Ventriculoperitoneal Shunts in Children: Indications, Equipment, and Techniques

John Kestle, MD

Introduction

The most common disorder treated by pediatric neurosurgeons is hydrocephalus. A recent review of inpatient data in the United States found that $1–2 billion is spent each year on the management of hydrocephalus.[13] This paper will review the indications for treatment of hydrocephalus, the selection of a procedure and equipment, implantation techniques, follow-up, and complications.

Indications for Treatment

The decision to implant a ventriculoperitoneal shunt in a child with ventriculomegaly should not be taken lightly. Once a shunt has been implanted, it is very difficult to determine that it is no longer necessary, and therefore the initial decision is very important. Sometimes the need is obvious, such as a baby who presents with irritability, vomiting, a full fontanelle, splayed sutures, and increasing head circumference. Similarly, older children with headaches, vomiting, and papilledema clearly require intervention. At the other end of the spectrum are children with moderately enlarged ventricles, normal development, and no progression in head size or ventricle size on imaging. Although the ventricles may be bigger than average in these children, a shunt should not be implanted unless their symptoms progress.

John Kestle, MD
Department of Neurosurgery, Division of Pediatric Neurosurgery
Primary Children's Medical Center
100 N. Medical Drive, Salt Lake City, UT 84132, USA
Email: john.kestle@hsc.utal.edu

The essential factor in the decision to treat hydrocephalus is a progressive change over time. This may be progression of ventricle size on imaging, head size, or neurologic function. In a baby, loss of neurologic function may be manifested as lack of normal developmental progress. A decision to implant a shunt on a single visit is rare except in the extreme situation, and observation over time, looking for progressive change, is the most useful test.

In rare situations, intracranial pressure monitoring may be helpful. Fouyas et al. monitored 18 previously unshunted patients in whom the diagnosis of hydrocephalus was suspected but uncertain.[3] Repeated examinations and imaging had failed to demonstrate a clear need for a shunt. In 9 of the 18 patients, the intracranial pressure was elevated on monitoring, and all of these 9 improved symptomatically with shunt placement.

The decision to treat hydrocephalus can be particularly difficult in the premature child after intraventricular hemorrhage. Typically, these children have been treated with an implanted reservoir, which is tapped periodically to maintain a reasonable head circumference. As the child matures towards term, the taps are weaned and the child is observed for apnea, bradycardia, progressive head enlargement, ventriculomegaly, and feeding difficulties. The likelihood of converting a ventricular access device or subgaleal shunt to a permanent shunt has recently been reviewed and found to be approximately 50 - 70% for patients with Grade III and IV intraventricular hemorrhage.[14]

Children with posterior fossa tumors have a significant incidence of hydrocephalus. In the past, preoperative shunting had been common practice, but this is no longer the case, since a significant proportion of patients remain shunt free after tumor removal. A predictive score, which can be used to identify patients at high risk of hydrocephalus, has been developed and validated for this population.[11]

Shunt Placement *vs*. Third Ventriculostomy

A subset of children with hydrocephalus are candidates for third ventriculostomy rather than shunt placement. The ideal candidates are older children with obstructive hydrocephalus at the level of the aqueduct. The failure rates of third ventriculostomy and shunts have been compared, and the complications associated with third ventriculostomy have recently been reviewed.[2] Candidates for third ventriculostomy are usually older than those who are treated with shunts, and the most common causes of hydrocephalus treated by third ventriculostomy are aqueduct stenosis and tumor. The success rate of third ventriculostomy is 65% at 1 year and 52% at 2 years, almost identical to that of initial ventriculoperitoneal shunts. Children of a younger

age, particularly neonates and infants, are thought to have significantly higher failure rates with third ventriculostomy.[2]

Selection of Shunt Equipment

Ventricular and peritoneal catheters that are impregnated with antibiotics are now available. The intent is to reduce the incidence of shunt infection, but the data are mixed, with some studies showing favorable results.[1,4,12] Others being equivocal.[5] Among these studies, the single randomized trial appeared to show a reduced infection rate, but HIV-positive patients, patients with a recent shunt infection, and adults were included in the patient population.[4] In addition, the infection rate in the control group was high (17%). As yet, a large, well-controlled, randomized trial demonstrating efficacy has not been done. Anecdotal experience has suggested that antibiotic-impregnated catheters may make a shunt infection more difficult to diagnose. Hydrophobic catheters (Bactiseal) are also available but have not been shown to reduce infection rates or decrease tissue adherence.

