PERITONEAL SHUNT FOR HYDROCEPHALUS

UTILIZING THE Fimbria of the Fallopian Tube for Entrance to the Peritoneal Cavity*

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Though recognized by the ancients, hydrocephalus, as noted by Dorothy Russell, remained an anatomical enigma until the time of Vesalius who gave the first accurate description of an autopsied case. It remains a partial etiological enigma until the present time. However, a great deal of knowledge has accumulated concerning its origin through the efforts of numerous workers from Magendie through Dandy. The saga of the treatment of hydrocephalus has been well documented in numerous reviews. On the whole, treatment has been directed toward either reducing the quantity of cerebrospinal fluid or shunting cerebrospinal fluid into areas where absorption or excretion may occur. Many ingenious shunting procedures have been devised.

Urerothecal Anastomosis. Shunting fluid from the subarachnoid space into the ureter after nephrectomy was first proposed and attempted by Drachter and independently by Heile in 1925. Heile anastomosed the kidney pelvis directly to the subarachnoid space. This procedure was modified by Matson who utilized a polyethylene catheter inserted into the subarachnoid space and into the free end of a ureter detached from the renal pelvis. Matson's method has had rather wide acceptance and has been effective in many instances. There are, however, as pointed out by Matson, certain disadvantages which warrant further search for a means of diverting the cerebrospinal fluid of a communicating hydrocephalus. These include: (1) sacrifice of a kidney, (2) loss of fluid and electrolytes resulting from excretion of the cerebrospinal fluid with the urine and (3) possible retrograde infection.

Ventriculomastoid Shunts. In 1950 Nosik proposed ventriculomastoid shunts employing a cannula connecting the dilated temporal horn of the lateral ventricle with the antrum of the mastoid. Because of the high incidence of middle ear infection in childhood and the attendant danger of meningitis, this ingenious method carries a significant risk.

Peritoneal Shunts. Cerebrospinal fluid diversion to the peritoneum was first attempted by Ferguson in 1898. He accomplished this with a U-shaped silver wire passed from the subarachnoid space about the cauda equina.

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through a drill hole in the 5th lumbar vertebra into the peritoneum. In 2 cases reported, the first patient died shortly, and the second after 3 months’ improvement. In 1905 Nicoll\textsuperscript{16} attempted a peritoneal shunt by attaching omentum, which was brought through a paravertebral opening, to a defect in the spinal dura mater. Ventriculoperitoneal shunt was attempted with a rubber tube by Kausch\textsuperscript{13} in 1905 and with a silver wire by Hartwell\textsuperscript{7} in 1910. The latter’s patient is particularly interesting in that he survived for 2 years. After death from a brain stem tumor without evidence of increased pressure, a patent scarred tube was found connecting the ventricle and the peritoneum. Cushing\textsuperscript{2,3} accomplished peritoneal shunts in 1905 by means of a silver cannula passed through the 4th lumbar vertebra into the peritoneal cavity. Twelve patients were treated in this way, but the operation was abandoned because of the development of intussusception and death in 2 patients. Cushing attributed these complications to the presence of pituitary secretion in the cerebrospinal fluid causing increased peristalsis. Further attempts at a peritoneal shunt were made by Heile\textsuperscript{4} by means of silk threads, vein grafts, and a rubber tube from the dura mater to the peritoneum.

Following these early trials with peritoneal shunts the procedure fell into disrepute among modern surgeons. It has recently been revived by Cone, Lewis, and Jackson\textsuperscript{12} who advocate ventriculoperitoneal and in some instances lumbar subarachnoid-peritoneal shunts. Analysis of their results has not yet been published. The experience of others seems to indicate frequent failure of the peritoneal shunts because of obliteration of the peritoneal end of the shunting tube by exudate or adhesions.\textsuperscript{1}

Other Shunting Procedures. Among other methods that have been suggested are shunts from the ventricles to the pleural cavity and to major venous sinuses. Experimental pleural shunts were found unsatisfactory by Ingraham and co-workers.\textsuperscript{11} This has also been our experience in patients. Attempts to sidetrack the cerebrospinal fluid into large venous channels have been made unsuccessfully since proposed by Payr\textsuperscript{18} in 1908 and Haynes\textsuperscript{8} in 1913.

