



Case Report

In situ clearance of a proximal shunt malfunction in a child with hydrocephalus post cerebral arteriovenous malformation rupture noted intraoperatively

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ABSTRACT

Background: Hydrocephalus shunt malfunctions remain treated with surgical intervention only. Despite efforts at identifying or preventing CSF shunt obstruction, no evidence currently exists to restore CSF flow following proximal occlusion, non-invasively.

Case Description: We present direct intraoperative evidence in the case of a 5-year-old male who developed hydrocephalus subsequent to hemorrhagic presentation post cerebral arteriovenous malformation rupture. After weeks of externalized CSF diversion for clearance of CSF red blood cells, he was taken to the operating room for removal of the external ventricular drain and placement of a ventriculoperitoneal shunt for hydrocephalus. At conclusion of placing his ventriculoperitoneal shunt with ReFlow flusher assist device, his shunt valve reservoir was noted to not refill. Following manual depression of the ReFlow flusher, we identified clearance of debris from the obstructed ventricular catheter allowing reestablished CSF flow through the shunt system under live intraoperative ultrasonography. Subsequently, there was return of brisk refill to the shunt valve reservoir.

Conclusion: Observations here demonstrate a potentially useful technical strategy toward clearance of proximal shunt obstructions, *in situ*.

Keywords: Posthemorrhagic hydrocephalus, Intraventricular hemorrhage

INTRODUCTION

Nearly half of all CSF shunt failures result from obstruction of the proximal ventricular catheter.^[1-4,6,8,11,13] Posthemorrhagic hydrocephalus (PHH) is one etiology of obstructive hydrocephalus in the pediatric and adult population and may commonly associate with germinal matrix hemorrhage of prematurity or intraventricular hemorrhage (IVH) resultant from trauma or cerebrovascular lesion rupture. Efforts in nonsurgical treatments to prevent obstructive hydrocephalus following intraventricular hemorrhage (IVH) such as irrigation, drainage, and fibrinolytic therapy examine reduction of present IVH and development of hydrocephalus, but not reduction of proximal obstructive shunt failure after shunt placement.^[5] While improperly placed ventricular catheters may become obstructed by the

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adjacent ventricular wall or choroid plexus, it may be that obstructive shunt failure occurs most commonly to proteins and inflammatory cells adherent to the catheter pores [10,12,14,15]. Despite surgical irrigation of the disconnected proximal catheter, evidence of non-invasive methods to reestablish CSF flow after proximal shunt occlusion does not exist.

Here, we present a novel intraoperative ultrasonographic observation of new shunt technology that utilized a non-invasive mechanism to clear an obstructed proximal ventricular catheter, *in situ*.

Technical case report

The patient is a 5-year-old male who developed hydrocephalus following an intraventricular hemorrhage secondary to pial AVM rupture. After endovascular embolization stabilization of the AVM and intraventricular hemorrhage controlled with temporary external ventricular drainage, he subsequently required ventriculoperitoneal shunt placement. At the time of internalization, his CSF profile included a protein count of 23 and RBC count of <50. We discussed with the family, consent for the placement of a novel shunt design that includes a ReFlow proximal catheter with relief membrane and assistive flusher device (Anuncia, Lowell MA) that allows for retrograde proximal catheter tip flushing for relief of debris occluding the proximal catheter tip in the ventricle through an assistive reservoir device placed in line before the shunt valve; this shunt construct allows for external depression of the assist device reservoir to induce retrograde flush to the proximal catheter tip to reestablish anterograde CSF flow through the ventricular catheter, *in situ*. The patient was brought to operating room where we first removed the external ventricular drain and then proceeded to tunnel the Codman Bactiseal distal catheter to the peritoneal space first and the Codman Certas valve attached proximally to the distal catheter and residing in the subgaleal cranial pocket. We then under live ultrasonography placed the ReFlow ventricular catheter into the frontal horn of the left lateral ventricle and away from the remaining intraventricular hemorrhage along the lateral wall [Figure 1a]. This was then attached to the ReFlow assistive flushing reservoir and then to the Certas valve and distal catheter, in series, respectively. All components were secured with silk ties and flow through the shunt system was confirmed with brisk refill after depression of the Certas shunt valve reservoir.

