Small-ventricle neuroendoscopy for pediatric brain tumor management

Clinical article

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Object. The use of intraventricular endoscopy to achieve diagnosis or to resect accessible intraventricular or paraventricular tumors has been described in the literature in both adults and children. Traditionally, these techniques have not been used in patients with small ventricles due to the perceived risk of greater morbidity. The authors review their experience with the effectiveness and safety of endoscopic brain tumor management in children with small ventricles.

Methods. Between July 2002 and December 2009, 24 children with endoscopically managed brain tumors were identified. Radiological images were reviewed by a radiologist blinded to study goals and clinical setting. Patients were categorized into small-ventricle and ventriculomegaly groups based on frontal and occipital horn ratio. Surgical success was defined a priori and analyzed between groups. Trends were identified in selected subgroups, including complications related to pathological diagnosis and surgeon experience.

Results. Six children had small ventricles and 18 had ventriculomegaly. The ability to accomplish surgical goals was statistically equivalent in children with small ventricles and those with ventriculomegaly (83% vs 89%, respectively, p = 1.00). There were no complications in the small-ventricle cohort, but in the ventriculomegaly cohort there were 2 cases of postoperative hemorrhages and 1 case of infection. All hemorrhagic complications occurred in patients with high-grade tumor histopathological type and were early in the surgeon’s endoscopic career.

Conclusions. Based on our experience, endoscopy should not be withheld in children with intraventricular tumors and small ventricles. Complications appear to be more dependent on tumor histopathological type and surgeon experience than ventricular size. (DOI: 10.3171/2010.10.PEDS10338)

Key Words • neuroendoscopic surgery • endoscope • intraventricular tumor • neuronavigation • pediatric surgery • endoscopy

Although neuroendoscopy was originally devised by L’Espinasse in 1908 and Dandy in 1922 for the treatment of hydrocephalus, innovation over the last half century has permitted more complex procedures to be performed, including the treatment of hydrocephalus, cyst fenestration, and tumor management.1,2 In 1978, Fukushima3 first reported on a series of patients with brain tumors managed by neuroendoscopic surgery. Since then, experience and medical advances have widened the spectrum of endoscopic tumor treatment from tumor biopsy to resection.4

Because several pediatric intraventricular tumors respond to nonsurgical therapies, minimally invasive procedures are especially attractive. Often, a pathological diagnosis can be obtained through endoscopic biopsy, with definitive treatment by radiation and/or chemotherapy. Moreover, in select circumstances, tumors can be resected endoscopically. Certain lesions not traditionally labeled as tumors lend themselves to endoscopic resection—in particular, selected colloid cysts and hypothalamic hamartomas. In general, the trend is moving away from invasive craniotomy and toward endoscopic management.5

Most patients presenting with intraventricular tumors have ventriculomegaly due to hydrocephalus, and traditionally, surgeons have believed that ventricular enlargement was necessary to avoid morbidity.6 A small
Small-ventricle neuroendoscopy

proportion of patients with intraventricular tumors present with small ventricles, and their candidacy for endoscopic surgery has been unclear. Recently, Souweidane reported a combined series of adult and pediatric patients whose tumors were successfully managed endoscopically despite an absence of hydrocephalus. Similarly, our study tested the hypothesis that the effectiveness and safety of endoscopic brain tumor management in a pediatric cohort is not dependent on ventricle size.

Methods

Patient Selection

Following institutional review board approval (approval number X091029017), a database of all neuroendoscopic procedures was retrospectively populated from medical records and review of imaging. The database was queried for patients undergoing endoscopic tumor biopsy or resection at the Children’s Hospital, Birmingham, Alabama, performed by the senior author (J.C.W.) between July 2002 and December 2009. This yielded 24 patients—20 patients who underwent biopsy and 4 patients who underwent tumor resection.

