Ventriculo-Peritoneal Shunt

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Introduction

The placement of a ventriculoperitoneal (VP) shunt requires meticulous planning and attention to detail. This chapter provides a review of the technique for placing a VP shunt. This procedure is indicated primarily for the treatment of primary or secondary hydrocephalus in adults and children.

Preoperative Planning

The diagnosis of hydrocephalus is reasonably straightforward in most patients. Patients with acute hydrocephalus experience classic symptoms (headaches, vomiting, and mental status changes) and signs (up-gaze palsy, declining mental status, and bradycardia) of elevated intracranial pressure.

Other patients might have more subtle considerations for cerebrospinal fluid (CSF) diversion. A variety of protocols exist for patients suspected to have normal-pressure hydrocephalus. Patients with idiopathic intracranial hypertension or pseudotumor cerebri can have multiple treatment options. Shunting in children with macrocephaly or subtle loss of developmental milestones might also merit consideration.

There are inherent complications with placing a shunt. In the hands of an experienced surgeon, the immediate surgical risks are generally acceptable, with an approximate 1% chance of clinically relevant intracranial hemorrhage and an approximate 1% chance of damaged abdominal viscera. The risk of shunt infection is approximately 5% to 8%. Approximately 50% of all children who undergo shunt placement will require a shunt revision within 2 years.^{1,2}

Some patients with hydrocephalus benefit from an endoscopic third ventriculostomy, which can often adequately treat obstructive hydrocephalus without all of the potential long-term complications of shunting (see [chapter](#) for further details).

Once the decision to place a shunt is finalized, the surgeon must evaluate the patient's ventricular anatomy. The shunt is placed most commonly on the right side and in the frontal horn of the lateral ventricle via a parieto-occipital entry point, but a different location might be required for patients with abnormal anatomy. Some children with severe hydrocephalus have a very thin or nonexistent cortical mantle. I prefer to place the proximal catheter through some cortex so that it acts as a gasket to prevent leakage of CSF around the catheter. **The use of neuronavigation is helpful for placing all catheters, but it can be critical for hitting a smaller target.**

After planning the target location of the proximal ventricular catheter, the surgeon then selects an appropriate distal terminus. Multiple anatomic locations are acceptable. The peritoneum is the most common distal site for a number of reasons. Accessing the peritoneum is safe, and the peritoneal cavity generally absorbs CSF quite well. In children, excess catheter can be placed to allow for the patient's growth.

The right atrium of the heart is also an acceptable distal site. The rates of shunt infection or malfunction between ventriculoatrial (VA) and VP shunts are similar. Because CSF normally is absorbed into the venous system, the atrium is an ideal physiologic location. However, the atrium is generally the second choice because of the risks of thrombosis, endocarditis, myocardial injury, nephritis, and arrhythmias. The distal catheter of the VA shunt is of a fixed length. A growing child might need lengthening of this distal catheter with age (see the [Ventriculo-Atrial chapter](#) for further details).

The pleural space is another accepted distal site. However, ventriculopleural (VPI) shunts have a higher failure rate than do VP and VA shunts, so the pleural space is considered a salvage location. A number of disadvantages to VPI shunts exist. The pleura is sensitive, and some

patients will have pain associated with the presence of the distal catheter. The lung capacity in infants is very small and might not be able to handle the amount of CSF, and many experienced shunt surgeons will not place a VPI shunt in children younger than 7 years of age for this reason. The pleural space also imparts a negative pressure on the shunt system. With every inspiration, the shunt is subjected to a “suck” that can lead to a low- or even negative-resistance situation. Proper valve selection is critical for avoiding overdrainage and slit-ventricle syndrome.

The gallbladder is an infrequently used distal terminus (see the [Ventriculo-Gallbladder chapter](#)) but can be quite effective in selected patients who have not tolerated other distal locations. Other distal sites that have been described include the transverse sinus and bone marrow.

Once the anatomy is defined, the surgeon selects the valve and shunt system. Multiple shunt valves are commercially available. The surgeon who treats hydrocephalus routinely should be familiar with the advantages and disadvantages of multiple valves and can select the optimal system for the patient (see [Ventricular Shunt Reference chapter](#) for further information about the valves).

Surgical Technique

The patient is positioned supine with his or her head turned opposite the side of the proximal catheter. The head should be rotated 45° to 60° away from the surgeon with a slight posterior tilt. More rotation is needed if an occipitoparietal shunt is planned. **A bump is placed under the shoulders to provide a straight line between the thorax, neck, and retroauricular region.** The mastoid process and the clavicle should be in approximately the same horizontal plane, which facilitates safe tunneling.