Ideally a shunt will provide for removal of excess cerebrospinal fluid from its usual habitat and for its reabsorption to prevent fluid and electrolyte imbalance. Persistent patency in the presence of normal cerebrospinal fluid pressure, minimal local reaction to the shunting mechanism and least opportunity for central nervous system infection are imperative. It is the purpose of this communication to propose a workable modification of the peritoneal shunt applicable to female hydrocephalics and to present the early results in 12 patients so treated.

METHOD

Preliminary Considerations. Demonstration of hydrocephalus and determination of its type is effected by combined ventricular and lumbar puncture. If PSP or indigo carmine dye placed in the ventricle appears in the lumbar cistern within 30 minutes, adequate communication is considered present. Air studies have been useful in excluding the presence of a tumor as
well as helpful in further determination of patency of the aqueduct of Sylvius. In patients whose hydrocephalus is secondary to meningitis inactivity of infection has been established by the following criteria: (1) absence of bacteria by culture, (2) normal temperature, (3) normal cerebrospinal fluid cytology, and (4) a rising spinal fluid sugar level of 35 mg. per cent or more. These rather arbitrary criteria have seemed satisfactory.

Operative Technique. With the patient in the right lateral recumbent position, laparotomy is performed through a McBurney muscle-splitting incision. The intestines are packed superiorly out of the operative field with moist sponges and the fallopian tube with its associated ovary is isolated. A heavy silk suture is placed through the mesosalpinx, around the fallopian tube, and the tube is ligated about 2-3 cm. proximal to the fimbria (Fig. 1). The mesosalpinx is left intact. A small rounded metal probe is then inserted into the fimbria and passed through the lumen of the salpinx in a retrograde fashion to the level of the previously placed ligature. An incision is made through the wall of the salpinx and the probe is passed free into the peritoneal cavity. A curved #18 polyethylene tube, preformed in hot water, is threaded over the probe which is retracted into the lumen of the salpinx, detached from the polyethylene tube and withdrawn. The polyethylene catheter is then secured with two sutures transfixing the lumen of both it and the salpinx, and a purse-string suture in the wall of the salpinx (Fig. 2).

Through a separate midline lumbar incision a partial right hemilaminectomy of

Fig. 1. Showing exposure of fallopian tube and ovary through a McBurney incision. Ligatures are placed on either side of point of incision (dotted line) into fallopian tube.
the 2nd or 3rd lumbar vertebra is performed. A Kelly clamp is passed through the paraspinal muscles to the retroperitoneal space, and under direct vision the posterior peritoneum is incised over the end of the clamp. The previously fixed polyethylene catheter is brought through this tunnel to present in the laminectomy wound (Fig. 3). The dura mater and arachnoid are opened between two stay sutures and the free perforated end of the polyethylene catheter is inserted caudally into the subarach-

noid space. Care is taken to ascertain that the tube is placed beneath the arachnoid and not merely subdurally. The dura mater is closed in routine fashion and the tube is secured with a single fine silk suture transfixing its lumen (Fig. 4). The intra-abdominal loop of the catheter is then fixed to the parietal peritoneum deep in the iliac fossa with a single silk suture. Routine closure of the wounds is then completed.

In certain instances (e.g. lumbar arachnoiditis, myelomeningocele, cisterna magna obstruction) it may be desirable to create a shunt directly from the cerebral ventricles to the salpinx. In these, telescoped tubes are passed through the paravertebral musculature, up the subcutaneous tissues of the back and through an occipitoparietal perforator opening into the ventricle (Fig. 5). It is felt that the use of a telescoped tube for the ventriculosalpingeal anastomosis may be of value to counteract discrepancies in body and tube length as the patient grows.
Fig. 3. Proximal end of polyethylene tube is pulled through paraspinal muscles for subsequent implantation into lumbar subarachnoid space.

Fig. 4. Through a partial hemilaminectomy the tube is inserted into lumbar theca and anchored by a transfixion suture to the dura mater.
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Postoperative Considerations. Following operation oral feeding is withheld for 24 hours to decrease the incidence of postoperative distention. Immediately after surgery there is depression of the fontanelle and some over-riding of sutures as a result of cerebrospinal fluid loss at operation. During the second and third 24-hour periods the fontanelle again becomes tense, presumably because of spasm of the salpinx secondary to operative manipulation. By the fourth day, the fontanelle gradually becomes soft and concave.

