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Ventriculoperitoneal shunts: What nurses need to know

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Abstract: A ventriculoperitoneal shunt (VPS) is the most common type of implanted cerebrospinal fluid shunt system. Nurses may care for patients who have undergone shunt placement or revision. This article discusses the indications for VPS placement in adults, possible complications, and nursing care for patients following a shunt placement procedure.

Keywords: antisiphon valve, cerebrospinal fluid shunt, CSFoma, hydrocephalus, normal pressure hydrocephalus, peritonitis, pseudocyst, ventriculoperitoneal shunt

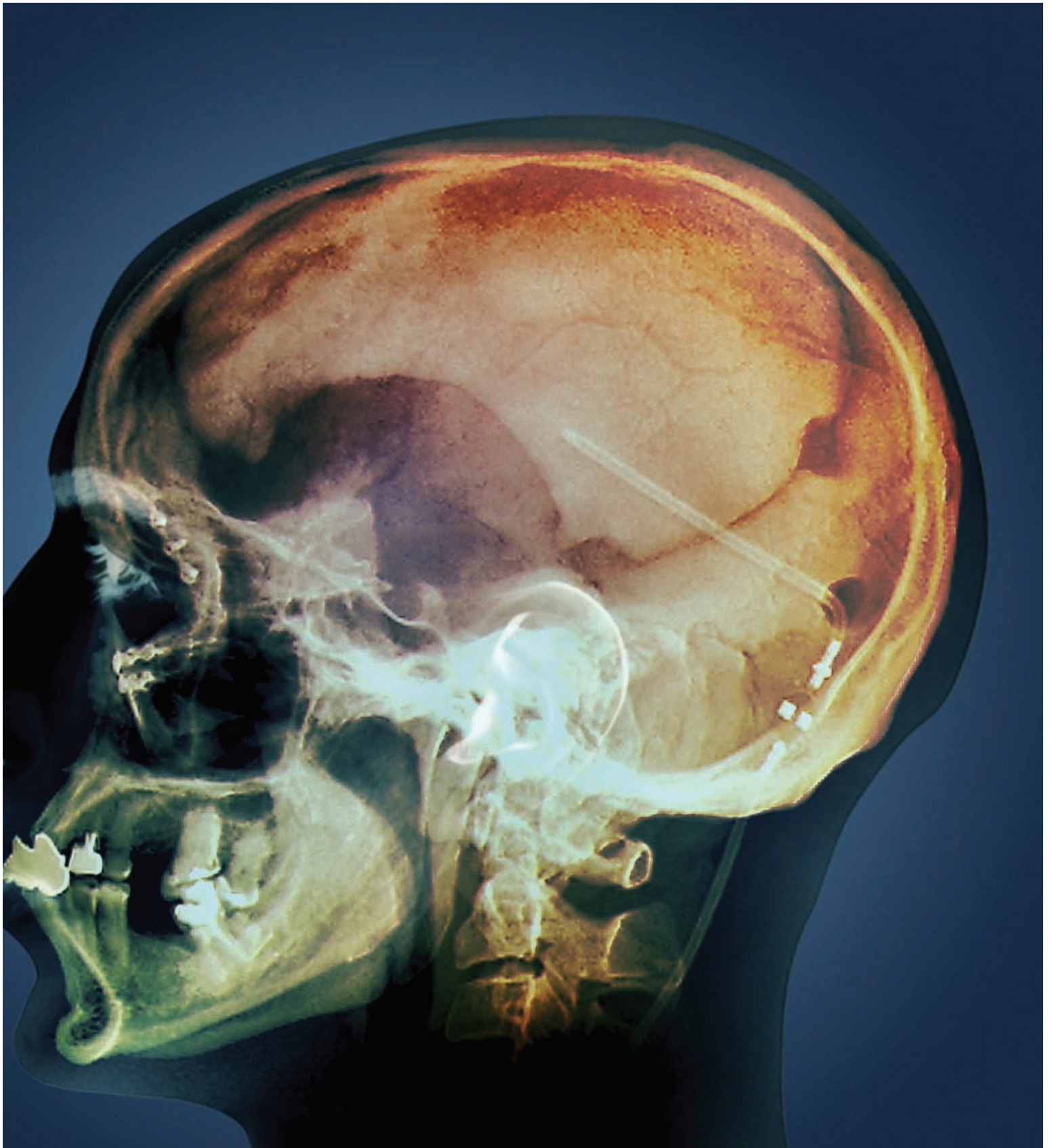
AN IMPLANTED cerebrospinal fluid (CSF) shunt system diverts excess CSF from the brain to another part of the body. A ventriculoperitoneal shunt (VPS) is the most common type of implanted CSF shunt system.^{1,2} An estimated 33,000 CSF shunt placement procedures are performed in the US annually, with most being VPS.³

