Percutaneous Placement and Management of Peritoneovenous Shunts

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Abstract

Keywords

- ascites
- pleural effusion
- catheter drainage
- shunts
- interventional radiology

Peritoneovenous shunts are used in the treatment of recurrent ascites or recurrent pleural effusions. Generally speaking, the shunts allow passage of ascites or pleural effusions (by either passive or active means) back into the central venous system. The most recent development in peritoneovenous shunts, known as the Denver Shunt, is a modification of a shunt developed for the treatment of hydrocephalus. In recent years, the Denver shunt has been placed by interventional radiologists. It is used to treat both cirrhotic and malignant effusions in the peritoneal and pleural cavities. Reported complications of the shunt are shunt occlusion, infection, post-shunt coagulopathy, deep vein thrombosis, catheter breakage, and leaks. This article discusses the technical aspects related to the percutaneous placement and maintenance of the Denver Shunt.

Objectives: On completion of this article, the reader will be able to identify the indications for and general techniques used in the placement of peritoneovenous shunts.

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In 1974 Harry H. LeVeen introduced a peritoneovenous shunt that he designed to transmit ascitic fluid from the peritoneal cavity back into the central venous circulation. The shunt, which was surgically placed, had a one-way valve to prevent backflow of venous blood.¹ Flow through the shunt depended on a pressure gradient between the fluid-filled peritoneum and the central venous system. It worked best in cases of high-volume ascites, most often associated with end-stage liver disease. In 1979, Lund and Newkirk introduced a unidirectional pump that could be manually compressed to move fluid through the tubing during times when the pressure gradient was too low to initiate flow or when elements in the peritoneal fluid coagulated and obstructed flow. The most

recent development is a modification of a shunt developed for the treatment of hydrocephalus,² commonly known as the Denver Shunt, and it is currently marketed by the CareFusion Corporation (San Diego, CA). The LeVeen Shunt is no longer commercially available. The Denver Shunt is used to treat both cirrhotic and malignant effusions in the peritoneal and pleural cavities.^{3–5} Reported complications of the shunt are shunt occlusion, infection, post-shunt coagulopathy, deep vein thrombosis, catheter breakage, and leaks.

Shunt Design

The shunt is offered with either a single or a double valve. These one-way (unidirectional) valves prevent the reflux of blood into the venous limb of the shunt. In the double valve iteration, the first valve opens for flow when the pressure exceeds 3 cm-water (cm H₂O). The second valve acts as a “check valve” to prevent reflux of ascitic fluid or blood from the venous limb of the shunt into the valve chamber while it is refilling following compression “pumping.” Therefore the two-valve model is more effective at preventing reflux and is the shunt most commonly placed.

The one-valve shunt may be most appropriate in cases where the ascitic or pleural fluid is very viscous or when the daily production of ascites is unusually large. Measures to

Table 1 Anticipated Flow Rates for Various Denver Shunt Systems

Venous Catheter Flow Rate		
Catheter Size	Double Valve	Single Valve
11.5 F	20–30 mL/min	30–40 mL/min
15.5 F	25–40 mL/min	40–55 mL/min

prevent venous reflux during refilling of the one valve chamber is discussed later and must be emphasized during postprocedure instructions to the patients and their caregiver.

The venous limb (catheter) of the shunt can be obtained with either 11.5F or 15.5F tubing (catheter). The smaller tubing may be chosen when the shunt is placed via the saphenous vein or the subclavian vein, where the larger tubing may occlude the vein as it passes between the first rib and the clavicle. Shunt flow characteristics based on a pressure of 10 cm H₂O are presented in ►Table 1.

Shunt Placement

The procedure can be performed on an outpatient basis; however I prefer to admit the patient for overnight observation following placement. The shunt placement procedure is routinely performed under moderate sedation. Broad-spectrum prophylactic antibiotics are given prior to the procedure and for 7 to 10 days after the procedure. The anterior and lateral aspects of one side of the body, from neck to pelvis, are prepped and draped in standard surgical sterile fashion. The side that is prepared is preferably the side of the abdomen or chest with the most fluid.