Patients were categorized by ventricle size into a study group of patients with small ventricles and a control group of patients with ventriculomegaly. Ventricle size was compared using the frontal and occipital horn ratio (FOR), which is a validated ratio representing ventricle volume and has been found to have high interobserver reliability in pediatric patients. A radiologist, who was blinded to the purpose of the study, performed all measurements and calculations of FOR using preoperative axial T2-weighted MR imaging sequences or CT scans. The normal FOR in children was taken from prior publications and established for the purposes of this study as an FOR of 0.37. Therefore, patients were considered to have small ventricles if their FOR was less than or equal to 0.37 and considered to have ventriculomegaly if their FOR was greater than 0.37.

The independent variables were age, sex, race, weight, ventricle size, presenting symptoms, tumor location, type and grade, procedure type, timing of procedure, use of neuronavigation, and use of an EVD. Dependent variables included the ability to accomplish surgical goals, complications, hemorrhage on postoperative imaging, and requirement for permanent CSF diversion. The ability to accomplish surgical goals was defined as determination of a pathological diagnosis from tumor biopsies or as gross-total resection for tumor resections. Complications were defined as any morbidity or mortality occurring within 30 days of surgery.

Statistical Analysis

Categorical variables were compared using the Fisher exact test (Biostats Calculator) because of the small number of patients. Continuous variables were compared using the Mann-Whitney U-test (Biostats Calculator) because parametric distribution could not be assumed. A statistically significant difference was recorded when the probability value was found to be less than 0.05.

Endoscopic Technique

Under general anesthesia, the patients were positioned in the supine position with the head slightly flexed to minimize egress of CSF. When neuronavigation (BrainLAB) was used, the head was positioned in 3-point pin fixation, and when neuronavigation was not used, the head was supported on a horseshoe headrest. An incision was planned based on the location of the tumor. A standard bur hole was made, the dura mater was opened in a cruciate fashion, and the pia mater was coagulated and opened.

Ventricle access was obtained either with assistance from neuronavigation or by freehand technique. When used, neuronavigation assisted with bur hole and trajectory planning, as well as ventricular puncture. Neuronavigation was used at the discretion of the surgeon; however, it was used for every patient with small ventricles.

In patients with small ventricles, the neuronavigation wand was used for initial ventricular puncture. Side accuracy and trajectory were confirmed by navigating a 1.1-mm endoscope (NeuroPEN, Medtronic) inside a 1.7-mm ventricular catheter (Innervation ventricular catheter, Medtronic) and into the ventricle. If the ventricles were very small, they were gently insufflated with approximately 10–20 ml of lactated Ringer’s solution. During insufflation, the heart rate was monitored for bradycardia. If bradycardia occurred, insufflation was halted. Next, a 12.5 Fr introducer sheath and trocar (Peel-Away catheter introducer, Codman) were exchanged down the same tract. Our technique has evolved to modifying the introducer sheath and trocar to allow the 1.1-mm-diameter neuroendoscope to pass through its lumen for endoscopic visual control down the same tract as the ventriculostomy catheter. Once the tract was dilated, the trocar and sheath were removed, and the rigid endoscope (Aesculap) was introduced down the tract.

In patients with ventriculomegaly, a freehand technique was often used to puncture the ventricle. In these cases, the introducer sheath and trocar were directly passed into the ventricle without the assistance of neuronavigation. After ventricular access was obtained, continuous irrigation at variable rates was maintained throughout the procedure. The rate of irrigation was subjectively adjusted based on the clarity of the CSF. A channel through the rigid endoscope remained open to allow the egress of spinal fluid and preserve safe intracranial pressure.

For biopsies, the lesion was identified under direct visualization with the endoscope, and multiple specimens were obtained using the endoscopic biopsy forceps. In cases in which the tumor could not be directly visualized because of a paraventricular location, neuronavigation was coregistered to the endoscope for tumor localization. After multiple specimens had been taken, bleeding was controlled with irrigation. If bleeding continued, endoscopic bipolar cautery was used. In all cases, pathological analysis was performed in both fresh-frozen and formalin-fixed specimens. A ventriculostomy catheter was left in place at the discretion of the surgeon.