Although VPS placement is a commonly performed neurosurgical procedure and shunt valves and systems continue to be refined, the lifetime VPS revision rate approaches 50%, and VPS malfunctions are reported in up to 85% of patients by 10 years.^{3,4} Consequently, nurses may care for patients who have undergone shunt placement or revision. This article discusses the indications for VPS placement in adults, possible complications, and nursing care for patients following a shunt placement procedure.

Obstructions to CSF circulation

Conditions that result in obstruction of CSF circulation and/or absorption can lead to the need for CSF diversion through a VPS or another implanted shunt. Overproduction or obstruction of CSF flow and/or impaired absorption leads to ventricular dilation, hydrocephalus, and increased intracranial pressure (ICP).^{5,6} Indications for CSF shunting include signs and symptoms of clinical deterioration due to an increase in CSF volume within the brain, often leading to increased ICP.⁷⁻⁹ (Normal ICP is 5 to 15 mm Hg in adults.⁶)

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Hydrocephalus, described as both an active and progressive dilation of the ventricular system, occurs when CSF production exceeds the absorption rate (see *Go with the flow: Normal anatomy and physiology*).^{5,6} Considered a clinical syndrome, it can result from CSF overproduction, obstruction of CSF circulation, or decreased CSF reabsorption.⁵

Hydrocephalus can be subdivided into *noncommunicating* or *communicating* hydrocephalus.^{5,10,11}

- In noncommunicating or obstructive hydrocephalus, the flow of CSF between the ventricles is obstructed or blocked. In adults, brain tumors, especially intraventricular tumors, are a common cause of noncommunicating hydrocephalus.⁶
- Communicating hydrocephalus occurs when there is a defect in the

sites of absorption of CSF.⁶ This form is called *communicating* because CSF can still flow between the ventricles. Most cases of communicating hydrocephalus are due to subarachnoid hemorrhage (SAH) or infection such as meningitis or gradual dysfunction due to aging.⁶ Debris from blood breakdown in SAH or exudate associated with meningitis can obstruct the arachnoid villi and prevent them from absorbing CSF normally.⁵ Signs and symptoms of hydrocephalus are variable, depending on the patient's age and type of hydrocephalus (see *Signs and symptoms of hydrocephalus in older children and adults*).

A subset of communicating hydrocephalus seen in older adults is normal pressure hydrocephalus (NPH), another indication for VPS.

This is defined by cerebral ventricular dilation seen on brain imaging and normal CSF pressure on lumbar puncture. It is associated with the clinical triad of gait disturbance, cognitive impairment, and urinary incontinence.¹² NPH may be idiopathic or develop as a complication of SAH, head trauma, infection, or a tumor.^{6,11} An estimated 700,000 Americans have NPH, but the actual number may be much higher because the disorder is often underdiagnosed.⁶

A useful diversion

Ventricular shunting is used to manage hydrocephalus by routing excess CSF to another part of the body. The peritoneal cavity is the most common extracranial site for distal shunt catheter termination because it is easy to access and provides the

