Endoscope-assisted placement of a multiperforated shunt catheter into the fourth ventricle via a frontal transventricular approach

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Object. Patients with symptomatic isolated fourth ventricle and multicompartmentalized hydrocephalus benefit from operative treatment, but the optimal surgical approach and technique have yet to be established. The authors report on their experience with the treatment of symptomatic adult patients by endoscope-assisted placement of a fourth ventricle shunt catheter via a frontal transventricular approach.

Methods. The authors describe a retrospective series of four patients treated for isolated fourth ventricle. The surgical technique is described in detail: use of a flexible endoscope with dual-port intraventricular access for direct visualization and for mechanical manipulation of a multiperforated panventricular catheter guided by frameless stereotaxy.

The transventricular approach allowed optimal catheter placement within the fourth ventricle. The use of the flexible endoscope permitted the neurosurgeon to use the endoscope as a tool to guide the ventricular catheter tip within the third ventricle and through the cerebral aqueduct. Clinical outcomes demonstrated neurological and radiographically verified improvement in all patients.

Conclusions. The endoscope-assisted dual-port technique provides a solution to the technical difficulties of fourth ventricle shunt placement. The multiple advantages of this technique include a single ventricular catheter shunt system that equalizes ventricular pressures, a frontal location for the ventricular catheter that facilitates valve placement and programming, and ventricular catheter placement within the fourth ventricle that does not allow the catheter to impinge on the fourth ventricle floor and makes the catheter less prone to obstruction.

KEY WORDS • isolated fourth ventricle • trapped fourth ventricle • shunt endoscopy • flexible, steerable endoscope • frameless stereotaxy

THE PHENOMENA OF compartmentalized hydrocephalus and IFV were described by Dandy more than 80 years ago. Isolated fourth ventricle has been variously referred to as “trapped,” “sequestered,” or “occluded fourth ventricle” and as an aspect of “double compartment hydrocephalus.” It has been characterized primarily in the pediatric neurosurgical literature, with adult cases more rarely reported. Typically, it occurs in hydrocephalic children with a history of infection or hemorrhage causing ependymal inflammation approximately 3 years after shunting of the lateral ventricles. It is relatively uncommon, with an estimated incidence of 2.4 to 3.0% in pediatric hydrocephalic patients with shunts. Its incidence and prevalence have not been reported in the hydrocephalic adult population. Symptomatic patients with IFV present variably with headache, nausea, vomiting, ataxia, cranial nerve palsies, and coma. The causes of IFV are heterogeneous in both the adult and pediatric populations. Regardless of its origins, shunting in IFV typically leads to clinical improvement.

In general, surgical treatment of IFV requires the placement of a shunt catheter into the fourth ventricle. Various approaches for catheter placement via a suboccipital cran-
Endoscopic interventriculostomy and retrograde aqueductoplasty

Although these techniques are sufficient in some cases, there are others that remain unaddressed. Here we discuss in detail our experience with a dual-port endoscopic technique for fourth ventricle shunt placement via a frontal transventricular approach. The trajectory from a posterior or inferior approach tends to leave the catheter tip touching or even impinging on the floor of the fourth ventricle, which can lead to disabling neurological deficits as well as direct irritation of the emesis center. In addition to these risks of deficit, posterior fossa approaches increase the risk of infection during fourth ventricle shunt placement because they usually entail repositioning of the patient to complete the distal portion of the shunt operation.

Alternatives to the posterior fossa placement of fourth ventricle shunt catheters have been devised for the treatment of IFV. Recently, advances in neuroendoscopic technique have generated diverse solutions to the difficulties posed by IFV and complex compartmentalized hydrocephalus, including ETV, aqueductal reconstruction, aqueductal stent placement, retrograde aqueductoplasty and stenting, and endoscopic interventriculostomy connecting the lateral, third, and fourth ventricles (Fig. 1). This multiperforated panventricular catheter consisted of a panventricular catheter modified by perforations corresponding to the lateral, third, and fourth ventricles (Fig. 1). This multiperforated panventricular catheter allowed simultaneous drainage of the lateral, third, and fourth ventricles, acting as a “drainpipe” that equalized the ventricular pressures and permitted the ventricular system to be served by one shunt. It is essentially a lateral-third-fourth ventricular shunt (or frontal fourth ventricular shunt). In our experience in four cases, this fourth ventricular shunt system led to good outcomes as assessed both clinically and radiographically.

