the time of surgery and the cast will still prevent collapse. (Dandy - Lewis 1946)

Third Ventriculostomy is employed in cases of non-communicating hydrocephalus with obstructions at the aqueduct of Sylvius or the foramina of Luschka and Magendie. Dandy has recently modified his original frontal lobe approach because of the necessity for cutting the optic nerve to gain access to the floor of the third ventricle in the region of the cisterna interpeduncularis. It is important that the floor of the ventricle is opened opposite the cisterna interpeduncularis and not over the cisterna chiasmatis because the latter quickly becomes obliterated. Permanent cures were affected in a few of these cases but others resulted in an external hydrocephalus usually with a fatal outcome. In addition, damage to the hypophysial stalk was occasionally a complication of the frontal lobe approach, producing diabetes insipidus. (Dandy - Lewis 1932) D'Errico in 1942 reported the use of frontal exposure and opening of the anterior wall of the third ventricle, especially adaptable as a palliative measure rather than a cure for the non-communicating type with congenital atresia of aqueduct, ependymitis, and with a slow growing inoperable tumor. (Fig. 4) (D'Errico 1942)

Fig. 4 Diagram showing opening of floor of third ventricle into cisterna chiasmatica (A) and cisterna interpeduncularis (B). (after D'Errico 1942)

The more recent lateral approach has greatly simplified the procedure. The optic nerve is spared, the cisterna interpeduncularis is reached more directly, and there is less frequency of secondary external hydrocephalus. For Dandy's technique for this method the reader is referred to the section on hydrocephalus by Dandy in Lewis' Practice of Surgery. (Dandy - Lewis 1946) The results obtained in cases of infantile hydrocephalus are disappointing but when the onset is after the first year of life and on through adult life, This procedure is almost always successful when the block is in the aqueduct of Sylvius. It is, moreover, the only attack which can control the hydrocephalus due to an inoperable tumor which closes the Sylvian aqueducts and therefore offers palliative relief in such cases.

Treatment of obstruction at Foramina of Magendie or Luschka. Obstructions at these foramina take two different anatomic expressions; (1) a membranous wall at the posterior aspect of the fourth ventricle, it being necessary only to make an opening in the membrane to restore the continuity of cerebrospinal spaces. (2) The foramen of Magendie may be closed by a dense scar or by herniation of the cerebellar tonsils into the spinal canal (Arnold-Chiari malformation, Fig. 5). In either type the cerebellum covers the posterior part of the fourth ventricle. Occasionally one or both foramina of Luschka will bulge laterally over the side of the medulla and when this is true a window in this cystic membrane will correct the hydrocephalus. In most cases a new foramen of Magendie must be created by making a large resection (2.5 cm in diameter) of the cerebellar tissue in the vermis of the cerebellum. The cerebellar lobes tend to fall together post-operatively and the opening heals by cicatrization. This reclosure is a difficult problem and is controlled by making the opening large and by iodizing the surface of the cerebellum to promote its adherence to the overlying muscle. In older children this latter procedure is necessary preliminary to making the opening in order to support the heavier cerebellum. (Dandy - Lewis 1946) The Arnold-Chiari malformation (Fig. 5) is probably a developmental