Figure 1: A 1-week-old infant positioned for a right occipitoparietal VP shunt placement. The infant is at the very end of the table with her head turned. A shoulder bump was placed to keep the mastoid process and the clavicle on the same plane.

The entire length of the shunt path should be exposed and surgically prepared. Enough hair is clipped to enable a clean incision and skip incision(s) if necessary. It is not necessary to shave the patient's entire head. Preoperative antibiotics are given. The surgical team should all double glove, because this practice has been shown to reduce the risk of shunt infection.

The proximal catheter is placed most commonly in the frontal horn of a lateral ventricle from either a frontal or occipitoparietal approach. Ideally, the catheter rests in front of the foramen of Monro, away from the choroid plexus. The skin incision is curvilinear and should be fashioned such that it is away from the shunt hardware.

The key anatomic landmarks for placing a frontal catheter include the medial canthus of the ipsilateral eye and the tragus of the ipsilateral ear. Kocher's point, located 1 to 2 cm **anterior to the coronal suture** and 3 cm **lateral from the midline**, is used for placement of the burr hole. In infants, the corner of the anterior fontanelle is a good site for entry. A

retroauricular skip incision is generally required for frontal shunts.

Figure 2: Kocher's point is located 1 cm anterior to the coronal suture and 2 to 3 cm lateral to the midline. A catheter placed perpendicular to the brain at this location should enter the ipsilateral lateral ventricle.

There are multiple ways to estimate the location of the incision for an occipitoparietal catheter. Frazier's point is 3 cm lateral from the midline and 6 cm superior to the inion. This point is a common anatomic landmark for placing the burr hole for an occipitoparietal shunt. The prefer the use of image guidance for mapping the location of the incision.

Figure 3: Frazier's point is defined as 3 cm lateral and 6 cm superior to the inion.

Another simple method for estimating the burr-hole placement for an occipitoparietal shunt is to measure a mark halfway between the external acoustic meatus and the inion. A second measurement is made halfway between this mark and the vertex of the skull. A flatter area of the skull exists just superior and posterior to this mark, which makes an ideal entry point for an occipitoparietal shunt catheter.

Figure 4: A burr hole location for an occipitoparietal entry point may be estimated by finding a point midway between the inion and the external acoustic meatus (A, left upper image). A second point (B) is defined as

halfway between A and the vertex. There is generally a flat area of the skull just superior and posterior to this point that makes an ideal entry point. A curvilinear incision behind this point is shown (C). The first mark (A) is made halfway between the external ear and the inion. A second mark (B) is made halfway between (A) and the top of the vertex. There is generally a flatter area of the skull just posterior and superior B. This is a good location for the burr hole. A curvilinear incision is then designed based on this information. This procedure for planning the incision can be used on any sized skull, including adults and newborns. The curvilinear cranial incision is completed. In an infant, it is critical to specifically identify the galea and keep it attached to the skin. The galea is the only layer that will reliably hold a deep stitch. The incision should be opened through the galea and into the periosteum of the skull. The galea should separate easily from the peritoneum with blunt dissection within the loose areolar plane. Next, a burr hole is created (bottom image).

A pocket for the valve is created between the periosteum and the galea in the plane of the loose areolar tissue. It is critical to define this plane precisely, because in infants, the galea is the only layer that will hold a deep suture. The galea must be kept attached to the skin. Some valves or antisiphon devices require a specific orientation in space and the surgeon must understand the nuances of each valve.

There are 3 common ways to access the abdomen, via minilaparotomy, laparoscopically, and with the use of a trocar. The trocar method requires a small incision that should be made superior to the umbilicus to avoid bowel perforation. The trocar is inserted through the skin and subcutaneous fat until it rests on the anterior rectus sheath. Then, while pulling the skin taut anteriorly, the trocar is advanced by aiming for the ipsilateral iliac crest. As the trocar is advanced, a “pop” should be felt when it passes through the anterior rectus sheath and again through the posterior rectus sheath. Afterward, the stylet is removed, and the sheath is left in place. The laparoscope-assisted method is especially useful in obese patients and is typically performed by a general surgeon.

Minilaparotomy is the most common method for accessing the peritoneal

space. Multiple sites for the incision have been described. Using a lateral subcostal incision confers the advantage of entering the peritoneal space over the liver, thus minimizing the risk of bowel perforation. The surgeon must navigate 3 layers of muscle.

A midline, vertical incision provides the advantage of going through the avascular linea alba. A common insertion site is superior and lateral to the umbilicus; either side is acceptable. The right side is preferred in patients who might need a gastrostomy tube. This is a simple exposure, and the muscle and the fascia act together as a gasket to support the distal tubing and prevent CSF leakage.