**CLINICAL MATERIALS AND METHODS**

Between October 2001 and December 2006, four consecutive adult patients with symptomatic compartmentalized hydrocephalus including IFV underwent endoscope-assisted placement of a fourth ventricular shunt with a multiperforated catheter via a frontal transventricular approach. All operations were performed at a single institution (UCLA Medical Center) by one neurosurgeon (M.B.). The preoperative clinical findings, surgical details, and outcomes data in these cases were evaluated in a retrospective analysis of unselected patients.

**Patient Demographics**

The clinical details of the four adult patients are featured in Table 1. This study consisted of a consecutive series. No cases were omitted because of technical failure. The mean age of the patients at the time of surgery was 42 years (range 24–70 years). All four patients had initially suffered hydrocephalus attributable to infection or hemorrhage. The specific causes of the compartmentalized hydrocephalus/IFV were heterogeneous and included cervicothoracic spine disease complicated by prior meningitis and by cervicothoracic subarachnoid and thecal shunting (one patient), subarachnoid hemorrhage due to a ruptured cerebrovascular lesion followed by lateral ventricle shunting and cerebrospinal fluid/shunt infections (two patients), and intraventricular neurocysticercosis (one patient). With regard to prior operations, all four patients had lateral ventricle shunts. Two of the four patients had previously undergone suboccipital placement of fourth ventricle shunts, which were either overdraining or nonfunctional.

The presenting symptoms of the four patients were as follows: 1) intractable nausea and vomiting due to a mass effect; 4) fourth ventricular shunt, that is, due to the pressure differential in the posterior fossa relative to the supratentorial...
Endoscope-assisted placement of a fourth ventricular shunt

TABLE 1
Summary of history and clinical findings in four patients with compartmentalized hydrocephalus and IFV treated with endoscope-assisted placement of a fourth ventricular shunt*

<table>
<thead>
<tr>
<th>Case No.</th>
<th>Age (yrs), Sex</th>
<th>Initial Diagnosis</th>
<th>Prior Operations</th>
<th>Symptoms/Signs</th>
<th>MRI Findings</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>24, M</td>
<td>meningitis, cervicothoracic subarachnoid cyst thoracic syrinx T2–6, lumbar arachnoiditis, HCP w/ IFV</td>
<td>lat ventricle VPS &amp; rev; cervicothoracic subarachnoid cyst, pleural cavity shunt &amp; rev; cervicothoracic subarachnoid cyst, peritoneal shunt &amp; rev</td>
<td>nausea &amp; vomiting, intractable for several months</td>
<td>large lat &amp; 3rd ventricles; massive 4th ventricle; aqueductal web; 4th ventricle outlet obstructed</td>
</tr>
<tr>
<td>2</td>
<td>70, F</td>
<td>SAH due to pst fossa aneurysm (clipped), posthemorrhage HCP, arachnoiditis, compartmentalized HCP, IFV</td>
<td>lat ventricle VPS &amp; rev; suboccipital 4th ventricle shunt; suboccipital cranectomy, C-1 laminectomy, pst fossa exp, lysis of adhesions, removal of suboccipital 4th ventricle shunt</td>
<td>nausea on standing; bilat CN VI palsy; rt CN VII palsy; dysarthria &amp; ataxia for 6 yrs</td>
<td>large lat &amp; 3rd ventricles; massive 4th ventricle; foramina of Monroe &amp; aqueduct patent; foramen of Magendie &amp; rt foramen of Luschka occluded; 4th ventricle outlet obstructed; cerebellar &amp; focal lt parietal encephalomalacia</td>
</tr>
<tr>
<td>3</td>
<td>29, F</td>
<td>SAH due to brainstem AVM rupture × 2, posthemorrhage HCP, compartmentalized HCP, IFV</td>
<td>lat ventricle VPS &amp; rev; suboccipital 4th ventricle shunt; frontal ventriculostomy</td>
<td>respiratory arrest requiring intubation due to acute worsening of HCP</td>
<td>large lat &amp; 3rd ventricles; massive 4th ventricle causing anterior mass effect on brainstem; rt temporal horn isolated; 3rd ventricle w/ multiple septations &amp; isolated; aqueduct not visible; foramen of Magendie occluded by web; lt MCA territory volume loss c/w chronic infract</td>
</tr>
<tr>
<td>4</td>
<td>45, F</td>
<td>neurocysticercosis (intraventricular cysticercosis); lt MCA infarct, chronic; compartmentalized HCP; IFV</td>
<td>lat ventricle VPS</td>
<td>chronic unresponsiveness on exam</td>
<td>large lat &amp; 3rd ventricles; massive 4th ventricle; aqueductal web; foramina of Luschka webs; foramen of Magendie occluded; right lateral ventricle outlet obstructed; right lateral ventricle outlet obstructed; cerebellar &amp; focal rt parietal encephalomalacia</td>
</tr>
</tbody>
</table>