In resecting 2 colloid cysts and 2 hypothalamic hamartomas, techniques similar to those of other authors were used. In colloid cyst resection, a 0° rigid endoscope was used. The capsule was sharply opened with en-
doscopic scissors, and cyst contents were aspirated using a pediatric pulmonary suction catheter. The cyst capsule was then resected using sharp dissection and traction, with bipolar coagulation complementing the process. Bleeding was controlled with irrigation and coagulation. The extent of resection was confirmed with a 30° rigid endoscope. A ventriculostomy catheter was left in place postoperatively. For hypothalamic hamartoma resection, the lateral ventricle on the opposite side of the third ventricle lesion was accessed to provide the correct trajectory for resection. After tumor identification, circumferential dissection around the abnormal tissue was performed while centrally debulking the tumor.

When closing, a Gelfoam plug was placed in the cortical corridor and bur hole defect. The scalp was closed in 2 layers.

Results

Patient Characteristics

Of the 24 children with endoscopically managed tumors, 6 (25%) had small ventricles and 18 (75%) had ventriculomegaly. Comparison of patient characteristics in the 2 groups showed a statistically significant difference in ventricle size (Table 1). There was a trend toward more malignant tumors in the ventriculomegaly group.

Presenting symptoms in the patients with small ventricles included medically refractory gelastic seizures in 2 patients with hypothalamic hamartomas, visual complaints and vertigo in a patient with a suprasellar low-grade glioma, and diabetes insipidus, precocious puberty, and hemihypoplasia in a patient with a multicentric germinoma (Fig. 1). One patient with a germinoma and another with a colloid cyst originally presented with symptoms of increased intracranial pressure due to hydrocephalus (Fig. 2); however, both had VP shunts placed at another hospital, so by the time they presented for tumor management, their ventricles were small. Therefore, for rigid endoscopy to be performed for biopsy or lesion removal, the trajectories had to be altered.

In the ventriculomegaly cohort, 15 patients (83%) presented with symptoms of increased intracranial pressure due to hydrocephalus. Of the remaining 3 patients, 1 presented with seizures, 1 was found to have a lesion during a routine oncological screening MR imaging because of previously treated medulloblastoma, and the last patient presented with an incidental radiological finding following head injury.

Tumor location was compared between cohorts. In patients with small ventricles, 4 tumors were located in the third ventricle, 1 was suprasellar, and 1 was in the lateral ventricle. In patients with ventriculomegaly, 14 tumors were in or adjacent to the third ventricle and 4 were in the lateral ventricle. Generally, endoscopy in the posterior third ventricle is technically more demanding; therefore, this location was specifically compared between the cohorts. One patient in the small-ventricle cohort and 6 patients in the ventriculomegaly cohort had tumors in the posterior third ventricle (p = 0.629).

Operative Characteristics

The majority of small-ventricle endoscopic cases were performed later in the senior author’s career; 4 of the 6 cases were performed in the last half of his endoscopic experience.

Neuronavigation was used in every patient with small ventricles and in 13 (72%) of the patients with ventriculomegaly. An EVD was inserted in all patients with small ventricles and in 8 (42%) patients with ventriculomegaly.

Both patients with small ventricles who presented with a shunt in place were able to have the shunts removed following endoscopic intervention. One patient with a colloid cyst had her bilateral shunts removed during the endoscopic resection of the tumor and did not require permanent CSF diversion. The other patient also had his shunt removed and an ETV performed during the same procedure as the endoscopic biopsy. None of the other patients in the small-ventricle cohort required permanent CSF diversion. In the ventriculomegaly cohort, 14 of 18 patients required CSF diversion procedures in addition to tumor management. This included 9 ETMs performed during the same procedure as the biopsy, placement of 3

