Neurosurgical Techniques

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The Ventriculo-Atrial Shunt

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A ventriculo-atrial shunt is of value in relieving internal hydrocephalus resulting from a variety of lesions that cause obstruction of the intracranial cerebrospinal fluid pathways. Among these are congenital obstructive and communicating hydrocephalus of infancy, inoperable tumors of the brain stem or other structures of the posterior fossa, and hydrocephalus secondary to adhesive arachnoiditis resulting from subarachnoid hemorrhage or various types of meningitis.

Although the ventriculo-atrial shunt was introduced to treat infantile hydrocephalus, it is applicable to all age groups. Because of the progressive withdrawal of the cardiac tube resulting from growth, this method of shunting cannot be considered to remain permanently operational in infants and young children. Surgical revision or the substitution of another effective operation may be required at a later date. It is not recommended as a substitute for ventriculocisternostomy or similar techniques designed to relieve obstructive hydrocephalus in adults.

Inasmuch as this technique introduces a foreign body into the blood stream, it should not be used in the presence of known focal or systemic infection, particularly with suspected meningeal inflammation. Additional contraindications are congenital heart disease and advanced, arrested hydrocephalus.

Preoperative Evaluation

In the management of infantile hydrocephalus, only those patients whose hydrocephalus has not been undergoing spontaneous arrest have been selected for operation. Following the original examination, all infants are seen at weekly intervals and the usual signs of increasing intracranial pressure are noted. The maximum circumference of the head is plotted on a graph containing the curves of normal growth of the head of male and female infants as reported by Westropp and Barber.¹¹

If serial plotting shows that the growth of the head is extending out of the normal range and is linear in time, surgery is recommended. In contrast, a growth curve of decreasing exponential pattern suggests that further observation is warranted and that surgery may not be necessary. This, however, is often a matter of clinical judgment and no hard and fast rules can be made.

It is interesting that the majority of the reports concerning the operative and nonoperative management of hydrocephalus have not presented these essential data. Unless it can be shown conclusively that the surgical procedure controlled the increasing intracranial pressure and arrested the growth of the head, its effectiveness cannot be evaluated.

The preoperative evaluation of the hydrocephalic infant should include a program similar to that outlined by Ingraham and Matson² and Murtagh and Kirkpatrick.³ Associated anomalies should be searched for in conducting the physical and neurological examinations. Roentgenograms of the skull will often shed light on the mechanism of the hydrocephalus. Subdural taps are performed to exclude the presence of blood or fluid in this space. Bubble ventriculograms, using 10 to 30 cc. of filtered air, will disclose the pattern and degree of ventricular enlargement. Larger amounts of air may be required to exclude the presence of an intraventricular tumor. Tests with phenolsulfophthalein dye are helpful in distinguishing between obstructive and communicating hydrocephalus. Ventriculography with 0.5 to 1.0 cc. of ethyl iodophenylundecylate (Pantopaque) will often provide excellent visualization of the site and nature of the obstructing lesion. Prior to operation a roentgenogram of the chest is made in the recumbent position. This film will outline the cardiac shadow and serve as a guide in the passage of the cardiac tube during the operation.

Materials

Description of the shunt system. The shunt
system in current use has 3 component parts.*

1. A ventricular tube with side perforations near the tip. The tip is impregnated with tantalum powder for roentgenographic contrast.

2. A flushing device employing a diaphragmatic valve that insures unidirectional flow. Compression and release of the dome of the flushing device ascertains the patency of both the ventricular and cardiac tubes.

3. A cardiac tube with 4 slit valves near the tip. The tip of this tube is coated with molybdenum disulfide to prevent the slits from sticking together.

All components of the shunt system are fabricated from medical-grade silicone rubber except for the connectors which are made of Nylon.

The shunt system is available in models for infants and adults. The ventricular tube for infants and the cardiac tube for adults have an outer diameter (O.D.) of 0.085 to 0.088 inches and an inner diameter (I.D.) of 0.048 to 0.050 inches. The infant’s cardiac tube consists of a distal end, 9 cm. in length, with an O.D. of 0.052 inches and an I.D. of 0.027 inches which is fused to larger tubing with an O.D. of 0.092 inches and an I.D. of 0.055 inches. The ventricular tube for adults is larger than the infant’s model with an O.D. of 0.110 inches and an I.D. of 0.055 inches. The flushing device for infants fits a 13-mm. burr hole, whereas the model for adults requires a hole 16 mm. in diameter. A flushing device of more rugged construction with a puncturable dome is also available. All components of the shunt can be sterilized in the autoclave.

* Manufactured by the Heyer-Schulte Corporation, Santa Barbara, California.

6. Contrast materials employed for angiography, e.g., sodium diatrizoate (Hypaque); methylglucamine diatrizoate (Renografin).