* AVM = arteriovenous malformation; CN = cranial nerve; c/w = consistent with; exp = exploration; HCP = hydrocephalus; MCA = middle cerebral artery; pst = posterior; rev = revisions; SAH = subarachnoid hemorrhage; VPS = ventriculoperitoneal shunt.

Surgical Technique

Preoperative Care. Preoperative evaluation and care included emergent ventriculostomy and/or lateral ventricle shunt externalization when indicated. After stabilization and before surgery, all patients underwent brain MR imaging with CISS sequences revealing enlarged lateral and third ventricles and a massive fourth ventricle. Three of the patients had evidence of an obstructed sylvian aqueduct on the CISS sequences.

Surgical Procedure. Either one or two separate incisions were marked for two ipsilateral bur holes. A far frontal bur hole approximately 3 cm above the eyebrow was made based on neuronavigational planning, so that a near-straight trajectory to the sylvian aqueduct could be obtained via the foramen of Monro. This straight trajectory to the posterior third ventricle (where the aqueduct is located) minimized the need to bend the endoscope significantly at the foramen of Monro, preventing the endoscope from applying pressure to the fornices there, and facilitating access through the aqueduct into the fourth ventricle. The second bur hole was located at the standard precoronal site used for ordinary shunting procedures. This port was used as the ventricular catheter entry point.

Using stereotactic guidance, a No. 14 French blunt-tipped peel-away catheter was inserted through the far frontal site into the frontal horn of the lateral ventricle. A flexible endoscope was then inserted to confirm a proper location in the lateral ventricle and visualize the foramen of Monro. We preferred using a small-diameter (2.5 mm) flexible, steerable neuroendoscope (Karl Storz GmbH and Co.) to minimize endoscopic trauma to the cerebral aqueduct. Plasmalyte (Baxter) irrigation was used for the gravity-fed setup.

Again using stereotactic guidance, a No. 9 French blunt-tipped peel-away sheath was inserted through the precoronal site into the lateral ventricle, aiming directly at the ventricular catheter.
foramen of Monro. We found that the peel-away sheath aided in passing the (weakened) multiperforated catheter and also permitted ETV from this approach, if required.

Via the far frontal bur hole port, an aqueductoplasty was performed. The initial entrance was made with the straight tip of a 0.032-inch diameter Bentson Glidewire (Boston Scientific), followed by enlargement of the perforation through the careful and limited expansion of a No. 3 French Cook elliptical balloon catheter (Cook Medical, Inc.). The goal was to establish a hole just wide enough for the ventricular catheter to pass through it into the fourth ventricle. The endoscopic view of the fourth ventricle from the frontal approach can be initially disorienting, given that most neurosurgeons are accustomed to visualizing the fourth ventricle from a posterior fossa approach. In the typical posterior approach, the brainstem and fourth ventricle floor are seen in the 6 o’clock position, whereas via this frontal endoscopic approach they appear in the 12 o’clock position and therefore can seem to be upside down.

Measurement for Ventricular Catheter Length and Perforation Location. With the flexible endoscope placed through the precoronal peel-away sheath, the tip of the endoscope was navigated into the fourth ventricle to a point within several millimeters of the foramen of Magendie. The point on the skull even with the endoscope was then noted, to calculate the optimal length of the ventricular catheter to be used. Measurements were then made for the optimal placement of perforations in the ventricular catheter to drain the third and lateral ventricles. For this purpose, the tip of the endoscope was backed out until it was positioned mid–third ventricle, and again the point on the endoscope even with the skull was marked. The same technique was used to locate the optimal site for the perforation within the lateral ventricle. The measurements made using the endoscope were translated onto the ventricular catheter after it had been cut to the desired length. An arteriotomy side punch tool (2.7-mm Ultimate single-use aorta/vein punch, Scanlan) was used to make holes in the catheter corresponding to the third and lateral ventricle drainage points.