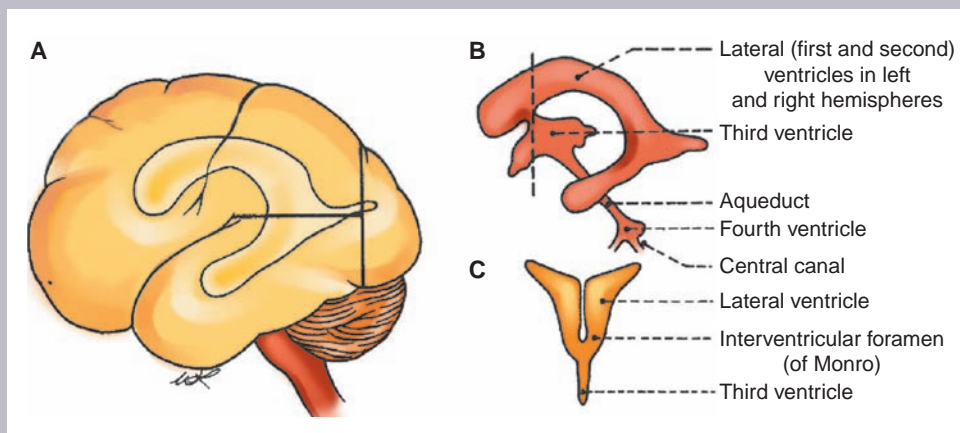
Go with the flow: Normal anatomy and physiology⁵

The major source of CSF is secretions from the choroid plexus, a cauliflower-like structure located in portions of the lateral, third, and fourth ventricles. The choroid plexus is a collection of blood vessels covered with a thin coating of ependymal cells. CSF is constantly secreted from these surfaces. It is estimated that the amount of CSF produced daily by the choroid plexus is 25 mL/h, or 500 to 600 mL per day.

CSF is formed by

choroid plexuses in the two lateral ventricles and flows through several structures, including the third ventricle and the cerebral aqueduct of Sylvius, before it enters the subarachnoid space. Most of the CSF produced daily is reabsorbed into the arachnoid villi, which are projections from the subarachnoid space into the venous sinuses of the brain. Arachnoid villi are very permeable and allow CSF, including protein molecules, to exit easily from the subarachnoid space into the venous sinuses, including the superior sagittal sinus.

CSF flows in one direction through the arachnoid villi (most of which are located in the subarachnoid space of the cerebrum), which have been compared with pressure-sensitive valves. When CSF pressure is greater than venous pressure, CSF leaves the subarachnoid space. As pressures are equalized, the valves close.

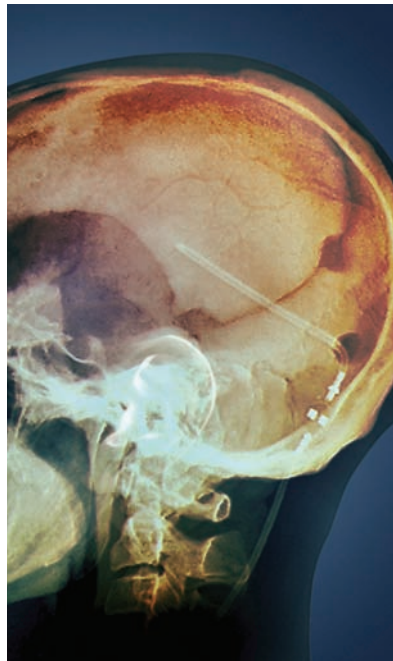


A: Lateral aspect of the left cerebral hemisphere showing the contour of the lateral ventricles and their relation to the cerebral lobes.
 B: Lateral outline of the four ventricles.
 C: Frontal (coronal) section of the lateral and third ventricles at the level of the dotted line (B), showing their communicating interventricular foramen.

