A Brief Review of Ventriculoatrial and Ventriculopleural Shunts

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Abstract:

Introduction: Alternate approaches such as ventriculoatrial (VA) or ventriculopleural (VPL) procedures still have a place in the surgical armamentarium for patients with recurrent ventriculoperitoneal (VP) shunt failures related to defective absorption, infections, or frequent malfunctions.

Methods: We reviewed the literature and our experience with these techniques, and offered suggestions for safely performing these operations. Historical perspectives were also included to facilitate an improved understanding of the technical developments.

Results: Our findings and the available medical literature suggest VA and VPL options are safe and effective alternatives for managing the complex patient with hydrocephalus. Potential issues and complications were discussed along the technical advances for a safer operation.

Conclusion: The VA and VPL options should be considered for patients with recurrent VP shunt issues. They are safe and effective options for managing complex hydrocephalus patients.

Key Words:

Atruim, complex hydrocephalus, pleural space, shunt complications, ventriculoatrial shunt, ventriculopleural shunt

Key Message:

Ventriculoatrial and Ventriculopleural shunts remain effective alternatives for patients with recurrent ventriculoperitoneal shunt failures. Percutaneous insertion techniques (Seldinger method or trocar insertion) have refined the operations, and these alternative shunt procedures should be considered in managing complex hydrocephalus.

Although ventriculoperitoneal (VP) shunts have remained the mainstay of hydrocephalus management, alternate options are sometimes necessary. Recent technological advances have made VP shunts more durable and consequently, experience with the less commonly used shunts is becoming scarce. Alternate approaches such as ventriculoatrial (VA) or ventriculopleural (VPL) procedures still have a place in the surgical armamentarium, and their use will be reviewed here.

Historically, VA shunts have always enjoyed good functional outcomes, although they required multiple revisions due to growth in children and other complications. The chronic low pressure in the atrium along with cardiac activity somehow improves a shunt function and many patients have identified long-term benefits by this physiologic phenomenon. These are excellent alternate sites for patients with abdominal issues, poor absorption,[1,2] or other reasons such as peritoneal tuberculosis,[3] where the peritoneum cannot be utilized as a primary option for distal shunt placement.

Brief history and evolution of the VA shunt

The neurosurgery historical review suggests that few other surgical procedures have undergone so many modifications as the CSF diversion technique.[4] The concept of VA Shunt to divert CSF into venous or lymphatic system was first proposed by Gartner,[5] almost a decade before the first VP shunt in 1905 by Kaush. Pudenz observed in his animal experiments that placing the distal catheter tip in internal jugular vein (IJV) or superior vena cava (SVC) resulted in catheter blockage and vein occlusion due to capsule formation at the tip.[6] Thus, the placement of catheter tip at right atrium had been standardized and in 1957, Pudenz introduced the VA shunt technique.[7] To access the right atrium, although various routes like external jugular vein,[8] transverse sinus,[9] or subclavian vein[10] had been described, the IJV became the choice for many surgeons due to infrequent complications.

The percutaneous access to the IJV for VA shunt insertion was first proposed by Sorge *et al*.[11] who used special instruments for the Seldinger's technique. Other surgeons later performed this procedure using various available sheaths and catheters to cannulate the IJV or subclavian vein to place the distal shunt tube into the right atrium.[10,12,13]

Preoperative evaluation

As the distal drainage of CSF is into the heart via the venous system, it is imperative that the patency of IJV and SVC be properly assessed preoperatively. Patients with a history of previous or current central venous line placement, history of pulmonary hypertension, or inherent cardiac abnormality should be evaluated with color doppler and 2D Echo.

Surgical considerations

The IJC vein is preferred over SCV due to anatomic advantage and fewer complications. Due to favorable venous anatomy, the right IJV is preferred over left unless contraindicated. Only the distal shunt insertion procedure will be reviewed here.

The patient is positioned supine, preferably on a radiolucent table with head turned to opposite side with mild extension of neck. Surgeon, assistant, and scrub nurse are ergonomically positioned to allow the fluoroscope during the placement of distal catheter.

For a VA Shunt, the distal catheter can be introduced into right atrium via an open method with IJV exposure or more commonly by using the percutaneous Seldinger's technique.

The original technique is suggested using the facial vein if large enough and easily accessible to insert the distal tubing (alternatively the IJV can be used, especially in small children). In an open method, the IJV is exposed after a vertical incision at the medial side of sternocleidomastoid muscle and catheter introduced after a small stab incision into the IJV. The distal catheter is then secured to the vein using a 6-0 Prolene suture in a purse string fashion.