After complete placement of his shunt system both ventricular and peritoneal sites and immediately prior to skin closure, his Certas valve was noted to not refill. With this concern, we manually depressed the ReFlow flusher device to generate a retrograde flush of CSF from the ReFlow CSF chamber to the ReFlow proximal catheter tip [Figure 1b] with evidence of immediate hyperechoic particles disengaging intraventricularly away from the catheter tip inlet holes under live intraoperative

ventricular ultrasonography [Figure 1c]. We could not identify the relief membrane opening under ultrasonography and this may be due to the diaphragm not appearing echoic enough to appreciate under ultrasound imaging. Clearance of debris was identified and flow within the ventricular catheter was restored [Figure 1d]. We subsequently identified his Codman Certas valve reservoir reestablished full of CSF and with return of brisk refill. Given this as a new catheter and shunt device technology, we removed the ventricular catheter and both inspected and irrigated the catheter tip diaphragm and catheter inlet holes to ensure there was not a ruptured catheter diaphragm or obvious remaining obstructive debris and was revised with new placement in a slightly more medial trajectory further away from the laterally collected IVH clot. On clinical follow-up 1 year later, the patient continues to improve neurologically from his AVM rupture and without concerns for shunt malfunction.

DISCUSSION

This is the first (ultrasonographic) evidence of a novel strategy to clear proximal shunt occlusions non-invasively,

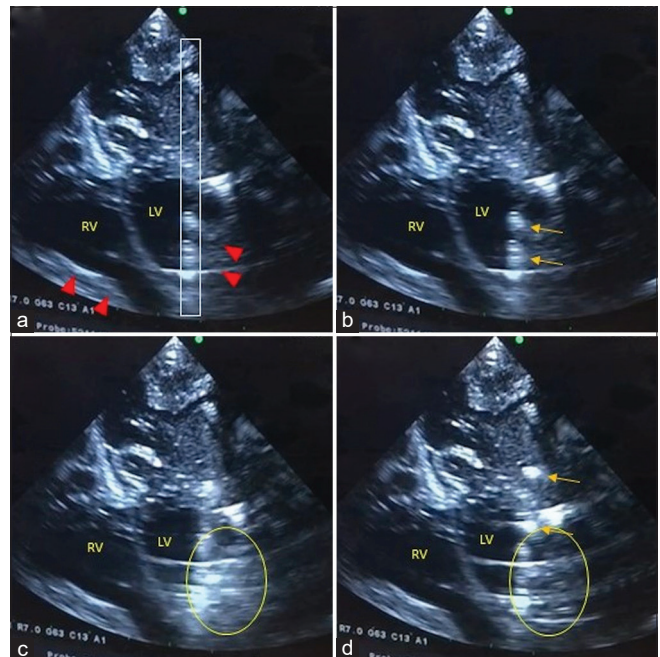


Figure 1: (a) Intraoperative ultrasonography in burr hole probe's eye view demonstrating bilateral residual intraventricular hemorrhage (red arrowheads) along the lateral walls of the bilateral frontal ventricular horns with the ReFlow ventricular catheter (gray rectangle) within the left lateral ventricle (LV). (b) Lack of flow within the ventricular catheter with echogenic densities (orange arrows). (c) Immediate single image post ReFlow flusher depressed, demonstrating extraluminal echogenic debris dispersing from the adjacent catheter inlet holes (yellow oval). (d) Ventricular clearance extraluminally (yellow oval) after few seconds and intraluminal CSF flow restored in anterograde flow (orange arrows).

