Imaging of the ventricular shunts: Normal findings and complications

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Authors: M. D. P. SANCHEZ-CAMACHO¹, I. Herrera¹, P. M. Hernandez Guilabert², M. Amosa¹, E. Capilla², R. González-Gutierrez¹, R. MORENO DE LA PRESA¹; ¹TOLEDO/ES, ²madrid/ES

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Purpose

Ventricular shunts are commonly used to treat hydrocephalus. The placement of cerebrospinal fluid shunts has become one of the most common procedures in modern neurosurgery. Despite significant improvements in shunt procedures, shunt complications remain common (1).

The ventriculoperitoneal (VP) shunt is the most commonly used type because the peritoneum is an efficient site of absorption. Modern VP shunts contain several components, usually including a proximal ventriculostomy catheter (shunt tubing), a pressure-sensitive valve and reservoir, and a distal peritoneal catheter. Ventriculoatrial shunts and lumboperitoneal shunts have rarely been used (2).

The purpose of our work is to retrospectively review the normal imaging findings as well as intra-extracranial complications after hydrocephalus treatment by ventricular shunting in our center from January 2011 to April 2012.

Another objective is to analyze intra-extracranial complication rates and to determine them according to urgent or programmed surgeries.

Methods and Materials

We retrospectively reviewed all patients subject to ventricular shunting surgical procedures performed at our center from January 2011 to April 2012, regardless age and sex, including first-time surgical placements and surgical explorations or replacements and differentiating between urgent and programmed surgeries.

Depending on the suspected complication, postoperative control was carried out either through computed tomography (CT), magnetic resonance imaging (MRI), conventional radiography, abdominal ultrasound and/or transfontanelar ultrasound.

We coded each surgical procedure according to urgent or programmed surgeries, the type of postoperative imaging studies, the presence or absence of complications and the possible type of these complications.

We evaluated both postprocedural normal imaging findings and complications. The complications were classified in intracranial and extracranial. Among the first
we found infections, shunt obstructions, pericatheter or intraventricular bleedings, overshuntings (with extra-axial fluid or blood collections, or resulting in small ("slit") ventricles), misplacements into brain parenchyma, ventricular loculation, corpus callosum edema, cerebral venous thrombosis and paradoxical herniation. The coded extracranial complications were abdominal pseudocysts, peritoneal fibrosis, distal catheter misplacement and atrial thrombosis.

The data analysis was carried out by descriptive statistics, calculating the percentages of the different variables (urgent and programmed surgeries, type of postoperative imaging studies, presence or absence of complications and possible complications).

Results

Out of overall 614 neurosurgical procedures, 205 were ventricular shunt placements (ventriculoperitoneal, ventriculoatrial and external ventricular drains). Postoperative complications were observed in 71 (34.63%) of them: 65 (91.55%) were intracranial and 6 (8.45%) extracranial (Fig. 1 on page 6).

143 were urgent surgeries of which 53/143 (37%) presented postoperative complications; 62 were programmed surgeries and complications were presented in 18/62 (29%).

As imaging studies in the immediate postoperative period were used CT, MR imaging and others (conventional radiography, abdominal ultrasound, transfontanelar ultrasound) (Fig. 2 on page 7). In all cases, image tests were made in the immediate postoperative period. The number and type of imaging studies were different depending on the complexity and evolution of the case. An imaging study was performed in 96% of surgical procedures and two in the remaining 4%.

The intracranial complications were 19 (26.76%) infections, 16 (22.54%) shunt obstructions, 11 (15.49%) pericatheter or intraventricular bleedings, 11 overshuntings (with extra-axial fluid or blood collections, or resulting in small ("slit") ventricles) and 4 misplacements into brain parenchyma. There were isolated cases of ventricular loculation, corpus callosum edema, cerebral venous thrombosis and paradoxical herniation (Fig. 3 on page 7).

The extracranial complications were 2 abdominal pseudocysts, 1 peritoneal fibrosis, 1 distal catheter misplacement, 1 broken shunt and 1 atrial thrombosis (Fig. 3 on page 7).
NORMAL FINDING

In patients with previous ventricular shunts, the most common and normal finding in this study was an area of malacia in the brain due to a prior ventricular shunt which had been replaced (Fig. 4 on page 8).

Another normal finding in this study was the diffuse and relatively thin pachymeningeal enhancement along the inner table of the skull and in the dural reflections, due to the continued use of the ventricular shunt (3) (Fig. 5 on page 9).