The site of the compressible valve and the course of the caudad and cephalad tubing, and their entries into the peritoneum/pleural space and systemic veins, respectively, are planned. The compressible valve must be placed over a firm, noncompressible area of the rib cage, but low enough so that all of the side holes of the caudal limb are in the peritoneal or pleural cavity. In addition, the pump valve must be 2 to 3 cm above the skin incision so that it can be compressed immediately following placement without causing trauma to the suture line. The venous access can be jugular or subclavian; as noted earlier, it is preferable to use the small caliber catheter (11.5F) when opting for subclavian venous access. The jugular vein can accommodate either size catheter; the current author prefers a jugular approach when feasible.

Generous local anesthetic is recommended for the peritoneal and venous access sites, the subcutaneous tunnel, and the chosen pocket site for the pump. I prefer a combination of bupivacaine without and with epinephrine, so that the pain relief is as prolonged as possible and the patient will not be discouraged from pumping the shunt valve as directed. A total of 2 to 4 L of peritoneal or pleural (target) fluid are drained. The aim is to have the abdomen be relatively lax and not tense with fluid; however, enough fluid should remain in the peritoneum/pleural space to prime the shunt system and

maintain continuous low-volume flow following shunt placement. Some operators recommend draining the fluid entirely and replacing it with 4 L of normal saline before placing the shunt.

Venous access is established before pulling the superior shunt limb catheter through the subcutaneous track. The lateral margin of the internal jugular vein is punctured as close to the clavicle as possible under ultrasound guidance (similar to an internal jugular access for a central venous catheter). The 5F outer transitional catheter of the micro-puncture kit is left in place, and a 0.035-inch guidewire is advanced to the inferior vena cava with a hemostat clamped to the wire so it cannot be inadvertently dislodged or removed. The skin incision over the internal jugular vein is extended to accommodate the large superior limb/venous limb catheter (11.5 or 15.5F).

The shunt is “primed” by immersing the entire shunt in normal saline and by intermittently compressing the pump valve to purge it from the air within. A subcutaneous pocket for the pump valve is created before establishing a subcutaneous track. The pump valve should fit snugly in the subcutaneous pocket; if the pocket is too large for the pump, the extra space may allow hematoma formation, which is more susceptible to infection. Moreover, a wide pocket may cause the pump to move or flip. A subcutaneous pocket that is too tight for the pump causes tension of the overlying sutures approximating the incision and thus increases the risk of wound dehiscence.

The superior (cephalad) subcutaneous track is formed first from the apex of the subcutaneous pocket to the jugular venous access site. Attention is then drawn to the caudal limb. Creating a subcutaneous tract that is not watertight will discourage the flow of peritoneal/pleural fluid along the tubing into the pump pocket (►Fig. 1). A hemostat is used to dissect ~1 to 2 cm of subcutaneous tissue along the caudad margin of the dermatotomy created to place the pump valve. The tract being created should be at the depth of the pump cavity. I use an 18-gauge Chiba needle to extend the peritoneal/pleural track for 5 to 6 cm caudally before depressing the

Figure 1 Following a zigzag course by changing direction of the needle as it advances through the subcutaneous tissues (dotted lines) forms a tighter seal around the caudal limb of the shunt.

Figure 2 (A) Contrast injected through a Huber needle placed into the valve outlines the shunt chamber and the venous limb, disproving any obstruction. (B) The lack of reflux into the peritoneal limb confirms patency of the one-way valve mechanism (the linear density below the valve chamber is an opaque strip embedded in the wall of the peritoneal limb by the manufacturer).

needle tip and advancing it into the peritoneal/pleural cavity under ultrasound guidance. An effort to create a zigzag pattern to the course of the track should be made; this can be achieved either by changing the course of the needle tip every centimeter or by pulling the skin laterally in alternating directions as the needle is advanced in the subcutaneous tissue. The track is then dilated over a stiff guidewire and the caudal limb of the shunt introduced into the remaining fluid (peritoneal or pleural) through the peel-away sheath supplied in the commercially available kit. ► **Figs. 2–4**

The pump valve is then compressed as many times as necessary to initiate the flow of fluid through the supraclavicular portion of the shunt limb. A hemostat is placed on

the tip of the venous limb to stop the flow when needed. Next, the distance between the internal jugular vein and the mid-right atrium is measured. The shunt catheter venous limb is cut to the proper length, inserted through a peel-away sheath, and placed into the superior vena cava via the percutaneous internal jugular vein venotomy. The pump is “re-primed” by compressing the pump at least 25 times.