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Small Ventricle (6 cases)</th>
<th>Ventricleomegaly (18 cases)</th>
<th>p Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>median age in yrs</td>
<td>14.5 ± 3.9</td>
<td>9.5 ± 5.5</td>
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</tr>
<tr>
<td>sex</td>
<td></td>
<td></td>
<td>0.67</td>
</tr>
<tr>
<td>M</td>
<td>3 (50)</td>
<td>10 (56)</td>
<td></td>
</tr>
<tr>
<td>F</td>
<td>3 (50)</td>
<td>8 (44)</td>
<td></td>
</tr>
<tr>
<td>race</td>
<td></td>
<td></td>
<td>1.00</td>
</tr>
<tr>
<td>Caucasian</td>
<td>5 (83)</td>
<td>14 (82)</td>
<td></td>
</tr>
<tr>
<td>African-American</td>
<td>1 (17)</td>
<td>4 (18)</td>
<td></td>
</tr>
<tr>
<td>median weight in kg</td>
<td>51 ± 15.1</td>
<td>31.5 ± 22.1</td>
<td>0.015</td>
</tr>
<tr>
<td>tumor type</td>
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<td></td>
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</tr>
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<td>germinoma</td>
<td>2</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>ganglioglioma</td>
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<td>1</td>
<td></td>
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<tr>
<td>colloid cyst</td>
<td>1</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>medulloblastoma</td>
<td>0</td>
<td>1</td>
<td></td>
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<td>hypothalamic hamartoma</td>
<td>2</td>
<td>0</td>
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<tr>
<td>pineoblastoma</td>
<td>0</td>
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<td>dysembryoplastic neuroepithelial tumor</td>
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<td>2</td>
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<tr>
<td>high-grade astrocytoma</td>
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<td>4</td>
<td></td>
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<td>3</td>
<td></td>
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<tr>
<td>tumor grade</td>
<td></td>
<td></td>
<td>0.64</td>
</tr>
<tr>
<td>malignant</td>
<td>2 (33)</td>
<td>10 (56)</td>
<td></td>
</tr>
<tr>
<td>not malignant</td>
<td>4 (67)</td>
<td>8 (44)</td>
<td></td>
</tr>
<tr>
<td>median ventricle size (FOR)</td>
<td>0.36 ± 0.02</td>
<td>0.43 ± 0.06</td>
<td>&lt;0.0005</td>
</tr>
</tbody>
</table>

* Values represent numbers of patients (%) unless otherwise indicated. Medians are reported with SDs.
VP shunts, and 2 septostomies. Two patients who underwent ETV progressed to needing a VP shunt.

After a pathological diagnosis was obtained, 3 patients underwent craniotomy for tumor resection. One patient with a glioblastoma multiforme required an emergent craniotomy for evacuation of an intraparenchymal hematoma that occurred in the first 6 hours postoperatively. The remaining 83% of patients were treated with nonsurgical therapies.

**Accomplishment of Surgical Goals**

Surgical objectives were accomplished in 21 (88%) of 24 endoscopic tumor management cases, with 18 (90%) of 20 biopsies yielding a pathological diagnosis and 3 (75%) of 4 resections resulting in a gross-total resection. When cases were categorized by ventricle size or target frontal horn size, there was no statistically significant difference in the ability to accomplish goals between cohorts (Table 2). In the small-ventricle cohort, all biopsies yielded a pathological diagnosis. Three resections were performed in patients with small ventricles, resulting in gross-total resection of 1 colloid cyst and 1 hypothalamic hamartoma (Table 1) and subtotal resection of 1 hypothalamic hamartoma due to extension into the interpeduncular cistern (Table 2).

In the ventriculomegaly cohort, there were 2 patients with nondiagnostic biopsies, 1 showing necrosis and 1 demonstrating an undefined inflammatory process. Both underwent repeat biopsy, with the lesion in the first patient determined to be a low-grade glioma despite the internal necrosis, and the biopsy findings remaining nondiagnostic in the other. (The pathological findings continued to favor an inflammatory process related to encephalitis of unknown origin.) Gross-total resection of a colloid cyst was accomplished in the only tumor resection in the ventriculomegaly cohort.

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The inability to accomplish surgical objectives was not related to surgeon experience with the procedure. When endoscopic experience of the surgeon was chronologically stratified into thirds, 2 failures occurred during the first third, 1 occurred during the second third, and 1 occurred during the most recent third of his career.