RESULTS

This method has been employed in 12 unselected patients. Salpingothecal anastomosis was performed in 8 instances and ventriculosalpingostomy in 4. Among the 12 patients there have been 2 deaths. The first patient had a salpingothecal anastomosis and death occurred 24 hours following cardiac arrest on the operating table. The second patient had had a ventriculosalpingostomy and died 2 months postoperatively. Her father reported that she had been active the day before her death and more alert than at any time prior to operation. Death was sudden without apparent increase in pressure and with no evidence of infection. Autopsy was not obtained. Of the 7 living patients with salpingothecal shunts, all are apparently functioning at the present time. Of the 8 living patients with ventriculosalpingostomies, 2 are apparently functioning; 1 is not. In evaluating the results of the operations, criteria for a functioning shunt have included: (1) retraction of the previously bulging fontanelle, (2) collapse and over-riding of the previously separated sutures and (3) cessation of disproportionate head enlargement (with actual shrinkage in the younger children).

Five of the patients in this series required two or more operative procedures because of initial failure. Subsequent reoperation on these has revealed

Fig. 5. (Left) For ventriculosalpingostomy, after fixing the distal end of the catheter in salpinx, the proximal end is carried subcutaneously up to the occipital area. Tubing is telescoped in anticipation of body growth. (Right) Rostral end of tube inserted into lateral ventricle through a burr hole. (Insets) Details of making lateral openings into tube and bending and sealing it over a small heating iron.
the following causes of failure: (a) Mechanical failure of the shunt caused by displacement of the polyethylene tube from the lumbar cistern. This has occurred in 4 patients. In the first the catheter had been placed extraperitoneally and the displacement was felt to have been incident to postoperative abdominal distention. Catheters are now placed transperitoneally and fixed to the dura mater with a suture transfixing the lumen of the tube. (b) Kinking of the tube at the site of the lumbar cisternal insertion. This can be avoided by preforming the tube with heat before placing it in the subarachnoid space (c) Arachnoiditis obliterating the lumbar cistern occurred in 1 patient (G.M.). The polyethylene tube was subsequently removed and placed in the ventricle. In one other instance in which the tube had slipped from the subarachnoid space, moderate arachnoiditis was noted at re-exploration. Reinsertion of a new tube into the lumbar theca has apparently proved effective. (d) Peritoneal adhesions about the fimbria were responsible for failure to function in only 1 patient (M.K.). In this infant initial salpingothecal anastomosis was found to be nonfunctioning after 2 months. A second operation revealed that the tube had slipped out of the lumbar cistern and re-anastomosis was performed using a new tube. The second procedure also failed. Re-exploration showed the presence of a constricting band and a large thin-walled cyst about the fimbria. Freeing the fibrous band and evacuation of the cyst resulted in a functioning shunt. It is of course obvious that the incidence and severity of adhesions increases with successive operations.

In this series of patients there has been no evidence of fluid or electrolyte imbalance; nor has there been evidence of meningitis or other central nervous system infection. Postoperative abdominal distention has been transitory and has responded to conservative management. There have been no untoward effects from reduction of cerebrospinal fluid pressure. Decompression has usually been slowly progressive except for that immediately incident to fluid loss during the insertion of the catheter into the ventricle or subarachnoid space.

All of the patients have had a communicating type of hydrocephalus except 3. Two of these infants had a noncommunicating hydrocephalus which had been treated with a tube running from the lateral ventricle to the cisterna magna. Following the Torkildsen procedure hydrocephalus progressed although communication between the ventricles and the lumbar cistern was subsequently demonstrated. In each a salpingothecal anastomosis was performed, leaving the Torkildsen tube in place. In one of these subsequent arachnoiditis led to failure to function. A ventriculosalpingostomy was then performed.

In 9 patients there was no demonstrable cause for congenital hydrocephalus. Two patients had hydrocephalus associated with myelomeningocele. In 1 infant hydrocephalus developed after meningitis.