INTRACRANIAL COMPLICATIONS

1.- Shunt infection. The prevalence of shunt infection is reported to happen in 2.6%-38% of cases. In our study, 26.76% of cases presented shunt infection. In most of our cases, there is a radiographic evidence of shunt malfunction. Most infections develop within 2 months from the shunt placement. The most common isolates microorganisms, coinciding with the literature, were *Staphylococcus aureus*, *Staphylococcus epidermidis*, or gram-negative enteric infections. Ventriculitis and meningitis can be visualized at CT and MR imaging as an enhancement of the ventricular ependymal lining or cerebral cortical sulci. Shunt replacement is usually necessary (2) (Fig. 6 on page 10). Repeated infections can lead to cerebral venous sinus thrombosis (Fig. 7 on page 12).

2.- Shunt obstruction can occur at any time after insertion, and all points along the shunt course are suspect when assessing for shunt malfunction. Shunt obstruction usually presents with clinical evidence of raised intracranial pressure. The two most common locations for obstruction in our study were the ventricular catheter tip, which can be blocked by ingrowth of choroid plexus, and the shunt valve, where blood or debris can block the lumen of the valve (Fig. 8 on page 12). These locations are also observed in the literature (4).

If the ventricular catheter is obstructed by ingrowth of choroid plexus into the lumen of the ventricular catheter tip, removal it is complicated by the risk of bleeding caused by avulsion of choroid plexus if the catheter is forcefully removed (4) (Fig. 9 on page 14, Fig. 10 on page 15 y Fig. 11 on page 15).

3.- Overdrainage refers to several scenarios where a shunt with proper operation removes more fluid than necessary for that particular patient. Early rapid reduction in ventricular size may result in collapse of the brain and accumulation of extra-axial fluid or
blood collections. Most commonly, benign cerebrospinal fluid collections are observed; however, subdural hematomas are possible (5) (Fig. 11 on page 15).

More commonly, the excessive drainage occurs over a long period of time resulting in small (“slit”) ventricles (Fig. 12 on page 16).

An important clinical distinction in diagnosing overdrainage vs shunt malfunction is the timing of the symptoms and the patient's position when headaches occur. In slit ventricle syndrome, the symptoms are commonly postural and patients note improvement when supine for a period of time. One proposed model suggests that overdrainage caused by siphoning at the distal catheter, either by gravity alone or, in the case of atrial or pleural shunts, by negative pressure at the distal end of the catheter tubing. It is hypothesized that overdrainage during the period of brain growth allows the brain to fill the intracranial space completely and, consequently, the ventricles remain collapsed. Overall brain compliance may be reduced and the ventricular catheter can be intermittently obstructed by the collapsed ventricular system (5).

4.- Ventricular catheter misplacement. The catheter can be located into brain parenchyma, the choroid plexus, or the temporal horn and leads to early shunt failure. In our study, 5.63% of cases presented misplacement into brain parenchyma (Fig. 13 on page 17), in patients with poor clinical outcome in the immediate postoperative period. Patients usually have postoperative evidence of raised intracranial pressure or fluid around the shunt, or both. Rarely, a misplaced shunt will be identified incidentally on follow-up imaging (4).

5.- Loculation of the ventricular system occurs when separate, non-communicating fluid pockets develop within the ventricles. Children with a history of hemorrhage or ventriculitis are most at risk for this. Often loculations are not observed at the time of initial shunt insertion because of ventricular enlargement. Over time, the loculations may develop and mature, resulting in isolated segments of the ventricular system that are not adequately drained and the loculated fluid compartments enlarge, causing symptomatic compression of the surrounding brain. The best choice is to create a communication between the loculated compartment and the rest of the ventricular system so that the child can be left with a single shunt (5) (Fig. 14 on page 18).

6.- Paradoxical herniation is an uncommon complication. In our study, 1.41% of cases presented paradoxical herniation. Patients with a large craniectomy defect who afterwards undergo a cerebrospinal fluid drainage have a resultant decrease in cerebrospinal fluid pressure, leading to a reduction in intracranial pressure and vulnerability of the cranial contents to atmospheric pressure. This pressure imbalance causes subfalcine and transtentorial herniation away from the craniectomy defect and
results in mesodiencephalic dysfunction. Paradoxical herniation is a neurosurgical emergency and urgent treatment is necessary to increase intracranial pressure (6) (Fig. 15 on page 19).