Many valves are available on the market; they can be categorized in terms of their flow characteristics and whether or not they are adjustable. The flow characteristics of differential pressure valves, Delta valves, and Sigma valves were compared in a randomized trial (Fig. 1) and no difference in overall shunt survival was found.[6] A randomized trial comparing the adjustable Codman valve also did not show an advantage.[9] A non-randomized cohort study of the Strata valve showed similar shunt survival to other valves on the market (Fig. 2).[8]

In the absence of strong evidence favoring one valve over another, the author's preference is as follows:
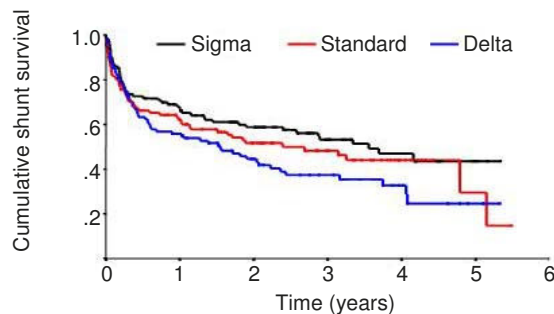

Figure 1: Time to first failure after initial shunt placement in children
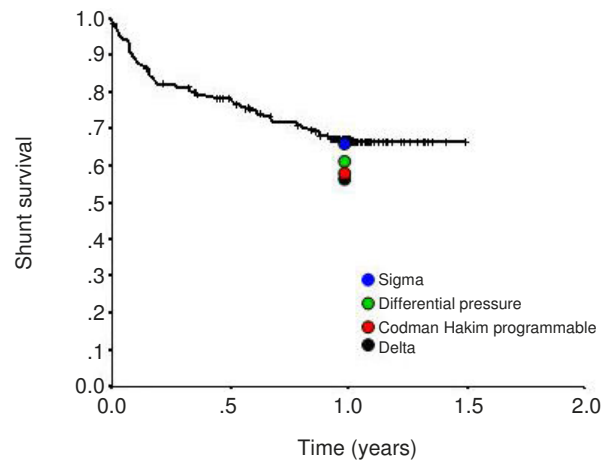
Figure 2: Time to failure of Strata valve

- For children with newly diagnosed hydrocephalus, a medium pressure differential valve is implanted.
- For older children with large ventricles who appear to be at high risk of acute overdrainage with subdural hematoma, an Orbis Sigma valve is implanted.
- Adjustable valves are not used unless they are part of a study protocol.

Some pediatric neurosurgeons use adjustable valves in newly diagnosed hydrocephalus. Then, after the intracranial pressure has been relieved and the wound has healed, they increase the setting to try to prevent the development of small ventricles. The efficacy of this approach has not yet been demonstrated.

Implantation Technique

The patient is positioned supine with the head turned contralateral to the site of ventricular catheter insertion. To prevent infection, prophylactic antibiotics are used, and the surgeon wears double gloves for the procedure. Cefazolin is administered before the first incision and once postoperatively. Hair is clipped along the incision site, which is prepped with chlorhexidine. Either a coronal or a posterior parietal entry site can be chosen, and the choice does not appear to affect the long-term survival of the shunt. The coronal site allows better visualization of the foramen of Monroe should the use of endoscopy be necessary at a later date. Endoscopic insertion of the ventricular catheter at the time of initial shunt placement was not shown to be advantageous, but shunt survival appears to be improved if the tip of the ventricular catheter is away from the choroid plexus.[7]