which would, otherwise, require invasive surgical revision.^[7,9] A strategy toward non-invasively clearing an obstruction may allow for immediate partial clearance restoring flow to the shunt system. The advantages of this type of strategy have obvious benefits toward potentially rescuing neurological decline amidst elevated intracranial pressure and obstructive hydrocephalus while en route to the operating room. Advancement in this technical strategy may prevent operative management as the sole solution for an obstructed shunt malfunction. Anuncia's ReFlow Ventricular Catheter and Flusher System is a reservoir system implanted in the ventricle and connected to the Flusher, which is a reservoir of CSF connected to a commercially available flow or pressure regulating valve. This device has the potential to send a retrograde pulse of fluid toward an obstructed ventricular catheter to open blocked inlet holes and restore CSF flow. The ventricular catheter is dimensionally similar to existing proximal shunt catheters, however, maintains a diaphragm (silicone relief membrane) that may aid to clear debris when opened by retrograde CSF pulsation. The ReFlow flusher system is used in combination with any commercial shunt valve to allow for passive flow regulation, as well as a commercial reservoir system to allow for investigation of shunt integrity by shunt taps or flushing. During compression of the flusher dome, the passive flow channel is manually occluded, and a controlled retrograde fluid pulse is redirected into the proximal catheter. This fluid pulse applies a force on cellular and proteinaceous debris overlying the catheter inlet holes, and dislodging this debris reestablishes patency of the inlet holes to allow for passive CSF flow through the shunt system. This controlled fluid pulse may place a force on cellular or protein debris that is obstructing the proximal catheter inlet holes such that this debris may be cleared leading to restoration of the patency of the catheter inlet holes. Following manual flushing, the flusher dome refills with CSF and free-flowing passive flow is resumed in an anterograde fashion toward the valve device and distal catheter. In addition, the ReFlow Ventricular Catheter contains a relief membrane that may be deployed in cases of complete proximal catheter obstruction. This membrane remains intact during implantation. This membrane opens in cases of high pressures resulting from manual depression of the flushing device against a complete obstruction that is not relieved from the retrograde pulse. In such cases, opening of the relief membrane allows for restoration of passive anterograde flow in the shunt system.

We could not identify here that this relief membrane deployed or that it played a role in the re-establishment of ventricular catheter CSF anterograde flow. It is possible, however, that retrograde CSF flow established from manual depression of the ReFlow flusher device was sufficient to reestablish anterograde flow through the ventricular catheter without the needing to break the relief membrane. Second, great care

was taken to document the ReFlow pump and programmable valve positioning extracranially for use during future shunt evaluations. In addition, we took great effort to note, intracranially, location of the catheter tip as it is not clear whether the catheter tip relief membrane requires adequate ventricular CSF volume surrounding it to be effective. Third, we could not quantify the amount of debris that was successfully cleared during this observation and longevity of this mechanism. Thus, the extent as to how much debris can be freed and the longevity of successful clearing without the need of replacement of the shunt system is beyond the scope of our observation reported in this report. Fourth, the observations reported here cannot be ascribed to clinical benefit given that the obstruction occurred in the OR while the patient remained under general anesthesia.

The observations reported here support a novel strategy toward the potential treatment of shunt malfunctions due to proximal occlusions. It remains to be tested whether this novel approach truly represents a mechanically viable option for nonsurgical treatment of proximal shunt obstruction outside of the operative theater. Long-term follow-up is needed in our patient to determine clinical benefit and cost-effectiveness of implantation of this new technical approach.

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Declaration of patient consent

Patient's consent not required as patients identity is not disclosed or compromised.

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Nil.

Conflicts of interest

The authors declare an interest in materials presented herein as follows: Dr. Joseph R. Madsen is a Co-Founder of Anuncia and Co-Inventor of the ReFlow Ventricular System. Dr. Sudhakar Vadivelu is a consultant for Alycone lifesciences.

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