In the percutaneous method, the right IJV is punctured at the cricoid level with an introducer needle at 30–40° angle to skin targeting the ipsilateral nipple. This is done while simultaneously palpating the carotid at superior apex of the sternocleidomastoid (SCM) muscle triangle. In case of altered anatomy due to previous surgeries or irradiation, ultrasound guidance is advised. The guidewire is inserted through the needle to approximately T6–T8 vertebral level (which corresponds to mid atrium) under fluoroscopic guidance with close monitoring of ECG or trans esophageal echocardiogram when available. A stab wound is made for the dilators. The introducer needle removed keeping the guide wire *in situ*. The serial dilators of the hemodialysis catheter are used to enlarge the track that is prepared over the guide wire. The dilator is removed, keeping the guide wire in place, and lastly, a peel-away sheath of 10-12 F (Mahurkar Chronic Carbothane catheter kit, Covidien, Mansfield, Massachusetts, United States) size is introduced over the previous dilator. The guide wire and the inner dilator are removed, leaving an open channel for passage of the distal catheter (brought to this site from above). The catheter is measured and cut to the approximate length for reaching the D6 spinal level. A heparin flush can be given in to the IJV before placement of the catheter. The distal tube is gently passed into the peel-away sheath with a simultaneous fluoroscopy and ECG tracking. After confirmation of proper distal tip placement, the outer sheath is gently peeled off while securing the catheter *in situ*.

Sometimes, peel-away sheaths are not available or the dilators are of a smaller diameter that will not allow passage of the distal catheter (i.e., Chabbra shunt (Surgiwear, India) that has an outer diameter of 7.5 F). In such instances, the distal catheter tube is measured and divided from the neck stab wound and advanced into the atrium over the stand alone guide wire (after dilator removal). The proximal and distal tubing are finally joined over a connector and secured.

The final position of the tube is confirmed again with the fluoroscope after repositioning the neck to the neutral position. If the catheter tip is not visible properly, a contrast agent can be administered via the catheter to improve visualization.

Final hemostasis is verified and the wounds are closed, with pressure padding applied over the cervical stab wound for a day.

Postoperative evaluation

A chest x-ray should be done postoperatively to document the position of the catheter tip and to rule out a pneumothorax. Postoperatively, ECG should be monitored closely for 1–2 days for cardiac arrythmias and if they persistently occur, the distal catheter can be withdrawn by 1–2 cm.

Complications

Complications after a VA shunt operation may be early or delayed [Table 1]. Early complications can be arrhythmias, pneumothorax, thrombosis, endocarditis, or pulmonary thromboembolism.[14] Venous thrombosis usually responds to low molecular weight heparin with or without the need for shunt revision. Sepsis with endocarditis needs urgent removal of the shunt system with appropriate culture sensitive antibiotics with simultaneous external ventricular drainage. Pulmonary thromboembolism is managed with low molecular weight heparin after removal of the shunt.

Table 1: Early and late complications after a VA shunt operation

Complications of VA Shunt	
Early complications	**Delayed complications**
Bleeding	Outgrowing the shunt
Arrhythmias	Shunt nephritis
Venous thrombosis	Shunt occlusion
Endocarditis and sepsis	Pulmonary thromboembolism
Pneumothorax	Delayed intracranial hemorrhage
Wound infection	Cor Pulmonale

Delayed complications such as shunt tip migration in growing children, shunt nephritis, delayed shunt occlusion due to venous thrombosis or shunt tip occlusion, or chronic pulmonary micro thromboembolism leading to life-threatening cor pulmonale.[15]

Shunt migration is one of the most common complications in VA shunt and requiring an elective revision in more than two-third of the patients.[16] In children where VA shunt is done before the cessation of growth spurt, chest x-ray every 2–3 years may give us an early clue of shunt migration. Shunt-related glomerulonephritis is a rare, reversible immune complex-mediated infection leading to end-stage renal disease. This complication may occur within a month or be diagnosed several decades later. Most patients will require antibiotic therapy with shunt removal, and will generally have a favorable outcome.[17,18] VA Shunt malfunction due to any of the above causes will present with features of raised intracranial pressure (ICP) and should be immediately noted and the cause must be addressed.

The ventriculopleural shunt

The pleural cavity is an excellent option for patients who are otherwise not good candidates for peritoneal or other distal placements.[19] Although rarely used today, this operation offers long-term successful shunt function for many individuals, and can be considered in children as young as 4–5 years of age. As such, the neurosurgeon should familiarize himself or herself with this technique and its nuances. Interestingly, the pleural cavity also has a vacuum that allows improved shunt function in certain cases. In addition, this cavity can accommodate extra tubing to allow for a child's growth.[20] Most patients tolerate a shunt within the pleural space, and the large surface usually accommodates the typical amount of CSF output in the hydrocephalic patient (after the initial period of adjustment to the new challenge).