For a coronal entry site, a semicircular incision is made at the lateral margin of the anterior fontanelle (in the mid-pupillary line), a second incision is made behind the ear, and a third in the side of the abdomen. The valve and peritoneal tubing are passed subcutaneously between these wounds before the ventricular catheter is placed. The ventricular catheter is then implanted, and some of the fluid is allowed to drain so that any debris or blood is drained off and does not enter the system where it might plug the valve. Fluid should be seen flowing from the peritoneal end of the catheter without aspiration before it is implanted in the peritoneum. Either an open minilaparotomy technique or implantation with an abdominal trocar is used. The use of a trocar should be avoided in children who have undergone multiple previous operations or have abdominal scars.

Once the system is in place, vancomycin 10 mg and gentamicin 4 mg are injected into the reservoir using a butterfly needle.[10]

Follow-Up

The patient is seen in follow-up one month after surgery to evaluate wound healing and clinical symptoms. Computed tomography scanning is performed at 3 and 12 months after surgery. Data from the Shunt Design Trial indicate the ventricle size will decrease by 3 months but will decrease further until 12 months after surgery and then stabilize (Fig. 3).

For that reason, both images are important. The 3-month image is necessary because failure is so common in the first year after shunt placement, and the 1-year image is necessary as the appropriate baseline for subsequent follow-up. Patients and their families are instructed with regard to symptoms of malfunction and infection. Patients who present with fever in follow-up are
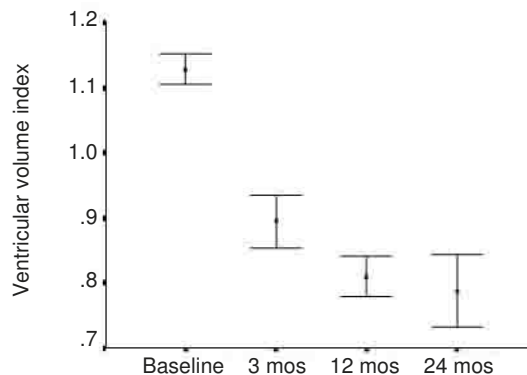

Figure 3: Ventricle size after shunt insertion

investigated for shunt infection if they present within 6 months of an operation. In a child who presents more than 6 months after a surgical procedure with a fever, other sources of infection should be evaluated before a shunt tap is warranted.

Complications

Shunt failure is common in the first year after implantation, with the shunt failing in a third of patients for noninfectious reasons and 5 - 10% of patients suffering shunt infection. The most common cause of failure is shunt obstruction, which can, of course, present at any time and is most commonly due to ventricular catheter blockage. Obstruction of a valve may occur, often quite soon after shunt implantation because of obstruction by cellular debris or blood getting into the valve at the time of implantation. The vast majority of infections occur within 6 months. Acute overdrainage resulting in subdural hematoma also usually occurs early (in the first few months). Shunt migration also occurs very early, but disconnection or fracture of the peritoneal tubing is a very late complication, after the outer surface has become calcified, rough, and adherent.

Complications related to intracranial catheter placement include hemorrhage and neurologic injury with misplacement of the catheter into eloquent areas of brain parenchyma. Fortunately, these are rare. At the distal end, abdominal perforation can occur either at the time of implantation or in a chronic fashion with erosion of the peritoneal tubing through the viscera wall. Patients with abdominal pseudocysts, presumably due to low-grade infection with *Staphylococcus epidermidis* or *Propionibacterium acnes*, may present with an abdominal mass and symptoms of shunt malfunction.

Conclusion

The management of hydrocephalus is the most common task of the pediatric neurosurgeon. It is therefore important to become familiar with its presentation, management, and complications. Further investigation into the indications for shunting, the prevention of infection, and optimal shunt hardware are needed.

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