**Anesthesia**

Infants less than 1 year of age are premedicated with 0.15 mg. of atropine administered 45 minutes before operation. Children between 1 and 9 years of age are given 32 to 65 mg. of secobarbital as a rectal suppository 2 hours before operation and hyoscine hydrobromide, 0.2 to 0.3 mg., 45 minutes before operation, with dosage adjusted according to age and weight. In all children under 9 years of age, anesthesia is induced with cyclopropane and they are intubated with an endotracheal tube of appropriate size. Anesthesia is maintained with halothane, using a Bloomquist circle absorber for children less than 3 years of age.

Children over 9 years of age and adults are given 50 to 100 mg. of secobarbital by mouth 2 hours preoperatively. One hour prior to operation, 20 to 100 mg. of meperidine hydrochloride and 0.2 to 0.4 mg. of hyoscine hydrobromide are administered. All dosages are regulated according to age and weight. In this older age group, anesthesia is induced with pentobarbital sodium and succinyl choline, following which they are intubated with auffed endotracheal tube of appropriate size. Anesthesia is maintained with nitrous oxide and pentobarbital sodium.

**Surgical Procedure**

The technical steps for insertion of the shunt components are illustrated in Figs. 1 and 2.

The patient is placed in the supine position on the operating table. The neck is moderately hyperextended by placing a soft pad of varying thickness beneath the neck and shoulders (Fig. 1A). The face is turned about 45 degrees to the left side. A grid cassette holder is located beneath the neck and chest so that roentgenograms can be made during the surgical procedure.

Following preparation of the skin, the planned incisions are outlined with methylene blue. The scalp flap is located in the temporo-occipital region (Fig. 1A). It is designed so that the incision in the skin lies beyond the edge of the flushing device. The
incision in the neck (Fig. 2F) is located over the point of entrance of the common facial vein into the internal jugular vein.

Sterile plastic drapes or towels may be used to drape the surgical field. If towels are used they should be sutured to the skin.

The technical steps for inserting the ventricular tube and flushing device are illustrated in Fig. 1. Following the reflection of the scalp flap, the wound is held open with an automatic mastoid retractor. A burr hole of appropriate diameter (13 mm. in infants and 16 mm. in adults) is made (Fig. 1B). The dura mater is incised in a cruciate manner and the vessels on the surface of the exposed cerebral cortex are cauterized. At this point the wound in the scalp is packed with moist cottonoid and gauze and covered with a towel.

The surgical technique for inserting the cardiac tube is shown in Fig. 2. The incision in the neck, 3 to 5 cc. in length, is made at the level of the angle of the jaw. The midpoint of this incision overlies the anterior

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**Fig. 1.** A. Position of head and body on operating table; location of incision and underlying craniectomy defect. B. Burr hole 13 mm. in diameter to accommodate flushing device. C. Flushing device sutured in place. D and E. Details of flushing device.
FIG. 2. A. Common facial vein exposed in neck. B. Silk sutures passed beneath vein. C. Cardiac tube passed into right atrium. D. Cardiac tube fits vein snugly. A suture may be tied cautiously around vein and tube, studiously avoiding constriction of the tube. E. Overall view of tube in neck and flushing device connected before closure of incisions (see connection Fig. 1B). F. Method by which cardiac end is drawn into scalp incision.
edge of the sternomastoid muscle. The common facial vein is mobilized to its point of entrance into the internal jugular vein (Fig. 2A). In older children and adults, other large vessels entering the internal jugular vein, e.g., the superior thyroid vein, may be used. In a few instances we have inserted the cardiac tube through the external jugular vein, although more difficulty is encountered in directing it into the right atrium. Occasionally, direct insertion into the internal jugular vein will be necessary.

Two 000-silk ligatures are passed beneath the mobilized vein (Fig. 2A). The cardiac tube is now prepared for insertion. It is important that the tip of this tube is located accurately in the midatrium. This is accomplished either by electrocardiographic control or by filling the tube with a contrast substance and determining its position with a roentgenogram of the chest. If the electrocardiographic method is used, a characteristic biphasic P wave is noted when the tube reaches the midatrium.9 We have used the contrast technique, filling the tube with Hypaque or Renografin.

Before the cardiac tube is inserted, it is filled with physiologic saline leaving the blunted 16-gauge needle and the syringe attached to it. The common facial vein is stretched between the ligatures and incised with the iris scissors (Fig. 2B). This incision is held open with fine mouse-tooth forceps held by the surgeon and his assistant. The cardiac tube is inserted and directed down the internal jugular vein into the right atrium (Fig. 2C). Since this tube completely fills the lumen of the vein, there is no risk of air embolism. The cardiac tube is now filled with 1.5 to 2 cc. of the contrast medium and a roentgenogram is made. Adjustments in the position of the tip of the tube in the right atrium can now be made. In general, the optimum position is usually at the level of the 5th or 6th dorsal vertebral body except in very young infants with a more transverse position of the heart. In these infants a more cephalad location may be necessary.