A transverse minilaparotomy incision is carried through the fat and Scarpa's fascia to the anterior rectus sheath. The anterior rectus sheath is opened transversely. The rectus abdominus muscle is visualized, and a hemostat is used to split these fibers vertically, in line with their orientation.

Figure 5: The abdominal incision is approximately 1.5 cm in a child of this size. In this example, it is transverse and located superior to the umbilicus and just to the right of the midline. Subcutaneous fat is identified just below the skin. Scarpa's fascia is a thin but definable layer, and more fat is seen below this fascia. The firm white anterior rectus sheath is opened transversely. The rectus muscle fibers are found just below the anterior rectus sheath, and these fibers are split vertically with a fine hemostat.

Then, the glistening white posterior rectus sheath is visualized and mobilized with 2 hemostats; the surgeon must take care to pull the sheath toward himself or herself. The surgeon will grab the sheath with 1 hemostat and use a second hemostat to sweep away the muscle. By working back and forth with the 2 hemostats, a section of the posterior sheath can be exposed. When this technique is used, the underlying bowel should fall away from the area.

Posterior
Rectus Sheath

Figure 6: The glistening white posterior rectus sheath is identified below the muscles, and the surgeon uses a fine hemostat to grab this sheath and pull it toward himself or herself. An area of approximately 1 cm is exposed by using a second hemostat to sweep muscle aside and then regrasp the sheath. By keeping tension toward the surgeon, any underlying bowel or viscera should fall away. The posterior rectus sheath is opened with scissors. The underlying transversalis fascia and peritoneum are often opened with the same cut. The transversalis fascia and the peritoneum will often be opened with this maneuver. A blunt instrument should pass deeply and not face any resistance. If resistance is encountered, the surgeon is probably in the preperitoneal space. The peritoneum is translucent and just below (posterior to) the preperitoneal fat. If the peritoneum has not been incised via the described maneuver, it should be grasped with fine hemostats and opened with scissors. Once

the peritoneum has been entered, the entire abdominal incision is covered with a bacitracin-soaked sponge.

The posterior rectus sheath is opened with scissors. Most of the time, the peritoneum is opened with this maneuver. A blunt instrument should pass without resistance. If resistance is encountered, the next layer encountered is generally the peritoneum, and preperitoneal fat might be seen. The peritoneum is generally translucent; the surgeon should be able to handle the scissor tips under direct vision through the tissue before cutting, which helps him or her avoid inadvertently cutting the bowel. The undersurface of the abdominal wall is very smooth and the surgeon's finger can feel this surface to assure himself or herself that the abdominal cavity has been entered.

The distal catheter will be difficult to pass or will curl up if it is within the preperitoneal space. A catheter left in this space will generally fail quickly. Fluoroscopy can be used to ensure that the catheter distributes freely into the appropriate space. A tightly coiled catheter (generally determined via C-arm imaging) is unacceptable. **The neurosurgeon should not hesitate to consult a general surgeon regarding any patient who has undergone multiple previous abdominal surgeries**, which can lead to adhesion formation. The entire incision is packed with a bacitracin-soaked sponge and the attention is diverted elsewhere.

Next, the subcutaneous tunneling is performed. In some ways, this tunneling is the most immediately dangerous part of the procedure. The shunt passer is generally passed from the head toward the abdomen, although the opposite way is acceptable. The most resistance is encountered in the neck. After the nuchal fascia is penetrated, it is critical for the surgeon to keep the passer above the clavicle to avoid a pneumothorax or lung injury. The tunneling should not occur too close to the skin to minimize the risk of inadvertent skin penetration or future shunt erosion.

Figure 7: A pocket is made in the subcutaneous layer of the cranial incision with a hemostat. A larger hemostat is used to puncture the nuchal fascia. A shunt passer is passed, in this case from the cranial incision down to the abdominal one. The passer is pushed deep into the nuchal fascia and then must be turned superficial to travel superficial to the clavicle. This process might require the surgeon to drop his or her hands below the level of the patient's skull. Therefore, it is critical to position the patient correctly at the very end of the bed to enable maximum freedom of motion for the shunt passer.

To avoid esophageal injury, the midline should not be crossed until the passer is palpated over the clavicle. Also, the shunt passer should not go directly under the breast in a developing girl, because it could injure the breast bud. In infants, tunneling might restrict ventilation. The anesthesia team should be notified before tunneling, and this part of the procedure

should be done as efficiently as possible.