Brief history and evolution of VPL shunt

Ventriculopleural (VPL) shunting for hydrocephalus was first introduced by Heile in 1914.[21,22] Hoffman, *et al*.[20] (1983) gave support to this option and provided a nice historical review, citing an initial attempt to drain CSF into the thoracic duct and pleural cavity by Ingraham and Sears. They chronicled other refinements by Ransohoff in 1954 and 1963, and Fein and Rovit, Venes (1979). With the advent of the VA shunt, this technique has lost some of its original popularity, although it remains an excellent option for challenging cases. The worldwide experience with VPL is limited in the literature but historically this technique has enjoyed a positive benefit for the patients in most instances.[22-25]

At King George Hospital, part of Andhra Medical College, Visakhapatnam, India (a tertiary care facility), only one VPL shunt was performed out of 112 shunt operations over the past 3 years. This speaks to the rarity of this surgical option in most centers and is offered for a patient who has exhausted most other options for effective shunting.

Technique

The proximal insertion technique is the same as others, and entering the pleural cavity is most easily done using a trocar. An open technique is also feasible but may be more cumbersome and time-consuming.

The pleural space is accessed after distal tunneling using a stabbing session and a trocar is used above the rib (to avoid the vascular and neural bundle on the lower side). The anesthesiologist requested not to ventilate the patient during penetration, and the area is continuously irrigated so as to avoid a large pneumothorax. A positive pressure Valsalva maneuver is performed by the anesthesia team to expel any excess air from the pleural cavity prior to removing the trocar. Approximately 25–30 cm of distal tubing can be easily inserted into the pleural cavity even in small children (this length helps keep the shunt in the pleural space, decreasing the possibility of external migration).

An immediate postoperative x-ray is obtained to assess the tube placement and free air in the pleural cavity. The patient will need to be followed up for several days for clinical issues (i.e., breathing difficulties) and radiographic deterioration (i.e., increasing plural effusion). The amount of pleural fluid buildup typically increases over the next few days prior to improved absorption.

Not every patient can readily absorb CSF output and the cavity needs to be 'primed' over a few weeks. During the initial phases of placement, the patient needs to observed closely for enlarging pleural effusions that sometimes require periodic thoracentesis. The patient will almost always maintain a small amount of pleural fluid that can be verified by x-rays, especially in the lateral decubitus position.

Rarely, the patient cannot tolerate the device and another distal insertion site might need to be considered. Pneumonia occurring close to the catheter may extend into the pleural space, leading to pleurisy or fibrosis. Loculated fluid collections may occur, causing issues with fluid absorption or symptoms of shunt malfunction.[26,27]

Surgical consideration (open technique)

An incision is made over sixth intercostal space and the pleura is entered at the upper border of the rib to avoid injury to neurovascular bundles that lie inferiorly. The intercostal muscles are dissected with a curved hemostat and the pleura is exposed. Positive pressure is performed by the anesthetist during pleural penetration and distal shunt insertion. Entry into the chest cavity is accomplished with a small mosquito hemostat along with the distal shunt tubing.

Approximately 25–30 cm of tubing is gently and freely advanced into the pleural cavity while the area is irrigated to minimize air entry. The wounds are closed after confirming that there are no air or CSF leaks. Rarely, additional deep sutures are required if a pleural opening is made.

An immediate 2-view chest x-rays are taken to asses distal tube placement and amount of free air in the chest cavity. Serial films are required (using lateral decubitus positioning) to evaluate CSF accumulation and the patient is followed closely for respiratory issues. Enlarging pleural effusions sometimes require periodic thoracentesis.

Complications

Complications after VPL shunt surgery include infections, CSF over drainage, catheter obstruction, distal catheter retraction,

Table 2: Early and late complications after a VPL shunt operation

Complications of VPL Shunts	
Early complications	**Delayed complications**
Bleeding	Pleural effusion
Pneumothorax	Shunt nephritis
Wound infection	Distal occlusion
Pleural effusion	Fluid loculation
	Outgrowing the shunt

and symptomatic and asymptomatic pleural effusions Table 2. In rare instances, loculations or focal abscesses/empyema may occur after a bout of pneumonia infecting the foreign body in the pleural space. The possibility of scarring and pleurisy with a pain syndrome may occur, but relatively unusual.[15,23,22]

Key points regarding VPL shunts

1. The pleural cavity should be without any fibrosis or adhesions and the lung should be free from any underlying pathologies.
2. Children with small chest and decreased pleural cavity may not accommodate or absorb CSF adequately. The patient should be above 5 years of age having good volume of pleural cavity.
3. Due to the negative pleural pressure, there may be over drainage of CSF resulting either slit ventricle syndrome or large pleural effusion.[28] Lower end with anti-syphon valve may overcome this.[29]
4. The distal tubing in the pleural cavity may irritate the pleura and produce pain. There are no studies regarding ideal tubing length, although it is known that short 9 (less than 10 cm) may migrate out of the pleural space.
5. The patients must be thoroughly screened pre- and post-operatively for pulmonary and pleural reserves. Inadvertent injury to lung should be evaluated with post procedure chest x-rays.
6. Entry into pleural space by trocar insertions is an alternative for open procedure 2.[30,31]

The failure rates may be equal as that of VP shunts, because similar mechanisms causing inadequate absorption may play a role in both sites, resulting in persistent pleural effusions and causing symptoms. In such cases, pleural shunt removal may be necessary.