Endoscope-Assisted Guidance of Fourth Ventricle Catheter Placement. The customized multiperforated ventricular catheter was then placed down the precoronal peel-away sheath and guided into the third ventricle using endoscopic visualization via the far frontal peel-away sheath. From the precoronal trajectory, the catheter tip naturally tended to veer toward the anterior floor of the third ventricle. Attempting to direct the catheter posteriorly using the stylet required exerting pressure on the choroid plexus and/or anterior septal vein; therefore, this maneuver was not performed. Instead, the endoscope was used physically to nudge the catheter tip into the posterior third ventricle and finally through the aqueduct. We refer to this maneuver as “sheep-herding,” because it is akin to a shepherd using a staff to prod a sheep into a pen. Once the catheter was placed through the aqueduct, no attempt was made to pass the endoscope simultaneously through the aqueduct for fear of injuring periaqueductal structures. The endoscope was used in the far frontal port to confirm that the perforations in the lateral and third ventricles were correctly situated.

RESULTS

The surgical details of these four adult patients with symptomatic compartmentalized hydrocephalus and IFV that had been treated with endoscope-assisted placement of a multiperforated panventricular shunt catheter into the fourth ventricle via a frontal transventricular approach are listed in Table 2; outcome data are featured in Table 3.

Operative Findings and Treatment

Intraoperative findings in these four cases included the following: visible web in the aqueduct in two patients (Cases 1 and 3), cysticercal cysts blocking the foramen of Monro and aqueduct in one patient (Case 4), and thick

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TABLE 2

<table>
<thead>
<tr>
<th>Case No.</th>
<th>Intraop Findings</th>
<th>Procedures</th>
<th>Valve Type</th>
<th>Valve Settings: Initial, Final (mm H2O)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>nonpatent aqueduct w/ visible web</td>
<td>perforation of aqueductal web; ETV; frontal 4th ventricle catheter placement; VAS</td>
<td>Medos-Codman</td>
<td>30, 60</td>
</tr>
<tr>
<td>2</td>
<td>suboccipital approach 2 days prior to remove suboccipital 4th ventricle catheter: thick arachnoid scar tissue in subarachnoid space under suboccipital midline dural opening; frontal approach: no debris or abnormal masses in 4th ventricle</td>
<td>frontal 4th ventricle catheter placement; VAS</td>
<td>Codman-Hakim</td>
<td>140, 60</td>
</tr>
<tr>
<td>3</td>
<td>aqueductal web; suboccipital 4th ventricle catheter tip clogged by ependyma</td>
<td>perforation of aqueductal web; ETV; frontal 4th ventricle catheter placement; VPS; removal of suboccipital 4th ventricle catheter</td>
<td>Codman-Hakim</td>
<td>100, 170</td>
</tr>
<tr>
<td>4</td>
<td>cysticercal cysts in lat ventricles blocking foramina of Monro; cysticercal cysts in 3rd ventricle blocking aqueduct</td>
<td>endoscopic removal of cysts; recreation of rt foramen of Monro &amp; aqueduct by cyst removal; frontal 4th ventricle catheter placement; rt temporal horn catheter placement; VPS rev</td>
<td>Codman-Hakim</td>
<td>170, 80</td>
</tr>
</tbody>
</table>

* frontal fourth ventricle catheter = lateral-third-fourth ventricle catheter; VAS = ventriculoatrial shunt.
arachnoid scar tissue blocking the fourth ventricular outlets in one patient (Case 2). Simultaneous endoscopic procedures consisted of ETV (Cases 1 and 3) and mechanical removal of cysticercal cysts from the foramen of Monro and aqueduct to recreate these apertures (Case 4). One patient underwent placement of a separate additional catheter in another compartmentalized ventricular space; specifically, in the patient in Case 4, a separate catheter was placed in a right temporal horn isolated by unremovable scarred-down cysticercal cysts, and the catheter was connected to the panventricular fourth ventricle shunt system used to drain the patient’s IFV.

All patients underwent placement of programmable valves for the fourth ventricle shunts, and all required postoperative reprogramming of the valves, with adjustments based on serial neurological examinations and serial computed tomography studies. With respect to distal drainage of the fourth ventricle shunt, two patients underwent ventriculoatrial shunting (Cases 1 and 2) and two underwent ventriculoperitoneal shunting (Cases 3 and 4).