The incisions are closed using subcutaneous and transdermal interrupted sutures so that, should bleeding or peritoneal/pleural fluid collect around the tube, it will have a means of exit and not build up in the subcutaneous tissue/spaces. Sterile gauze dressings are placed over the incisions and changed when necessary. Patients are discharged with

Figure 3 (A) Contrast injected into the peritoneal limb does not enter the peritoneum, confirming obstruction of the catheter by debris. (B) Debris is removed by cleaning the lumen with a bronchial cytology brush. (C) Photograph of the bronchial cytology brush.

Figure 4 (A) Contrast injection into the valve chamber demonstrates debris obstructing chamber outflow toward the venous limb. (B) Following infusion of 2 mg of tissue plasminogen activator, a guidewire is used to dislodge debris from the valve and venous limb. (C) Completion image demonstrates restored flow through the valve and venous limb.

prescriptions for oral analgesics and antibiotics, a contact phone number, and, most importantly of all instructions, on how and when to compress the shunt pump. A return visit in 2 to 3 weeks to check the incisions and to be certain everything is proceeding properly is recommended.

Two specific caveats should be emphasized to patients and their caregivers postprocedure. First, for single-valve systems it is vitally important that the venous limb of the shunt is compressed while pressure on the single-valve chamber is released (but not while it is being compressed). If this is not done, blood will be drawn by negative pressure into the venous limb and eventually the shunt chamber, leading to occlusion of the entire system. This point is stressed in the patient instruction manual supplied by the company. It is a good idea to highlight this paragraph and read it to the patient and caregiver. Second, flow through the shunt is affected by patient position. Maximal flow will occur in the supine position, significantly less if the head and shoulders are elevated 45 degrees, and little or no flow if the patient is upright or sitting in a chair. Therefore manual pumping of the chamber should only be performed while the patient is in the supine position.

Commonly Encountered Problems

The two commonly encountered sets of problems center on patient education about pumping and pump care and ascitic fluid leakage.

Pumping and Pump Care

The most common problem encountered is that the patient or their caregiver is not pumping the valve properly or frequently enough. It is imperative that a physician member of the implanting care team invest time to be certain that patients understand how to pump the shunt properly before discharge. A recommended practice is to have the patient and/or caregiver describe their maintenance methods on each return visit or if they return with a particular problem.

Ascitic Fluid Leakage

Leakage commonly occurs through the most inferior skin incision and is most often associated with poor flow through the system related to improper pumping. However, it may be due to loose placement of the caudal limb. This can sometimes be helped by placing sutures around the shunt tube and leaving them in place for several weeks. However, the operator must also make sure that the sutures do not significantly compress the peritoneal limb.

Evaluation and Repair of the Denver Shunt

Denver Shunt Evaluation

It is important to be able to evaluate the Denver shunt and its components. These evaluations are either done by manual palpations/manipulations or by radiography. A shunt chamber that is firm and difficult to compress indicates an obstruction of the venous limb or coagulated blood in the pump chamber. A pump chamber that is slow to refill following compression indicates an obstruction of the caudal limb.

A description of radiologic evaluation of a Denver shunt is described here. It is best to evaluate the shunt with a non-coring needle such as the Huber needle or an 18-gauge Chiba needle with the stylet in place. It can be placed into the shunt chamber and either limb without causing significant damage. The needle is placed into the lumen of the superior limb of the shunt, and contrast is injected under fluoroscopy to identify and clear any accumulated material. The superior limb of the shunt is then compressed cephalad to the needle while contrast is injected. Contrast reflux into the pump system will identify a defective valve that requires replacement. After placement of a needle into the caudal limb, injection of contrast into the shunt limb below the valve should reflux into the peritoneal/pleural cavity when the limb is compressed between the needle and the valve, or flow through the valve if compressed caudad to the needle puncture site.