The patients in this series were between 3 months and 3 years of age at the time of operation. The longest postoperative interval is 12 months; the shortest, 8 weeks (Table 1). The postmeningitic patient has been followed
TABLE 1

<table>
<thead>
<tr>
<th>Case</th>
<th>Age (mos.)</th>
<th>Type</th>
<th>Operation</th>
<th>Remarks</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>E.S.</td>
<td>3</td>
<td>Communicating</td>
<td>Salpingothecal (2)</td>
<td>First tube slipped out of theca; replaced.</td>
<td>Functioning shunt, 12 mos. follow-up.</td>
</tr>
<tr>
<td>R.B.</td>
<td>5½</td>
<td>Mixed</td>
<td>Torkildsen Salpingothecal</td>
<td>Aqueductal stenosis and obliterated lateral cisterns.</td>
<td>Functioning, 10 mos. after salpingothecal.</td>
</tr>
<tr>
<td>B.J.</td>
<td>3</td>
<td>Communicating</td>
<td>Salpingothecal</td>
<td>Cardiac arrest at operation, temporary response to cardiac massage.</td>
<td>Died, 24 hrs.</td>
</tr>
<tr>
<td>M.R.</td>
<td>6</td>
<td>Communicating</td>
<td>Salpingothecal</td>
<td>Postmeningitic hydrocephalus</td>
<td>Functioning, 6 mos. follow-up.</td>
</tr>
<tr>
<td>C.P.</td>
<td>4½</td>
<td>Communicating</td>
<td>Salpingothecal (2) Ventriculosalpingostomy</td>
<td>First tube slipped, replaced; inadequate communication from kinking (?)</td>
<td>Functioning, 5 mos. after ventriculosalpingostomy.</td>
</tr>
<tr>
<td>C.C.</td>
<td>7</td>
<td>Communicating</td>
<td>Salpingothecal</td>
<td></td>
<td>Functioning, 5 mos. follow-up.</td>
</tr>
<tr>
<td>M.K.</td>
<td>7</td>
<td>Communicating</td>
<td>Salpingothecal (2) Exploratory laparotomy</td>
<td>First tube slipped out of lumbar cistern; replaced. Subsequent laparotomy showed cyst around fimbria, plus adhesion across fimbria.</td>
<td>Functioning, 3 mos. after freeing perifimbrial cyst.</td>
</tr>
<tr>
<td>A.B.</td>
<td>7</td>
<td>Communicating</td>
<td>Salpingothecal (2)</td>
<td>First tube slipped out of lumbar theca; replaced.</td>
<td>Functioning, 3 mos. follow-up.</td>
</tr>
<tr>
<td>J.P.</td>
<td>36</td>
<td>Non-</td>
<td>Ventriculosalpingostomy</td>
<td>Rapid progression of previously considered “arrested hydrocephalus.” Shunt apparently successful for 2 mos.; died suddenly at home, exact cause unknown.</td>
<td>Died, 2 mos. after functioning shunt.</td>
</tr>
</tbody>
</table>

for 6 months without evidence of failure of the shunt or of recurrence of meningitis.

ILLUSTRATIVE CASE REPORT

R.B., a 3-month-old white female infant, was first admitted to the St. Louis...
Children's Hospital on Oct. 1, 1952, with a history of enlargement of the head for 2 to 3 weeks.

Examination revealed an obviously hydrocephalic head with a circumference of 47.2 cm. The fontanelle was tense and bulging, the sutures were separated and the veins of the scalp were prominent. Reflexes were hyperactive and muscle tone was increased in all extremities. X-ray films of the skull revealed separation of the cranial sutures. Combined ventricular and lumbar punctures revealed no communication. Ventriculograms showed markedly dilated lateral ventricles. A diagnosis of aqueductal stenosis was made.

1st Operation. Ventriculocisternostomy (Torkildsen procedure) was done.

Course. There was immediate collapse of the fontanelle and over-riding of the sutures. After 1 week the head began to re-expand. The patient was discharged 2 weeks after operation to be followed in the Washington University Clinics. As the head continued to enlarge she was readmitted to St. Louis Children's Hospital on Nov. 8, 1952.

2nd Operation. Combined puncture demonstrated communication between the lateral ventricles and the lumbar cistern. Re-exploration of the suboccipital region confirmed patency of the Torkildsen tube with free communication between the lateral ventricle and the cisterna magna. It was noted that the lateral cisterns were obliterated and it was assumed that this factor was responsible for failure of reabsorption of cerebrospinal fluid.