EXTRACRANIAL COMPLICATIONS

1.- Abdominal pseudocyst. A pseudocyst is a loculated intra-abdominal fluid collection that develops around the peritoneum. Pseudocysts are more common than ascites. In our study, 2.82% of cases presented abdominal pseudocysts. Symptoms consistent with bowel obstruction can be evident if the pseudocyst is large. Some authors propose that development of a pseudocyst indicates the presence of a chronic low-grade infection; however, it is not unusual to find sterile fluid within the pseudocyst cavity when it is aspirated (5). In our cases, no pathogens were isolated in liquid culture (Fig. 16 on page 21).

2.- Shunt misplacement can also occur at the distal end of the catheter, including the abdomen, atrium, or pleura. Patients present with abdominal discomfort and eventually may develop headache, nausea, or vomiting. When the peritoneal distal tubing is misplaced, a CT scan often discloses ventricular dilatation after some delay (4). In our study, the distal end of the shunt was located in the preperitoneal space, resulting in a fluid collection under the abdominal incision. A lateral projection of the abdomen demonstrated the location under the anterior abdominal wall (Fig. 17 on page 21).

3.- Broken shunt. The typical presentation of a fractured shunt system is usually many years after initial insertion and is related to both biomechanical stress as the subject grows and the inherent degradation of indwelling components because of host reactions. The distal tubing should be free to slide in the subcutaneous tract; however, scar tissue may tether the tubing and produce shear forces that promote fractures as the children grow, as in our case (Fig. 18 on page 22). The common presentation is that of mildly elevated raised intracranial pressure. It is also common for patients to present with pain, mild erythema, or swelling over the shunt tract often in a location over the shunt fracture (4).

Images for this section:
Fig. 1: Percentage of postoperative complications, and intra-extracranial complications.

Fig. 2: Percentage of postoperative imaging studies.
Fig. 3: Percentage of postoperative complications, divided into two groups (intracranial and extracranial).
Fig. 4: Axial non-contrast cranial CT in a patient with right parietal VP shunt (black arrow) and area of malacia in the right frontal lobe (white arrow) due to a prior ventricular shunt.
Fig. 5: Patient with multiple replacements by shunt dysfunctions. (a) Axial T1-weighted MR image demonstrates a right parietal VP shunt (black arrow) with normal ventricular size. (b) Coronal gadolinium-enhanced T1-weighted MR image demonstrates diffuse and relatively thin pachymeningeal enhancement along the inner table of the skull (black arrows) and in the dural reflections of the falx and tentorium (white arrows), due to the continued use of the ventricular shunt.
Fig. 6: Axial contrast enhancement cranial CT in a patient with a right thalamic hemorrhage, extended into the ventricles. The external ventricular drain was removed. Hydrocephalus with transependymal edema (white arrow), detritus in occipital horns of lateral ventricles (asterisk) and ependymal enhancement (black arrow) were observed, in those patients with ventriculitis.
**Fig. 7:** Cerebral venous sinus thrombosis in a patient with multiple infections and shunt failure. Sagittal T1-weighted MR (a) image demonstrates hyperintensities within the superior longitudinal (thin white arrows), straight (black arrow), and right transverse sinuses (thick white arrows), which in the contrast-enhanced T1-weighted MR (b) and the contrast-enhanced MR angiography (c, d) images correspond with partial fullness defects.
Fig. 8: Fourteen days after surgical placements, axial T2-weighted MR image shows VP shunt across the atrium of the right lateral ventricle, third ventricle and proximal end in the frontal horn of left lateral ventricle. Tetraventricular hydrocephalus with cystic dilation of the third ventricle (white arrow) and a collection isointense to cerebrospinal fluid around
the extracranial course of the shunt (black arrow) were observed, in a patient with shunt obstruction.

**Fig. 9:** Axial non-contrast cranial CT in a term newborn with communicant tetraventricular hydrocephalus secondary to intracranial hemorrhage. Three days after
ventriculoperitoneal shunt placements, this patient presented acute bleeding remains in the fornix body (black arrow) and hemorrhage in occipital horns of lateral ventricles (white arrows).