Appendix 1 Commercially Available Denver Shunt Ordering Information

Denver Ascites Shunts	
Catalog no.	Description
42-2000	Double-valved, 15.5 F venous catheter. Flow rate 25–40 mL/min
42-2005	Single-valved, 15.5 F venous catheter. Flow rate 40–55 mL/min
Optional Components	
10383-006	Percutaneous lead introducer set, 12 F with guidewire
10383-010	Percutaneous lead introducer set, 16 F with guidewire
42-3100	Tunnelor, 18 F, 15 inch (for initial placement or revision)

Source: http://www.carefusion.com/pdf/Interventional_Specialties/Denver_shunt_brochure.pdf.

Appendix 2 Commercially Available Denver Shunt Kit Ordering Information and Contents

Denver PAK (Percutaneous Access Kits)	
Catalog no.	Description
42-2050	Denver PAK: Double valved shunt, 11.5F venous catheter Flow rate: 20–30 mL/min
42-2055	Denver PAK: Single valved shunt, 11.5F venous catheter Flow rate: 30–40 mL/min
The following components are included in the PAK product codes: <ul style="list-style-type: none"> • Shunt with 11.5F venous catheter and 15.5F peritoneal catheter • 12F peel-away introducer • 16F peel-away introducer • 15F, 13-inch tunnelor • "J"-tip guidewires (two) • 12-mL syringe • 18-gauge needles (two) 	

Source: http://www.carefusion.com/pdf/Interventional_Specialties/Denver_shunt_brochure.pdf.

The infusions described will also flush out debris that was blocking the shunt system. Shunt function should be restored following re-priming the system by pumping the valve.

If debris is present that cannot be removed in this manner, a guidewire can be placed into the shunt limb through the Chiba needle should dislodge the debris. Occasionally, the caudal limb of the shunt becomes lodged between inflammatory or neoplastic adhesions. An attempt should be made to reposition the shunt catheter using similar means to those used to reposition peritoneal dialysis drains/catheters.⁶ Furthermore, the peritoneal/pleural and venous limbs can be

replaced and repositioned if attempts to recanalize them are unsuccessful. (see the appendices for replacement availability and ordering instructions). **Appendix 1** and **Appendix 2** It may be possible to fibrinolyse the clotted blood in the pump chamber that cannot be removed otherwise by injecting tissue plasminogen activator directly. Replacement pumps are not sold separately, but it should be possible to replace the defective pump while retaining the functioning venous and peritoneal/pleural limbs by splicing a new pump to the existing limbs using nylon tubing connectors available from the manufacturer (**Appendix 3**).

Appendix 3 Commercially Available Denver Shunt Replacement Component Ordering Information

Replacement Components	
Catalog no.	Description
42-2321	Venous catheter, 15.5F, 60 cm
42-2322	Peritoneal catheter, 15.5F, 27 cm
42-2521	Venous catheter, 11.5F, 60 cm
42-3019	Nylon tubing connector (required for all replacements)
42-3100	Tunnelor, 18F (optional component)
10383-006	Percutaneous lead introducer set, 12F with guidewire (optional component)
10383-010	Percutaneous lead introducer set, 16F with guidewire (optional component)

Source: http://www.carefusion.com/pdf/Interventional_Specialties/Denver_shunt_brochure.pdf.

Care following Denver Shunt placement should include observation for consumptive coagulopathy/disseminated intravascular coagulopathy (DIC), and fluid overload. Obtaining a DIC profile may be advantageous; such screens include prothrombin time, active partial thromboplastin time, fibrinogen, D-dimer, and antithrombin III activity. Measuring serum creatinine and a 24-hour urine volume may also be helpful. I usually see patients 7 to 10 days following the procedure for an evaluation and counseling.

More information about Denver shunt design, care and management is available at the manufacturer's Web site (<http://www.carefusion.com>).

Conclusion

The practice of percutaneous placement, management, and maintenance of Denver shunts is an important skill set in the armamentarium of interventional radiologists for the management of portal hypertension complications and certain malignancies. Meticulous technique is required for Denver shunt placement to achieve the desired clinical outcomes. Intricate knowledge of the design and maintenance manage-

ment of Denver shunts is required for any interventional radiologist caring for these patients.

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