most reliable absorption of the diverted CSF.³ Another less common CSF shunt option may be chosen if a VPS is contraindicated (for example, because of recent or impending abdominal surgery, recent peritonitis, or multiple abdominal adhesions).⁶ Other CSF shunt options include lumbar-peritoneal, ventriculo-atrial, ventriculo-pleural, or ventriculo-gallbladder shunting.¹³

VPS systems have four basic components: the proximal (primary or inflow) catheter, the reservoir, a one-way valve, and the distal (terminal or outflow) catheter.^{5,6,8,13}

- The *proximal catheter*, which drains CSF from the ventricle, typically originates in one of the two lateral cerebral ventricles.
- The proximal catheter connects to a *reservoir* in the overlying subcutaneous tissue. Although not always used, a reservoir provides support to the proximal catheter, which can prevent kinking as it curves exiting the skull. It is also useful as an access to obtain CSF samples and for ICP monitoring.
- From the reservoir, a *one-way valve* controls CSF flow into the distal catheter.
- The *distal catheter* is tunneled subcu-



The shunt valve is engineered to control ICP over a range of postural positions and pressures.

taneously and commonly terminates in the peritoneal cavity via a separate incision. Shunted CSF is then absorbed by the peritoneal cavity.

To prevent infection associated with shunt placement, antibiotic-impregnated shunt systems are increasingly being used.¹⁴

CSF shunt valve types and function

Within the shunt system, the valve functions as a flow-resistance mechanism and is engineered to control ICP over a range of postural positions and pressures. Most shunt valves operate on the difference between the pressure at the proximal catheter tip and the pressure at the drainage end. This pressure gradient is called *differential pressure* (DP).¹⁵

CSF shunt valves have either fixed or programmable (adjustable) pressure settings. Fixed shunt valves,

which are not programmable, have opening and closing pressures set by the manufacturer and are not adjustable. They function as a pop-off valve and have fewer parts and are potentially associated with fewer complications. However, if the CSF drainage rate needs to be adjusted, a fixed valve cannot be reprogrammed and the patient will need another surgical procedure.^{6,8,15}

With programmable valves, the opening and closing pressures can be adjusted without the need for a surgical procedure. Using a transdermal magnetic device, a low-pressure setting can be changed noninvasively to a medium-pressure setting. Although the programmable valves are more expensive than fixed valves, they may be associated with fewer surgeries as the programmable valve can be adjusted based on changes in the patient's clinical status.^{6,8,18}

CSF flow dynamics

Siphoning of CSF is a posture-related "suction" effect on CSF flow dynamics through the shunt system caused by increased hydrostatic pressure with the patient in the upright position. Siphoning can cause rapid overdrainage of CSF from the brain. As discussed below, overdrainage can cause collapse of the ventricles and tear blood vessels.^{2,16,17} Based on the results of the Study of Idiopathic Normal Pressure Hydrocephalus on Neurological Improvement (SINPHONI) and more recently SINPHONI-2 trials, the programmable DP antisiphon valve is commonly recommended as the first-line shunt valve to prevent overdrainage.^{17,18}

Shunt valve designs include slit, miter, diaphragm, and spring-loaded ball-in-cone. Shunt valves can be set at a fixed opening and closing pressure or can be externally programmed using magnetic tools.¹⁶ This is useful for the patient whose

Signs and symptoms of hydrocephalus in older children and adults²⁸

- headache
- increased ICP
- anorexia
- lethargy or restlessness
- deteriorating mental status
- difficulty walking
- diplopia
- incontinence
- irritability
- nausea and vomiting
- seizures.

CSF drainage needs will change over time.