After the distal catheter is passed, its end is covered with a sterile towel. Then, the valve is attached. The system is then flushed with fluid that does not contain bacitracin; bacitracin fluid can cause bubbles that can airlock the system and cause an obstruction.

Figure 8: The distal catheter is passed. The valve and reservoir (in this case) are attached to the distal catheter and flushed with Ringer's lactate solution. The flush fluid should not contain bacitracin, because on rare occasion it can cause bubbles that can airlock the valve. However, the shunt equipment is covered with bacitracin-soaked sponges.

A small cruciate opening of the dura suffices, and the edges of the dura are coagulated with bipolar electrocautery. The pia is coagulated and opened, and the proximal catheter is inserted using navigation. It is important to resist the temptation to pass the frontal catheter too deeply (max of 7cm in adults.) Ideally, the distal system is in place and flushed before placing the proximal catheter. Then, the proximal catheter can be connected to the system quickly to prevent excessive egress of CSF or inadvertent dislocation of the proximal system. **Distal flow is confirmed.**

Figure 9: The proximal catheter is placed. In this case, intraoperative ultrasonography is used to define the ventricular anatomy and pass the catheter. Once the catheter is in the ventricle and immediately after it has penetrated the ependyma, the stylet should be removed and the rest of the catheter inserted into the ventricular space.

The surgeon then “taps” the valve with a 25-gauge butterfly needle; this maneuver confirms proximal flow and enables the injection of intrathecal antibiotics. A standard protocol is to use 10 mg of intrathecal vancomycin and 4 mg of intrathecal gentamycin. This dose is the same regardless of the age or size of the patient. The distal catheter is occluded for this injection to force the antibiotic into the ventricle. Once the distal flow is confirmed, the valve is pulled into the subcutaneous pocket, and the distal catheter is placed into the peritoneal cavity.

Figure 10: The proximal catheter is cut to the appropriate length and attached to the reservoir. Then, the valve is pulled into the subcutaneous pocket. **The last move of positioning a shunt should always be a “pull” not a “push,” because pushing the valve into the pocket can lead to kinking of the distal catheter.** Therefore, the shunt system should be pulled through the abdominal incision. Distal flow is confirmed. The reservoir is then

tapped with a 25-gauge butterfly needle. Intrathecal antibiotics can be injected. Note that an assistant occludes the distal catheter in order to force the antibiotics into the ventricle.

The last move in positioning the valve should be a “pull” not a “push”; the valve must be pulled into the pocket from below, not pushed from above. Pushing can cause the segment of the catheter just distal to the valve to kink and occlude.

In infants, the reservoir and proximal catheter can “piston,” because relatively little scalp tissue is there to hold it in place. Such pistoning can contribute to CSF leaks and potential infections. I recommend placing a stitch through the periosteum on either side of the burr hole in an effort to tack the reservoir or valve down.

Figure 11: The skin of infants is very thin and pliable. As a result, the reservoir can “piston” in and out of the skull, which can lead to a CSF leak by creating space around the proximal catheter; a leak is a risk factor for shunt infection. In this case, the reservoir is secured by a suture attached to the periosteum on either side.

The incisions are closed, and a sterile dressing is applied. The incision should be irrigated copiously with antibiotic-impregnated solution before closure.

Postoperative Considerations

Antibiotics are continued for 24 hours after shunt placement. Surgeons who routinely place shunts are encouraged to adopt a shunt infection-prevention protocol. The [protocol](#) from the hydrocephalus research network is cited below.³ Dressings are removed 48 hours after the procedure, and the patient then can shower and wash his or her hair.

Patients are mobilized as quickly as possible. Newborns are positioned with their head elevated above the heart in an effort to prevent CSF pressure on the cranial incision.

The most surgical pain is generally in the neck and results from the shunt passage. Ice packs are beneficial. Many surgeons document the position of the catheter and distal system with a head computed tomography scan without contrast and a “shunt series” of radiographs. Patients without complications are observed overnight and discharged the next day.

Pearls and Pitfalls

- Stereotactic navigation and intraoperative ultrasonography have been used with great success for guiding catheter placement. These tools have led to greater accuracy and lower revision rates.
- Routine use of an endoscope to place a shunt catheter is not indicated and can increase complication rates.
- Puncturing the lung during subcutaneous tunneling is a risk. It is critical to keep the tunneler within the subcutaneous space and

palpable throughout the entire tunneling process.

- Each institution is encouraged to adopt a protocol for minimizing the risk of shunt infection.
- A general surgeon should be consulted regarding patients with multiple previous abdominal surgeries or with a previous abdominal shunt infection. These patients are at high risk for adhesions and surgical bowel perforation.

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