**Complications**

There were no patient deaths within the perioperative period. Three complications occurred in 24 patients (for a complication rate of 13%), all occurring in the ventriculomegaly cohort. These complications included 2 hemorrhages: 1 intraoperative and 1 postoperative. The first occurred in a patient who presented with acute signs of raised intracranial pressure and underwent a biopsy plus ETV. The ventricles collapsed after initial cannulation, making navigation more difficult. This patient required an EVD and, ultimately, a VP shunt. The pathological diagnosis was pineoblastoma. In retrospect, an EVD placed initially to allow the intracranial pressure to normalize before formal biopsy and ETV would have been less likely to result in endoscopic navigation under less than ideal conditions. The other hemorrhage occurred 6 hours after a biopsy of a thalamic glioblastoma multiforme under normotensive conditions. Subsequently, this patient required 2 craniotomies for evacuation of the he-

**TABLE 2: Comparison of achieving surgical goals between 6 children with small ventricles and 18 with ventriculomegaly**

<table>
<thead>
<tr>
<th>Op</th>
<th>Small Ventrices</th>
<th>Ventriculomegaly</th>
<th>p Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>biopsy</td>
<td>3/3 (100)</td>
<td>15/17 (88)</td>
<td>1.00</td>
</tr>
<tr>
<td>resection</td>
<td>2/3 (67)</td>
<td>1/1 (100)</td>
<td>1.00</td>
</tr>
<tr>
<td>all</td>
<td>5/6 (83)</td>
<td>16/18 (89)</td>
<td>1.00</td>
</tr>
</tbody>
</table>

* Values represent the number of cases in which procedure was successfully performed/the number in which it was attempted (%).
matoma and tumor; eventually, she needed a VP shunt. She died of tumor progression 2 months after the biopsy. One patient with a pineoblastoma developed an infection requiring wound revision and antibiotics. There was no intraoperative hemorrhage requiring abortion of the initial endoscopic procedure in either cohort.

Chronologically, both hemorrhages happened early in the senior author’s career, occurring during the first third of his endoscopic tumor cases. Additionally, both hemorrhages occurred in histologically high-grade tumors. Immediate postoperative imaging was not routinely performed. In the small-ventricle cohort, only 2 patients underwent postoperative imaging, and neither had findings of hemorrhage. In the ventriculomegaly cohort, 16 of 18 patients underwent postoperative imaging and 4 patients had findings of hemorrhage.

Discussion

Brain Tumor Endoscopy

In this small retrospective study, there was no difference in the ability to accomplish surgical goals between cases involving patients with small ventricles and those involving patients with ventriculomegaly. These findings show that endoscopy in patients with small ventricles is a relatively effective and safe treatment option.

Accomplishment of Surgical Goals

Depending on the surgical indication, pathological diagnostic yield or gross-total resection is the surgical goal in tumor management. More than 30 years ago, Fukushima4 first reported on a series of 22 patients undergoing endoscopic biopsy. Eleven biopsies (52%) resulted in pathological diagnosis, but his technique was limited by sampling only 1 specimen per patient, relatively primitive equipment, and lack of neuronavigation, making the results all the more remarkable. Since Fukushima’s series, surgeons have improved diagnostic yield through technique modification, including routine use of neuronavigation, endoscopic monopolar and bipolar coagulation, and taking multiple biopsy specimens, routinely 5 per patient in our series. In cohorts in which most of the patients had ventriculomegaly, contemporary authors have reported diagnostic yields ranging from 92% to 97%,. Specifically in a pediatric cohort, Oertel et al.12 reported a similarly high diagnostic yield of 92% in 22 patients. Our study found a comparable yield in pediatric patients with an overall biopsy diagnostic yield of 90% and a yield of 100% in the patients with small ventricles.

Endoscopic tumor resection has been reported at varying success rates ranging from 71% to 100%.5,16,18,19 In the current study, only a small number of patients underwent tumor resection, with gross-total resection being accomplished in 3 of 4 patients. We also recognize that neither colloid cysts nor hypothalamic hamartomas are traditionally considered tumors but for the sake of brevity are considered as such here.