### TABLE 3

<table>
<thead>
<tr>
<th>Case No.</th>
<th>Clinical Outcome</th>
<th>Neuroimaging Outcome</th>
<th>Follow Up (mos)</th>
<th>Complications</th>
<th>Reoperation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>dramatic relief from nausea &amp; vomiting</td>
<td>normal size of lat, 3rd, &amp; 4th ventricles</td>
<td>61.5</td>
<td>recurrence of HCP causing lethargy due to choroid plexus in lat ventricle; hole blocking perforation in frontal 4th ventricular catheter</td>
<td>yes, rev of rt frontal 4th ventricle catheter perforation site</td>
</tr>
<tr>
<td>2</td>
<td>dysarthria &amp; ataxia after each valve adjustment</td>
<td>normal size of lat, 3rd, &amp; 4th ventricles</td>
<td>36</td>
<td>scalp breakdown over rt frontal 4th ventricle catheter site</td>
<td>yes, removal of rt frontal 4th ventricle shunt &amp; placement of lt frontal 4th ventricle shunt</td>
</tr>
<tr>
<td>3</td>
<td>MS improved from lethargy to alertness</td>
<td>normal size of lat, 3rd, &amp; 4th ventricles</td>
<td>30</td>
<td>none</td>
<td>no</td>
</tr>
<tr>
<td>4</td>
<td>MS improved, increased responsiveness; motor exam improved from minimal movement (to noxious stimulus) to localizing</td>
<td>smaller lat, 3rd, &amp; 4th ventricles</td>
<td>2</td>
<td>none</td>
<td>no</td>
</tr>
</tbody>
</table>

* MS = mental status.

**Outcomes and Follow Up**

There was no intraoperative procedural morbidity or any perioperative death. Specifically, there were no new cranial nerve palsies or findings suggestive of syndrome of the sylvian aqueduct. All patients showed both clinical and neuroimaging improvement according to serial neurological examinations and imaging studies (Fig. 2 and Table 3). The mean follow-up period was 32 months (range 2–61.5 months).

Two patients had postoperative complications and underwent subsequent reoperation. The gradual development of lethargy and increasing sizes of all ventricles occurred in one (Case 1) of the two patients during a 1-month period after fourth-ventricular shunting. At reoperation 4 weeks after the first surgery, the ventricular catheter holes in the lateral ventricle were found to be clogged by choroid plexus. The distances for placement of the ventricular catheter holes were remeasured at this subsequent surgery, and the ventricular catheter was revised using...
these new measurements. Perforations were made at different points along the ventricular catheter so that the draining holes were not at a level at which they would be blocked by choroid plexus. After this revision, the patient improved clinically from bed-bound lethargy to an alertness that allowed him to complete his university education and take skiing vacations.

The second patient (Case 2) who required reoperation had a history of multiple right frontal lateral ventricle shunts. Skin breakdown developed in this patient over the right frontal scalp site where the ventricular catheter exited the precoronal bur hole (not an incisional site) 7 months after fourth ventricular shunting. The right frontal fourth ventricle catheter was removed and a right frontal ventriculostomy was placed. Although there was no evidence of infection according to cerebrospinal fluid cultures, the patient was treated with a full course of intravenous antibiotics because of the shunt hardware exposure. The fourth ventricle catheter was then replaced via a left frontal transventricular approach and panventricular endoscopic-assisted approach to avoid the right frontal area of scalp insufficiency.

**DISCUSSION**

Cases of IFV typically involve multicompartamentalized hydrocephalus with prior shunting of the lateral ventricles. Patients with compartmentalized hydrocephalus usually have ependymal inflammation as the underlying cause, due to either infection or hemorrhage. Such cases are complex and notoriously difficult to treat to satisfactory resolution. Many practitioners attempt to address the compartment problem by placing individual shunt catheters in each isolated ventricular component, including a suboccipital (posterior fossa) catheter in the IFV, and thereby creating parallel shunt systems with associated management complexity and potential for differential ventricular compartment pressures. Additionally, as noted previously, fourth ventricle catheters placed via a suboccipital approach have anatomical disadvantages.

