Endovascularly implantable CSF shunt: Can we simplify communicating hydrocephalus treatment?

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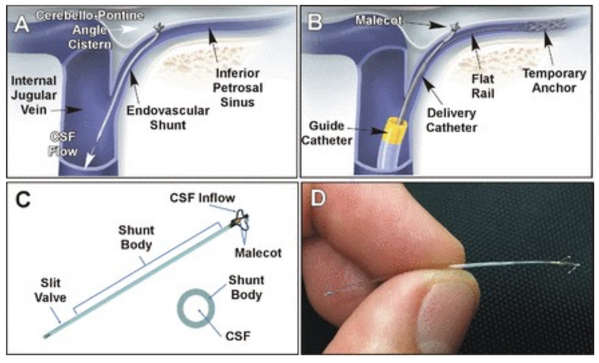
Purpose

To do an educational review of the eShunt system and the novel ETCHES I Study (Endovascular Treatment of Communicating Hydrocephalus With an Endovascular Shunt)

Background

Communicating hydrocephalus results from an imbalance between cerebrospinal fluid (CSF) production and its resorption, leading to increased intracranial pressure and ventricular dilatation. Current standard treatment of hydrocephalus remains ventriculoperitoneal (VP) shunt surgery first introduced over 60 years ago, requiring multiple scalp, neck, and abdominal incisions, a burr hole, and catheter traversing cortex and white matter. The hydrostatic column pressure when the patient stands upright makes VP shunts prone to a siphon effect, leading to CSF overdrainage and resulting in subdural fluid or blood collections. Despite its maturity, the VP shunt has remained largely unchanged except for development of externally adjustable valves and modifications to mitigate siphoning. These incremental developments and the introduction of antibiotic-impregnated tubing have not eliminated a risk of surgical infection of around 10% and high overall VP shunt failure rates, estimated to be between 21% and 42% by the first year following placement. A recent, National Institutes of Health-sponsored symposium noted that first-time shunts fail within 2 years at a rate of over 40%.

The shortcomings of VP shunts served as impetus to seek a less invasive alternative approach for patients with communicating hydrocephalus. A biomimetic strategy inspired an approach to replicating the function of the arachnoid granulation which passively transports CSF from the subarachnoid space to the venous sinuses with a valved micro-implant to be positioned straddling the dura mater and enable CSF flow from a brain cistern to an adjacent draining vein.



Device design and deployment

A novel minimally invasive endovascular CSF shunt was developed for delivery through a retrograde percutaneous transvenous approach from the femoral to the jugular vein (figure 1A and B). The eShunt System (CereVasc, Inc, Auburndale, Massachusetts, USA) is a miniature 3 cm long (figure 1C and D) intracranially implantable valved endovascular CSF shunt designed for transdural deployment at the inferior petrosal sinus (IPS) to establish a CSF pathway from the cerebellopontine angle (CPA) cistern to the IPS, replicating arachnoid granulation function by restoring natural CSF reabsorption into the venous system.

The fixed nature of the IPS, being encased within the bony inferior petrosal sulcus and its cistern-facing dural wall make it an ideal site for accurate catheter navigation and transdural puncture (figure 1A). A proprietary two-step delivery system was designed employing initial deployment of a temporary exchange-length anchor/flat wire into the cavernous sinus/IPS junction to act as a low-profile rail for subsequent advancement of the eShunt-containing delivery catheter (figure 1B). Preoperative high-resolution T1-weighted gadolinium-enhanced MRI (figure 2A) is used to segment bilateral IPS and adjacent arterial vasculature, enabling virtual simulation of the transdural trajectory and selection of the deployment site; the latter is then highlighted on the intraprocedural cone-beam CT venographic reconstruction, and the site transferred to the 3D-roadmapping guidance. This workflow enables consistent identification of the target site for deployment with fluoroscopy under various working views and magnification (figure 2A–C).

Once the delivery catheter reaches the target implantation site within the IPS, a needle on the distal tip is unsheathed and the system advanced under 3D-roadmapping guidance to slowly penetrate the taut dural wall of the IPS (figure 2D), enabling access to the adjacent CPA cistern, and controlled deployment of the endovascular shunt (figure 2E). The eShunt implant is proximally ensconced by a nitinol shroud enabling depth adjustment until final release by the operator (figure 2F). The implant's differential pressure slit valve resides within the internal jugular vein and regulates CSF flow in a pressure-driven manner proportional to the positive pressure gradient between ICP and venous blood pressure. The pressure gradient between ICP and venous pressure is estimated at 3–5 mm Hg in healthy patients and rises significantly in patients with untreated hydrocephalus. The valve prevents blood reflux into the cistern during certain transient physiological conditions (eg, coughing, straining, sneezing) which can cause transient (<2 s) venous blood pressure spikes, although research indicates dynamic coupling between ICP and local venous pressure with a constant favorable transdural positive pressure gradient. The implant is designed to drain 10 mL/h at a pressure gradient of ≤8 mm Hg.

Conclusion

Percutaneous endovascular treatment could reduce the need for invasive surgery and rates of post-operative complications. Outcomes from the first described case has been positive, however, we look forward to complete data set from the ETCHES I trial.

References

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