Small-Ventricle Endoscopy

Tumor endoscopy studies have included a small number of patients without hydrocephalus. In initially reporting management of third ventricular tumors, Souweidane et al.23 described 4 of the 12 patients as without hydrocephalus. Similarly, Gaab and Schroeder9 discussed their experience with intraventricular tumor management, and 9 of the 30 patients were without hydrocephalus. There was no objective definition of ventricle size in either of these important studies, nor was there any dedicated analysis of these patients with small ventricles. Yamamoto et al.24 first reported an endoscopic technique for surgery in small ventricles. Using a flexible endoscope, surgical goals were accomplished in 3 adults without complications, but no objective measurement of ventricle size was included.

As neuroendoscopic techniques became more refined, Souweidane20 retrospectively analyzed a cohort of 15 adult and pediatric patients who underwent endoscopic tumor management with an FOR of 0.37 or less and compared it with a similar cohort of 65 patients with an FOR greater than 0.37. Similar to our results, the findings of these authors showed no difference in accomplishing surgical goals of tumor resection or biopsy. For select adult and pediatric patients with intraventricular tumors, endoscopy became a reasonable treatment option. Likewise, Rekate et al.14 performed endoscopic resection of hypothalamic hamartomas in 44 patients, most of whom were pediatric. There was no objective measurement of the ventricle size, but the ventricles were described as “normal” in size. This study was published as a technical note and discussed complications but excluded accomplishment of surgical goals with respect to gross-total resection. In our small-ventricle cohort, the only subtotal resection was in a patient with a hypothalamic hamartoma.

Complications

Neuroendoscopy did not initially reach widespread acceptance due to high morbidity.3 Advances in technique and technology have allowed progressive reduction in the rate of complications. One barrier to endoscopy for tumor management has been small ventricle size. Endoscopy was thought to be inadvisable in patients with small ventricles because of concerns about accessing and navigating within the ventricles.6,21 In contemporary endoscopic tumor management studies, the complication rate has ranged from 0% to 25%,.5,13,14,16,20,21 Three studies directly address endoscopy in small ventricles; Rekate et al.14 incurred complications in 25% of patients; most resolved, but permanent deficits remained in 6.8% of patients. In the other 2 small-ventricle studies, Souweidane and Yamamoto et al.24 reported no complications. Ironically, we only experienced complications in patients with ventriculomegaly. Our complication rate, irrespective of ventricle size, was 12.5%, which is comparable to the findings of other studies.

Outcomes Related to Malignant Histopathology

All complications occurred in patients with malignant histopathology, which was prevalent in the patients with ventriculomegaly (56%). Bernstein and Parrent22 reported on 300 stereotactic biopsies, in which 5 deaths
and 19 complications were incurred. All mortalities and 63% of the morbidities were in patients with malignant histopathology. The authors concluded that more aggressive pathology was a significant predictor of hemorrhagic complication. Hall performed 134 biopsies, and all morbidity and mortality occurred in patients with malignant histopathology. Therefore, it is reasonable to conclude that the same risks for complications in stereotactic biopsies apply to patients undergoing endoscopic tumor management and that the hemorrhagic complications may result from inherent properties of the tumor rather than ventricle size.

Outcomes Related to Surgeon Experience

In the current study, all hemorrhagic complications occurred during the first third of the surgeon’s endoscopy experience. Souweidane emphasized that negative outcomes occurred earlier in the surgeon’s career and were related to inexperience. Schroeder and Gaab described colloid cyst resection and found that 2 of 3 incomplete resections occurred in their first 2 resections. Teo et al. reported a decrease in intraoperative complications as endoscopic experience increased and went on to describe endoscopic education as having a steep learning curve. This trend in our study, albeit not statistically analyzed, agrees with these findings that experience yields better endoscopic outcomes.