The technique described here as a solution to the problem of IFV compartmentalized hydrocephalus consists of the endoscopic placement of one panventricular catheter, which extends from the fourth ventricle through the aqueduct to the third ventricle, through the foramen of Monro to the lateral ventricle, and up to a right frontal point where it is connected to a standard ventriculoperitoneal or ventriculostomy shunt system. This technique has several advantages. First, the trajectory of the fourth ventricle catheter runs toward the posterior fourth ventricle, and therefore the catheter tip cannot impinge on the sensitive floor of the fourth ventricle. Second, a single panventricular catheter shunt system allows an equal distribution of pressures. Third, the panventricular catheter is secured at the frontal site where it is connected to the valve and distal catheter; this frontal site of fixation prevents migration of the catheter. Fourth, the frontal entry site allows optimal placement of the adjustable valve for reprogramming ease.

**Comparison of Techniques**

We have described the endoscope-assisted frontal placement of a multiperforated shunt catheter spanning the lateral and third ventricles and terminating in the fourth ventricle as the operative treatment in four adult patients suffering from symptomatic compartmentalized hydrocephalus with IFV. The technique requires dual ports (one far frontal entry site for endoscope insertion and one precoronal site for ventricular catheter placement) and multiple perforations in the panventricular catheter. This technique shares some similarities with the technical solutions described by Fritsch and colleagues and Cinalli and associates for endoscopic aqueductal stent placement in children with IFV and that reported by Torres-Corzo and associates for fourth ventricular shunt placement in adults with IFV. The important differences are discussed here. Similar to Torres-Corzo and colleagues, we used a frontal transventricular approach and panventricular catheter. However, we have found the single-port precoronal approach inadequate for reasons detailed later. We found dual-port access crucial for endoscopic visualization and physical manipulation of the ventricular catheter, similar to Cinalli and colleagues’ maneuvers through two bur holes for aqueductal stent placement in pediatric patients with IFV. Multiple perforations in the ventricular catheter were likewise extremely important, as also described by Fritsch et al. for interventricularstomy in the pediatric population with IFV. However, we do not advocate segmental aqueductal stenting or interventricularstomy as treatment for IFV because of the danger of stent dislodgement and migration. The panventricular catheter that we use is securely fixed by using the frontal approach and for this reason is much less likely to be dislodged than a stent. In addition, an aqueductal stent does not place the lateral ventricles in communication with the third and fourth ventricles; the patient treated with a stent is put at risk for the development of slit lateral ventricles given the typical requirement for a separate lateral ventricle shunt in such patients.

**Flexible Endoscope and Endoscope Size**

The described technique for fourth ventricle catheter placement requires a flexible endoscope. Using the endoscope as a tool physically to nudge the ventricular catheter toward the posterior third ventricle and then through the aqueduct would be technically challenging, if not impossible, with a rigid endoscope. Moreover, we prefer the Storz 2.5-mm flexible, steerable neuroendoscope (Karl Storz GmbH and Co.) primarily for its small diameter and given that IFV is often associated with narrowed, and by definition occluded, aqueductal passageways.

Passing any endoscope through the sylvian aqueduct should be performed only when clinically indicated. Neurological deficits such as internuclear ophthalmoplegia, sixth and seventh cranial nerve palsies, and syndrome of the sylvian aqueduct are possible complications. In making use of a flexible steerable endoscope, careful patient selection based on MR imaging studies, and strategic frameless stereotactic planning, we encountered no such complications in the four cases described or in more than a dozen others (not discussed here) in which a fourth ventricular exploration was performed without the plan of leaving a catheter.

Other surgical techniques, including the use of a rigid-lens endoscope via a single bur hole approach, could be used to accomplish the same goal of placing a fourth ventricular catheter. However, we have found that the optical
resolution provided by modern flexible, steerable endoscopes is more than adequate for this procedure (see video). We have noted that the ability to nudge the tip of the ventricular catheter using the flexible endoscope allows precise placement of the catheter at the aqueductal orifice. In our hands, this shepherding technique would not be possible using a rigid endoscope within the third ventricle.

Video. Case 3. Example of endoscope-assisted placement of a multiperforated shunt catheter into the fourth ventricle from a frontal transventricular approach.

Click here to view with Windows Media Player and a broadband connection or here to view with RealPlayer.