Fig. 10: Axial non-contrast cranial CT in a patient with focal left basal ganglia hematoma extended into the ventricles, secondary to arteriovenous malformation. Left temporoparietal craniotomy (asterisk) and external ventricular drain (white arrow) were observed. After external ventricular drain replacement, this patient presented an increase of pericatheter bleeding with air bubbles (black arrow).
**Fig. 11:** Axial non-contrast cranial CT in a patient with overshunting and subsequent development of hyperdense extra-axial fluid collection consistent with an acute subdural hematoma (black arrow). Edema in the corpus callosum (asterisk) was observed in this patient with an antecedent of hydrocephalus, that became evident after decompression. Pericatheter bleeding (white arrow) was also observed.
Fig. 12: Axial non-contrast cranial CT in a child with symptoms of shunt malfunction. Ventriculoatrial shunt with proximal end in the septum pellucidum (white arrow) and very small ventricles (black arrow) in connection with "slit ventricle syndrome" were observed.
Fig. 13: Axial non-contrast cranial CT in a 2-year-old girl with numerous replacements by shunt dysfunctions. After one of them, this patient presented a misplacement of the ventricular catheter into the left temporal subcortical region (black arrow). This catheter passes through the third ventricle (white arrow) and the left temporal cyst (asterisk).
Fig. 14: (a) Axial T2-weighted MR image demonstrates a left VP shunt (white arrow) passing through the left temporal porencephalic cavity and proximal end in the left anterior temporal pole. Hydrocephalus with transependymal edema (black arrows) and loculations in basal ganglia (asterisks) were observed. (b) Axial FLAIR MR image demonstrates an increase in size of the right parietooccipital and left frontal loculations (asterisks), comparing with previous MR (not shown), and transependymal edema (black arrows).
Fig. 15: Axial non-contrast cranial CT in a patient with a right frontoparietal decompressive craniectomy who then underwent an external ventricular drain (black arrows). Image shows a sunken skin flap (white arrow), midline displacement and subfalcine herniation (black asterisk), in connection with paradoxical herniation. Also subacute infarct in the territory of the right middle cerebral artery (white asterisk) was observed.
Fig. 16: Abdominal ultrasound in a patient with ventriculoperitoneal shunt malfunction. A cystic lesion, containing a septum, was observed around the distal shunt tip (black arrows), consistent with abdominal pseudocyst (asterisk).
**Fig. 17:** Supine, lateral abdominal x-ray revealing the distal end of the VP shunt into the soft tissue of the anterior abdominal wall (arrow), in connection with distal catheter misplacement.

**Fig. 18:** Sagittal contrast-enhanced CT images in a 21 year-old patient with a VP shunt since childhood, who goes to the doctor due to present with a lump of hard consistency, non-painful, left laterotracheal, of 7 days of evolution. He denies fever, sweating or other
symptoms. Image (a) shows a collection (asterisk) behind the left sternocleidomastoid muscle (black arrow), at the tip of the proximal end of the broken VP shunt (white arrow). This was surgically correlated with a cerebrospinal fluid cyst (asterisk). Image (b) shows the distal end of the broken VP shunt (white arrow).
Conclusion

As ventricular shunting is the most widely accepted treatment of hydrocephalus, it is important for radiologists to be familiar with the normal imaging findings, the signs of intra-extracranial complications and the role of the different imaging modalities to assess them.

Although patient history and physical examination provide an initial suspicion of a shunt failure, medical imaging often confirms the diagnosis and reveals the underlying cause. Understanding of the specific types of obstructive shunt malfunction, potential causes of failure, and management options is important for neurologists and pediatrics who often are the first providers to evaluate and triage these often markedly ill patients (4).

Radiologists have a variety of procedures they can use to discover the cause of the malfunction or complication. Communication with the treating clinicians is essential for tailoring the diagnostic imaging work-up to the particular problem (2).

The most frequently used imaging study in the immediate postoperative period is CT, due to fast acquisition and availability in the urgency. On the majority of occasions, CT provides enough information for a correct handling.

In our study, the postoperative complications were detected more frequently in urgent surgeries than in elective surgeries.

Intracranial complications were more frequent than extracranial. Infections, shunt obstructions, pericatheter or intraventricular bleedings and overshuntings were the predominant complications.

References


**Personal Information**

Maria del Pilar Sánchez-Camacho González-Carrato, Department of Radiology, Hospital Virgen de la Salud, Toledo, Spain; piluka486@hotmail.com

Isabel Herrera Herrera, Department of Radiology, Hospital Virgen de la Salud, Toledo, Spain; isabel.herherrera@gmail.com

Paula María Hernández Guilabert, Department of Radiology, Hospital Virgen de la Salud, Toledo, Spain; maria.hg@hotmail.com

Manuel Amosa, Department of Neurosurgery, Hospital Virgen de la Salud, Toledo, Spain; manu.amosa@gmail.com

Elena Capilla, Department of Radiology, Hospital Virgen de la Salud, Toledo, Spain; elenacapilla@gmail.com

Rafael González Gutiérrez, Department of Radiology, Hospital Virgen de la Salud, Toledo, Spain; rggarjona@hotmail.com

Raquel Moreno de la Presa, Department of Radiology, Hospital Virgen de la Salud, Toledo, Spain; rmp1983@hotmail.com