Over time, the senior surgeon gained valuable experience in more complex neuroendoscopy and in the avoidance and management of hemorrhage. In addition to known safety practices such as the use of neuronavigation, variable irrigation, and the use of the endoscopic bipolar, specific techniques were progressively incorporated into the senior surgeon’s technique including 1) reduced manipulation of the choroid plexus to lessen venous bleeding thus maintaining visualization, 2) accessing the ventricle using an existing shunt tract or initially with a small-caliber catheter to access small ventricular systems and then modifying the introducer sheath and trocar to avoid misplacement into critical paraventricular structures, and 3) gentle ventricular insufflation with irrigation to enlarge the working space. This latter maneuver should be performed carefully and after judicious review of the patient’s ventricular system correlated with the patient’s symptoms. One patient with a posterior third ventricular germinoma presented with papilledema and had ventriculomegaly. He underwent VP shunt insertion at another institution, and the ventricle size decreased in size. The trajectory of this existing catheter was not ideal for ETV or biopsy, so the shunt was removed, and in the operating room, a ventricular drain was inserted down the same tract that was occupied by the ventricular catheter of the shunt system. Gentle insufflation assisted in enlarging the ventricles, whereas neuronavigation provided access and a trajectory into the lateral ventricle for a posterior third ventricle biopsy and then again for an ETV.

It is crucial to define surgical roles prior to any endoscopic procedure and communicate clearly during the procedure itself. If both the surgeon holding the endoscope and the surgeon using the instruments believe that it is their job to steer once inside the ventricle, bleeding will quickly ensue, and the situation will spiral into further difficulty.

Neuronavigation

Navigational guidance has been inconsistently used by endoscopists for bur hole and trajectory planning, as well as tumor localization. In our series, navigation was used for all patients with small ventricles. In the other small-ventricle studies, neuronavigation was used in 33%–100% of cases. Schroeder et al. described an objective preference for navigation use versus freehand technique in patients with small ventricles. Reports of freehand ventriculostomy placement in trauma patients with small ventricles appear to support the use of neuronavigation in elective endoscopic procedures in patients with small ventricles. A prospective study to evaluate the necessity of navigation in these cases is not ethically feasible. Therefore, we recommend use of neuronavigation in patients with small ventricles.

Frontal and Occipital Horn Ratio

O’Hayon et al. found that the FOR is a valid representation of ventricle volume and has a high interobserver reliability. They reported that normal pediatric patients without hydrocephalus had a mean FOR of 0.37; therefore, in our study, all patients with an FOR of 0.37 or less were considered to have small ventricles. In a study of neuroendoscopy in patients without hydrocephalus, Souweidane used FOR to represent ventricle volume; in this study, all of the patients without hydrocephalus were found to have an FOR of less than 0.37. Although FOR is a valid measurement, the ventricles in some of the children in the ventriculomegaly cohort were still considered, on a subjective basis, small for endoscopy. Because of this, target frontal horn width was considered the measurement tool to define ventricle size. Target frontal horn width is clinically reasonable because it measures the location of ventricular access and where most of the endoscopic maneuvering occurs. When ventricle size was analyzed on the basis of frontal horn width, some patients did cross over to the small-ventricle cohort; however, none of the outcome results changed.

Limitations

This study is limited by a relatively small number of patients (due to the low incidence of intraventricular tumors in patients with small ventricles) and by the bias issues inherent in a retrospective study.

Conclusions

Innovation has provided new, safe options for intraventricular tumor management. In children, obtaining a pathological diagnosis or resection of an intraventricular lesion through an endoscope continues to move closer toward preferred practice. Neuroendoscopy in small ventricles and large ventricles offers comparable ability to accomplish surgical goals. Complications may be associated with surgeon experience and tumor histological type rather than ventricle size. These findings may be of assis-
tance to the endoscopic neurosurgeon when considering surgical options.

Disclosure

The authors report no conflict of interest concerning the materials or methods used in this study or the findings specified in this paper.

Author contributions to the study and manuscript preparation include the following. Conception and design: Wellons. Acquisition of data: Naftel, Shannon, Reed, Martin. Analysis and interpretation of data: Naftel, Shannon, Reed, Martin, Wellons. Drafting the article: Naftel, Reed. Critically revising the article: Blount, Tubbs, Wellons. Reviewing final version of the manuscript and approved it for submission: all authors. Statistical analysis: Naftel, Shannon. Administrative/technical/material support: Blount, Wellons. Study supervision: Wellons.

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References


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