Discussion and Conclusion

Among the various time-tested procedures for CSF diversion, the VP shunt remains the gold standard. In select cases and because of technical advances, the minimally invasive endoscopic third ventriculostomy (ETV) operation has emerged as a better alternative. However, in few situations where both VP and ETV procedures have failed, other options need to be explored to minimize the morbidity. For such patients, VA and VPL shunts remain an excellent alternative (along with others such as ventriculo-subgaleal or ventriculo-gall bladder options).

The VA shunts are considered an excellent alternate for patients with abdominal issues like impaired absorption, peritoneal tuberculosis, and the like. Improved shunt function has made this a reliable alternative for many surgeons. However, the major drawbacks of infection, chronic lung/kidney issues or multiple revisions in the pediatric population remain as major concerns of this procedure.

The VPL shunts are an effective alternative to overcome some of these challenges. The revision rate is low and for the most part, the operation is similar to a conventional shunt. Only the distal end insertion into pleural cavity by a trocar or conventional open method are different. This is relatively a simple technique, but the surgeon should be careful about lung contusion or development of a large pneumothorax. Patients often require to improve CSF absorption from the pleural space, and in some cases become symptomatic with respiratory issues.

In spite of few such challenges, the VA and VPL shunts still remain effective alternatives for patients with recurrent VP shunt failures related to defective absorption, infections, or frequent malfunctions. Especially with technical advances of percutaneous insertion (Seldinger method for VA and trocar insertion for VPL), the standardized procedures have become less cumbersome and more effective. They should be added to the surgeon's options for managing patients with complex hydrocephalus.

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Conflicts of interest

There are no conflicts of interest.

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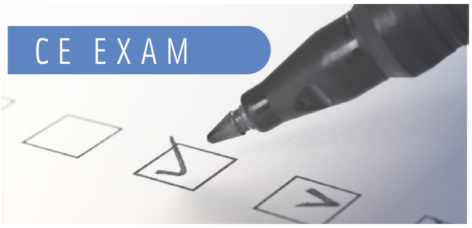

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1. Which of the following physiological functions of the heart contribute to a positive outcome of a ventriculoatrial (VA) shunt?
- **A.** Left ventricle high pressure
- **B.** Right atrium low pressure
- **C.** Right ventricle low pressure
- **D.** Left atrium high pressure

2. Which vein is the preferred choice for surgeons to access the atrium?
- **A.** Left external jugular
- **B.** Left internal jugular
- **C.** Right external jugular
- **D.** Right internal jugular

3. What type and size of suture should the CST have available for the surgeon to secure the distal portion of the VA catheter to the vein when the open method is utilized?
- **A.** 6-0 Prolene
- **B.** 5-0 Vicryl
- **C.** 7-0 Nylon
- **D.** 8-0 Monocryl

4. What level is the guidewire inserted through the needle when the percutaneous method for a VA shunt is utilized?
- **A.** T1 – T3
- **C.** T6 – T8
- **B.** T3 – T5
- **D.** T7 – T9

5. What size French peel-away sheath should the CST confirm is available for use when the percutaneous method for a VA shunt is performed?
- **A.** 4 - 6
- **B.** 7 - 9
- **C.** 10 - 12
- **D.** 13 - 15

6. Which of the following is the most common complication of a VA shunt?
- **A.** Migration
- **B.** Venous thrombosis
- **C.** Cor pulmonale
- **D.** Glomerulonephritis

7. What length of distal tubing in centimeters is required for insertion into the pleural cavity?
- **A.** 9 - 13
- **B.** 14 - 18
- **C.** 19 - 24
- **D.** 25 - 30

8. Which intercostal space is the incision made for an open procedure for ventriculoperitoneal (VP) shunt placement?
- **A.** Second
- **B.** Fourth
- **C.** Sixth
- **D.** Eighth

9. A patient should be more than ___ years of age to have an adequate pleural cavity when a VP shunt is placed.
- **A.** 2
- **B.** 3
- **C.** 4
- **D.** 5

10. What solution should the CST have ready when the surgeon wants to flush the internal jugular vein before placing the catheter during a VA shunt placement?
- **A.** Lactated ringers with antibiotic
- **B.** Heparinized saline
- **C.** 0.9% sodium chloride
- **D.** Sterile water

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