When the tube is properly located, the common facial vein is divided between the ligatures (Fig. 2D). As the tube usually fills the lumen of the vein, it is seldom necessary to tie the encircling ligature. Should bleeding occur from the host vein, the ligature should be tied cautiously so that it does not occlude the tube. The contrast medium is now flushed from the tube and the operating pressure of the slit valves is checked by gravitational flow from the attached syringe. The cardiac tube is now drawn into the cranial wound through a subcutaneous tunnel (Fig. 2F and G). This may be done with the McMurtry-Schlesinger shunt-tube passer or similar device or by passing a curved hemostat beneath the skin. In adults, an additional incision in the region of the mastoid may be required to facilitate the passage of the tube.

The ventricular tube, cut to appropriate length, is now fastened to the flushing device (Fig. 1B). This tube should occupy the posterior two-thirds of the body of the lateral ventricle. This will place the tip of the tube in the region of the foramen of Munro. The cardiac tube, similarly cut to appropriate length, is now fastened to the other end of the flushing device (Fig. 1B and C). A thin layer of dry gauze is helpful in forcing the ends of the silicone tubes onto the flushing device while making these connections. Care should be taken in tying the knots so that the silicone tubes will be secured to the connectors but not cut through. A surgeon’s knot holds more securely than a square or a triple-throw knot.

When the unit is completely assembled, a ventricular needle is inserted into the posterior horn of the lateral ventricle. A few drops of cerebrospinal fluid are permitted to escape. The ventricular tube is directed into the ventricle through this track of the needle. The shunt system is now operational and the patency of the system can be checked by repeated, gentle compression of the chamber of the flushing device (Fig. 1D and E). The latter is now fastened to the skull with 000-silk ligatures placed through the marginal holes (Fig. 1C). The wounds are meticulously closed in layers. The completed operation is illustrated in Fig. 3.

Postoperative Care

It is advisable that all patients be given a broad spectrum antibiotic during the first 4 to 7 days following operation. Listless, inactive patients should have their position changed every 2 hours. This is done not only
Fig. 3. Completed procedure.
to avoid pulmonary complications but to prevent continuing pressure on the cranial wounds predisposing to possible breakdown of the skin. Except for these special orders, routine postoperative measures are instituted.

Before the child leaves the hospital, the parents or another responsible member of the family are instructed in the operation of the shunt system. They are advised to report any faulty functioning of the flushing device or tightness of the skin in the region of the anterior fontanelle. It is particularly important that respiratory infections and other febrile illnesses are reported immediately. These illnesses predispose to the development of bacteremia and should be treated with appropriate antibiotics.

All patients should be examined within 2 weeks after leaving the hospital and then at intervals of 1 month for 6 months. Obviously, more frequent examination is required if the surgeon is concerned about the operation of the shunt. Roentgenograms of the chest should be made after 6 months to determine if cor pulmonale or embolism in the pulmonary arterial system is developing.

Complications

The serious complications of ventriculo-atrial shunting are atrial or major venous thrombosis, septicemia, and mechanical failure of the shunting system.

It is obvious that the insertion of a foreign body into the blood stream may invite the formation of a thrombus. Laboratory and clinical experience have indicated that improper placement of the cardiac tube is the most common cause of this complication. If the tip of the shunt tube is properly located at the D5-D6 level, the shunt tubes have operated satisfactorily for 2 years or longer. If major thrombosis develops, the shunt system should be removed and an angiocardiogram performed to determine the nature of the thrombotic lesion.

Septicemia is a serious complication and demands early recognition. It may develop either insidiously or in the presence of known infections elsewhere in the body. Intensive chemotherapy should be instituted. In most instances, removal of the shunt system will be required.

Mechanical failure of the shunt system will result from growth of the infant with progressive withdrawal of the cardiac tube, plugging of the shunt system with blood, fibrin or fragments of brain, or disconnection of the component parts.

The problems incident to growth are solved by operative revision of the shunt system. The cardiac tube can be advanced or replaced in a proper position. The shunt can be repeated on the left side or some other effective procedure can be used.

The plugging of the shunt system with particulate matter usually can be corrected by operating the flushing device. At times, surgical exploration may be required.

Separation of the component parts of the system may precipitate a serious problem. This is particularly true if the cardiac tube becomes disengaged from the connector and wanders into the right side of the heart. Removal of the tube from the heart requires a thoracotomy and atrioventricular exploration.

References