Dual-Port Compared With Single-Port Endoscope-Assisted Surgery

We use a dual-port rather than a single-port technique for fourth ventricle catheter placement because we have found the latter cumbersome. Note, however, that positive experiences with the single-port technique have been reported for fourth ventricular shunt placement. Specifically, Torres-Corzo and associates have described the use of a Codman peel-away catheter through which, it is implied, both the ventricular catheter and the Codman flexible neuroendoscope are passed simultaneously. Given that the summed diameters of the catheter and this endoscope exceed the internal diameter of the Codman No. 14 French peel-away catheter, this arrangement does not seem physically possible. Even if the peel-away catheter could be distorted to achieve an oval cross-section, we have found it impossible to slide the ventricular catheter forward past the endoscope due to friction resistance. When the endoscope and ventricular catheter are inserted down the same track (single-port technique), it is more difficult to use the endoscope as a tool to push the catheter because the two objects are directly parallel to each other; with parallel placement, the desired displacement of the ventricular catheter tip by the endoscope is limited. In addition, the single-port technique creates the risk of the endoscope inadvertently dragging the ventricular catheter out with it as the scope is withdrawn. Of course, one option is not to use a peel-away sheath, although in our experience this strategy introduces other technical problems, such as a difficulty in maintaining irrigation egress and in limiting mechanical trauma to the cortex.

We have found that the use of two ports, a precoronal bur hole and a far frontal bur hole, overcomes many technical challenges of this procedure. From an anatomical perspective, the far frontal port allows a straighter trajectory for the endoscope through the foramen of Monro to the aqueduct. This trajectory can be advantageous for the use of transendoscopic instruments, given that they may not function properly with acutely angled flexible endoscopes. Moreover, the straight trajectory made possible by the use of the far frontal port for the endoscope protects the structures near the foramen of Monro (including the fornices) by limiting the pressure applied to the posterior aspect of the foramen. In contrast, when the standard coronal/precoronal bur hole approach is used, fourth ventricle exploration requires two acute angulations of the endoscope, one at the foramen of Monro and the other at the aqueduct, exerting pressure at both sites.

There are, of course, potential downsides to a dual-port technique. First, the use of frameless stereotaxis adds logistic issues. Because there are no standard landmarks for precise cannulation of the lateral ventricle from the far frontal entry point, however, computer-assisted navigational guidance is essential for targeting. Second, penetrating the cortex twice obviously doubles the risk of intracerebral hemorrhage, although in our experience this complication is exceedingly rare in endoscopy cases in which there is direct visualization of the corticectomy site. Third, the dual-port technique requires an anterior frontal incision that permits far frontal access for the endoscope. In our use of this technique for fourth ventricle shunt placement and for other types of endoscopic operations such as colloid cyst resection, the far frontal incision has not presented significant cosmetic issues.

Patient Treatment and Outcomes

In the small number of cases reported on in this paper, patients show clinical and neuroimaging improvement after panventricular shunting. Not unexpectedly, patients who improve most dramatically after shunting have pathophyslogies confined to compartmentalized hydrocephalus and IFV. Those who have additional devastating pathological entities (for example, a chronic large dominant-hemisphere infarct as in the patient in Case 4) are unlikely to return to their premorbid neurological status after the correction of compartmentalized hydrocephalus. Nonetheless, given the individual variations in recovery from neurological disease, it behooves the neurosurgeon to give every patient every possible chance, and for this reason shunting in such cases is indicated. As we perform this procedure in a greater number of patients, we will be better able to assess outcomes.

With regard to technique, the reoperation in the patient in Case 1 illustrates the importance of the location of the ventricular catheter perforations, given that the patient required revision of the ventricular catheter because of choroid plexus–clogged catheter holes in the lateral ventricle. The fact that all patients required postoperative reprogramming of their valves is unsurprising given the complicated nature of compartmentalized hydrocephalus and emphasizes the necessity of implanting a programmable valve as part of the shunt system.

CONCLUSIONS

In a subset of adult patients with compartmentalized hydrocephalus that includes IFV, fourth ventricular shunting is necessary. We have presented one solution to the technical difficulty of fourth ventricular shunt placement that has shown good outcomes in a small number of cases. Our solution consists of a dual-port technique in which a flexible endoscope is used for direct visualization of the ventricular system and also as a mechanical tool, in combination with frameless stereotactic neuronavigation, for placement of a multiperforated panventricular catheter. This technique is minimally invasive, rapid, and accurate. It allows excellent visualization for precise ventricular catheter trajectory and thereby minimizes complications of fourth ventricular catheter placement. The panventricular catheter equalizes ventricular pressures by putting the
compartmentalized ventricles, including the IFV, in communication with one another. We have used this method successfully in a small number of adult patients suffering from compartmentalized hydrocephalus and IFV. This technique is equally applicable in appropriately selected pediatric patients.

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K. Upchurch, M. Raifu, and M. Bergsneider