Note that programmable shunt valve settings must be checked and confirmed following MRI, which could potentially read a programmable shunt to an inappropriate setting. If uncorrected, this could lead to significant complications related to over- or underdrainage of CSF.¹⁹

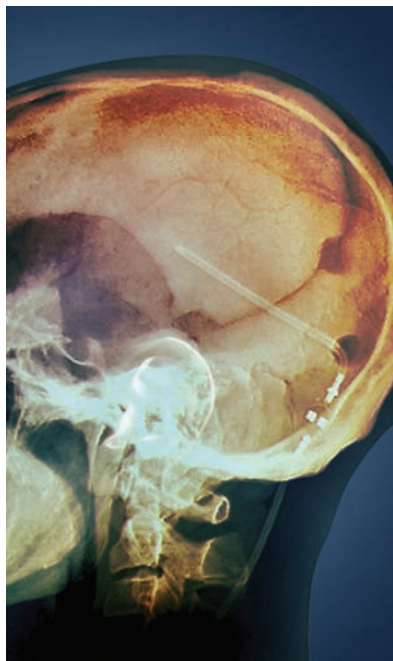
Perils of CSF over- and underdrainage

The goal of cerebral ventricular shunting is to regulate the flow of CSF in order to control the volume of CSF, ventricular dilation, and ICP.¹⁵ CSF **overdrainage** can result in the cerebral ventricles shrinking or collapsing, causing the meninges to pull away from the inner surface of the skull. Overdrainage can cause a condition called *slit-ventricle syndrome*, which is more common in children and in young adults who have had a shunt in place since childhood. Slit ventricle syndrome can cause severe but intermittent headaches that are often relieved only by lying down.²⁰⁻²² In adults, overdrainage can tear arterial or venous blood vessels, which can become a neurosurgical emergency.⁶

CSF **underdrainage** causes the cerebral ventricles to enlarge in conjunction with signs and symptoms of hydrocephalus. When underdrainage occurs, the patient may need a shunt revision or, if the valve can be externally adjusted, the valve settings can be interrogated and reset magnetically.^{6,22}

VPS complications

Shunt malfunction and infection are the most common VPS complications, according to the Hydrocephalus Association.²² Obstructions causing shunt malfunction are often due to CSF protein or debris buildup. The



Although the risk of shunt complications is highest in the first year following shunt placement, they can occur at any time.

shunt can become obstructed at any section of the system, from the ventricular catheter in the brain to the distal catheter.²² Because a VPS obstruction leads to increased ICP, signs and symptoms include headache, vomiting, lethargy, irritability, and confusion.²³ The VPS can also malfunction if the catheter disconnects, migrates, or fractures.³

Infection may develop when the shunt is colonized by skin flora. Staphylococci are the most common cause.^{13,24} An estimated 8% to 10% of CSF shunts become infected, most within the first 4 to 6 months after placement.¹³

Shunt infection can lead to abscess formation or shunt occlusion. If the patient develops an infection, the shunt will probably need to be revised.³

Additional biologic complications

include:

- **abscess.** When the patient with a VPS complains of abdominal pain, the patient must be assessed for formation of an abdominal abscess. Abdominal abscess can occur from shunt contamination or from the shunt migrating into the bowel.³
- **pseudocyst.** This develops when the body walls off CSF around the terminal portion of the peritoneal catheter. An abdominal CSF pseudocyst, also called CSFoma, is a hallmark of shunt infection. The incidence of pseudocyst formation is estimated at 0.7% to 10%.¹³ It can necessitate removal of the VPS and treatment with appropriate antibiotics prior to VPS replacement. A pseudocyst may develop at any time—within months of VPS placement or years later.^{3,25}
- **subdural hematoma (SDH),** a collection of blood between the dura and the arachnoid membranes.³
- **peritonitis,** which causes general signs and symptoms of infection in conjunction with abdominal pain.³
- **bowel perforation** by the peritoneal section of the distal shunt catheter.^{3,6}

The complication rates following insertion of a shunt tend to be high, with up to half of patients experiencing some type of complication and requiring shunt revisions. These complications often involve an overlap of both biological and mechanical factors.^{3,13}