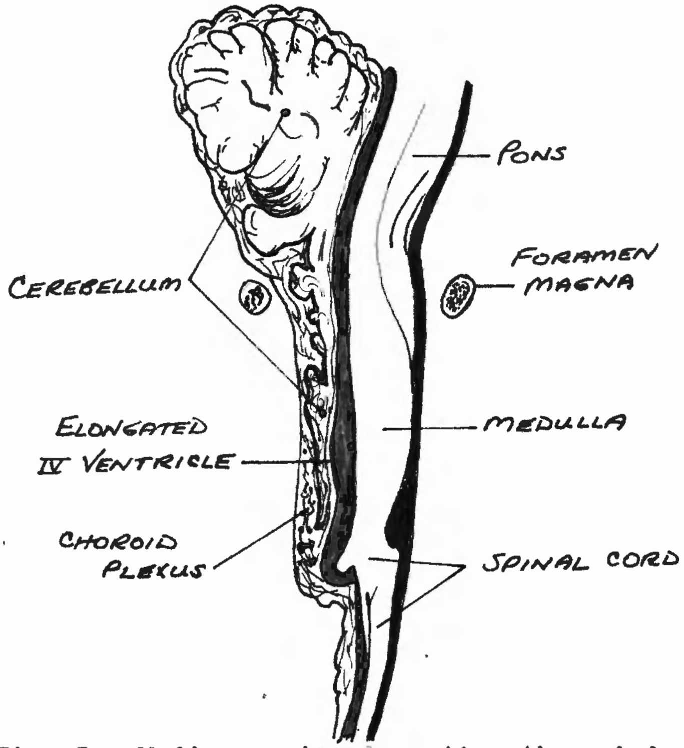

Fig. 5. Median sagittal section through brain stem to show Arnold-Chiari malformation. Gross elongation of medulla. (Russell - Donald 1935)

defect often associated with spina bifida and platybasia. Hydrocephalus from the Arnold-Chiari malformation usually follows excision or decompression of the sac in spina bifida with resulting herniation into the spinal canal. A preventive measure can thus be realized in cases of spina bifida by precautionary consideration of cerebellar herniation. (Russell 1935). When roentgen examination shows platybasia, suggesting the possibility of the Arnold-Chiari malformation, decompression of the foramen magna and spinal cord with the freeing of foraminal adhesions and occasionally amputation of the cerebellar tonsils has been suggested by Gustafson and Oldberg. (1940)

Treatment of hydrocephalus due to a cisternal block. This form of hydrocepahlus does not appear to offer any hope of side-tracking the ventricular fluid since the cisternae are destroyed.

It is anatomically impossible to remove all of the choroid plexus within the brain but it is possible in some cases to destroy or remove enough of it that equilibrium may be maintained. The choroid plexus in the third ventricle and frequently that in the lateral recesses of the cerebellum cannot be reached for extirpation or destruction. To remove the remainder means, in most instances, two or even three severe operations, any one of which may end fatally if every step does not go well.

(1) Removal or coagulation of the choroid plexus in each lateral ventricle is done as follows. The ventriculoscope is introduced into the lateral ventricle from an occipital approach and then the choroid plexus electrocauterized throughout its extent in the lateral ventricles. Both ventricles must be attached at the same time, because an external hydrocephalus will collapse both hemispheres for some time afterward and if only one choroid has been coagulated the second could not be reached later because of the collapse. This is the most hazardous of the proposed procedures and carries a fairly high mortality, perhaps twenty-five per cent.

(2) Coagulation of the choroid plexus in the posterior cranial fossa is carried out by a modified cerebellar approach, the coagulation being done under direct vision. Care must be taken at this stage to avoid injury to the vagus nerve.

(3) Through an opening over the anterior horn on the right side a ventriculoscope is passed into both ventricles, the atrophied septum pellucidum making both ventricles continuous, and the choroid coagulated from the foramina of Monro to the scar where the choroid has been previously removed. (Dandy - Lewis 1946)

Treatment of other types. External hydrocephalus due to the residual of a subdural hematoma is treated by complete evacuation of the clot. Chemotherapy is important in controlling meningitis and preventing many of its complications. Anti-luetic treatment is of course indicated in any case of syphilis and when initiated early enough will prevent gummatous tertiary lesions of syphilis. Treatment of otorhinogenic hydrocephalus is, decompression by lumbar puncture (ventricular puncture if no relief), chemotherapy, and cranial exploration if localized brain abscess is suspected. (Reeves 1941) Acetarsone is said to show some promise in the treatment of the rare type of hydrocephalus complicating the parasitic disease of toxoplasmosis.*

*Personal communication from Robert Allen, M.S. University of Nebraska, College of Medicine.

CONCLUSIONS

There exists today a widespread pessimism in regard to the possibility of cure of hydrocephalus. A survey of recent literture indicates that the treatment of hydrocephalus is by no means hopeless. The procedures now developed on a sound physiological basis have given promising results in a limited number of cases. With the constant addition of newer diagnostic methods, early diagnosis and more efficacous treatment will be possible. The important factors to keep in mind are; (1) proper selections of cases for surgical procedures, with due regard to the infant's mentality and prognosis for survival, (2) early operation in favorable cases, and (3) the choice of the operation after localizing the lesion and deciding what must be done to establish effective equilibrium.

While it must be admitted that the majority of all cases of hydrocephalus are hopeless with regard to successful treatment, this is no reason for neglecting the minority which would respond favorably to surgical treatment.

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