Course. Enlargement of the head progressed to 40 cm. in circumference. The anterior fontanelle was large, tight and bulging and the cranial sutures were separated.

3rd Operation. On Dec. 24, 1952, a salpingothecal anastomosis was performed.

Course. The fontanelle remained full but soft for 2 days, and then progressively receded. The patient was discharged 8 days after operation in good condition.

Since discharge she has been followed regularly, and was last seen on Oct. 26, 1953, 10 months after salpingothecal anastomosis. There has been steady mental and social development. She is now 16 months old—walks without assistance, chatters incessantly, and has a small vocabulary compatible with her age. The head measures 48 cm. (O.F. circumference), the chest 48 cm. The fontanelle is concave, firm and closing. She is apparently bright and of normal intelligence. There has been no gastrointestinal disturbance, and no evidence of fluid accumulation in the abdomen.

DISCUSSION

Davidoff stated "the difficulty... with the operations [i.e. shunting procedures] though logically conceived in relation to the mechanism of the liquor circulation, is that they often fail to take into consideration the reaction on the part of the body toward the newly established pathways and toward the material utilized in establishing these pathways." It is believed that the operation herein proposed overcomes at least part of these difficulties. It has long been felt that the reason for failure of cerebrospinal-peritoneal shunts has been the ability of the peritoneum and its omentum to form protective adhesive coatings about foreign bodies and other irritants. It is therefore apparent that a "physiological" access to the peritoneum for cerebrospinal fluid is most desirable. Such an entrance is apparently afforded by the fimbria of a ligated fallopian tube. Since the end of the polyethylene
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catheter is enclosed within the salpinx, peritoneal or omental reaction to the catheter itself would not be expected to be of significance.

Jackson$^{12}$ pointed out that arachnoidal reaction to a polyethylene catheter among the roots of the cauda equina may occur. In the present group of cases, this proved to be responsible for failure in only 1 patient and was overcome by performing a ventricular shunt.

As shown by Matson$^{15}$ the main disadvantage of shunting procedures that allow for escape of cerebrospinal fluid outside the body is fluid and electrolyte imbalance. Reabsorption of cerebrospinal fluid from the peritoneum precludes this possibility.

The pitfalls of early optimism for therapeutic procedures for hydrocephalus are manifold. Final evaluation of the efficacy of the proposed procedure must come only after much wider trial and more prolonged follow-up. There are many areas of possible concern for the future. Growth discrepancy is perhaps primary. Although little disproportion between body growth and tube distance is anticipated in the salpingothecal anastomoses, this looms as an important factor in ventriculosalpingeal shunts. It is hoped that the telescoped polyethylene tube, with its potential for insertion of an additional length of tubing, will be effective over the period of normal growth.

Other sources for concern include: (1) the possibility of back pain from lumbar arachnoiditis, (2) the sequelae of pregnancy with its enlarged uterus and possible compression of the polyethylene and fallopian tubes.

The ultimate test of the efficacy of any therapeutic procedure must depend upon the patient’s subsequent intellectual and social development. The follow-up of these patients has been too short to warrant definite conclusions. Furthermore, in the earlier cases at least, no attempt has been made to select patients with early or mild degrees of hydrocephalus. Despite this it seems apparent that all but one of the patients with successfully arrested hydrocephalus have progressed favorably and that at least some give promise of adequate behavior and intelligence.

SUMMARY

1. Modern surgical procedures for treating hydrocephalus have been briefly reviewed.

2. A modified method of cerebrospinal fluid-peritoneal shunt, utilizing the fimbria of the fallopian tube for entrance into the peritoneal cavity, is described.

3. An analysis of the results in 12 patients so treated and a representative case summary are presented.

REFERENCES


7. HARTWELL. Cited by Haynes.8


ADDENDUM

One month after preparation of this manuscript, the nonfunctioning ventriculolosalpingostomy (G.M. Table 1) was revised; the tube was found to be obstructed at ventricular end and had retracted out of the fallopian tube; a new tube was inserted with subsequent restoration of function. At time of proofreading, an additional 4-month follow-up shows that all shunts are functioning satisfactorily except for the doubtful status of C.P., whose head circumference after primary decrease has returned to pre-operative dimensions, although the fontanelle has decreased in size and is concave.