Caring for a patient with a VPS

Immediate postoperative care includes positioning, managing pain, ensuring proper function of the shunt device, monitoring the patient's neurologic status, assessing for complications, and caring for the surgical sites.¹⁴ Assess both proximal (head) and distal (abdominal) shunt catheter site incisions for bleeding, drainage, and signs of wound infection. Signs and symptoms of infection include ery-

thema or edema at the incision site or along the catheter pathway, fever, lethargy or irritability, abdominal pain, anorexia, headache, nuchal rigidity, low-grade fever, and elevated white blood cell count.^{6,14} After a CSF specimen for culture has been obtained, start treatment with a broad-spectrum antibiotic such as vancomycin as prescribed.⁶

To optimize CSF drainage, elevate the head of bed, typically to 30 degrees, although the shunt will drain as programmed independent of head of bed elevation. Perform frequent neurologic and other organ system assessments to detect changes that may result from intracerebral hemorrhage, SDH, increased ICP, meningitis, or peritonitis.

Peritonitis may develop as a peritoneal response to the foreign object. Assess for abdominal pain or tenderness, erythema, and warmth and tenderness over the shunt tubing. CSF malabsorption from the peritoneal cavity can lead to abdominal distension and discomfort, and frank ascites.^{14,26}

Shunt malfunction leads to retention of CSF, resulting in increased ICP. Report signs and symptoms of increased ICP, including change in level of consciousness, headache, vomiting, lethargy, and confusion, to ensure that the provider and neurosurgeon take prompt action.^{14,23}

Delayed intracranial hemorrhage can be a result of erosion of vasculature by catheter cannulation or sudden ICP reduction after VPS placement. Monitor for signs of bleeding such as pallor, tachycardia, and hypotension, and notify the care team quickly.¹⁴

If the patient is scheduled for an MRI, inform appropriate personnel that the patient has a VPS in place. Generally, all shunts used in the US are safe for MRI. However, because

Potential patient problems related to VPS^{6,29}

Besides adverse reactions related to CSF overdrainage and underdrainage, possible complications related to VPS include:

- infection
- intracranial hemorrhage
- mechanical complications (shunt malfunction)
- pain
- seizures
- abdominal injury (ascites, peritonitis, abdominal perforations, volvulus).

Patients with a VPS must be educated to recognize and report signs of complications or shunt malfunction. Teach them that although the risk of shunt malfunction, infection, and other complications is highest within the first year following shunt placement, these can occur at any time.

the MRI can redial a programmable shunt to an inappropriate setting, the shunt must be checked and redialed if indicated following the MRI to confirm correct pressure setting.⁸

Discharge teaching

Most patients are discharged within a week of the procedure.²⁷ Visible staples or sutures are generally removed within 1 to 2 weeks postoperatively. The patient's head should not be showered or shampooed until those staples or stitches are removed. Instruct patients not to submerge or soak the surgical wound before it is completely healed.

Once postoperative edema resolves, a raised area at scalp and abdominal insertion sites will remain visible.⁶ Teach patients and caregivers to protect these areas. When the hair regrows, the raised area is usually unnoticeable.¹⁴

Educate the patient, family, and caregivers about potential complications associated with the CSF shunt, including over- and/or underdrainage, infection, and signs and symptoms of increasing ICP (see *Potential patient problems related to VPS*). Also explain the need to use caution with devices such as cell phones containing magnets that could theoretically alter the programmed shunt valve.⁶ The FDA advises patients to keep

products that contain magnets at least two inches away from the location of an adjustable CSF shunt valve and to use the ear opposite the shunt for devices requiring listening, including cell phones and earbuds.⁸

Patients, families, and caregivers should know the signs and symptoms that indicate shunt failure or infection and call their assigned clinic immediately if they suspect any problems.¹⁴ Inform them that shunt complications can occur at any time regardless of how long a shunt has been in place. All patients with a shunt require close monitoring for complications.²³

Referral to a local support group or to the Hydrocephalus Association can be beneficial. For more information, direct patients and families to the Hydrocephalus Association website: www.hydroassoc.org. ■

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