Intraoperative assessment of endoscopic third ventriculostomy success

Clinical article

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Object. The authors’ aim in this study was to determine if standardizing the evaluation of intraoperative findings during endoscopic third ventriculostomy (ETV) could predict patients with hydrocephalus in whom endoscopic treatment will fail and require ventriculoperitoneal shunt treatment. The creation of a uniform scale with predictive outcomes may reduce returns to the operating room for shunt treatment and reliance on postoperative externalized ventricular monitoring and MR imaging.

Methods. The authors evaluated the preoperative history, intraoperative findings, and postoperative monitoring and imaging findings in 109 consecutive patients undergoing 112 consecutive attempted ETVs for obstructive hydrocephalus. A 5-grade scale was developed to assess preoperative risk factors and intraoperative evaluation to unify criteria that have been suspected to influence outcome independently. A grade of 0 was assigned to patients with no negative predictors, whereas increasing scores were assigned to patients who had multiple preoperative and intraoperative risks identified. Patients’ grades were compared with outcome of the procedure, utility of externalized ventricular monitoring, and results of postoperative MR imaging.

Results. Of 112 ETVs, 77 were successful and 35 were unsuccessful. Fifty-nine patients received a grade of 0, 27 received a grade of 1, 11 received a grade of 2, and 15 received a grade of ≥3. In all 15 patients receiving a grade ≥3 attempted ETV procedures failed, and the patients required a ventriculoperitoneal shunt. Postoperative monitoring with externalized ventricular drains and MR images demonstrating radiographic evidence of flow was independently less reliable than intraoperative grading in predicting success. Patients with a grade of 0 almost uniformly had successful surgery, independent of MR imaging findings. Patients with a grade of 1 or 2 who had successful surgery almost always lacked negative intraoperative predictive findings.

Conclusions. Despite reliance in recent years on post-ETV MR images and externalized ventricular monitoring, these modalities, although often useful adjuncts, appear less reliable as predictive tests than a simple assessment at the time of endoscopic fenestration. By using a uniform grading scale, the authors have introduced a novel means through which intraoperative and postoperative decision making can be aided, with the goal of reducing unnecessary procedures and tests and preventing unnecessary returns to the operating room. (DOI: 10.3171/PED.2008.2.11.298)

KEY WORDS • brain tumor • endoscopy • hydrocephalus • pediatric neurosurgery • shunt • third ventriculostomy

Preoperative risk factors for failure of ETV have been thoroughly examined, and the postoperative evaluation of patients has been largely standardized. In contrast, the intraoperative assessment of ETV has had a more limited role in helping neurosurgeons predict the success of their procedures. Surgical criteria studied independent-
monitoring or CSF diversion procedures. To assess this, we retrospectively evaluated the intraoperative dictations and postoperative records of the last 112 ETV procedures performed by one surgeon (M.M.S.) and compared preoperative risks, intraoperative findings, and postoperative assessments to see if a newly created scale would be as predictive of eventual success or failure as current modalities.

Methods

All procedures were performed using a 0 or 30° rigid lens endoscope (MINOP, B. Braun Aesculap). Specific technical details of the endoscopic procedure are detailed elsewhere; however, operative nuances specific to the ETV grading used in this study will be briefly reviewed. After successful cannulation of the lateral ventricle and identification of the intraventricular anatomy for proper orientation, the endoscope was advanced through the Monro foramen into the third ventricle. As the endoscope passed beneath the arch of the fornix, the lateral and third ventricles were inspected for the presence of unusual anatomical variations and evidence of past hemorrhage, infection, or metastatic tumor. Once within the third ventricle, the mammillary bodies and infundibular recess provided caudal and rostral boundaries between which the fenestration of the floor was created.

When the fenestration created was judged to be sufficient, the endoscope was used to evaluate the prepon tine subarachnoid space for the presence of scarring or adhesions and unfenestrated membranes of Liliequist. If necessary, blunt perforation and balloon dilation could be used on scarred or adherent membranes in a fashion similar to that used on the floor of the third ventricle. At the completion of the procedure irrigation, was briefly held. If the CSF pulsations transmitted from the cardiac cycle were not adequate to create a generous movement of CSF through the newly created defect, then the fenestration was briefly held. If the patient was < 2 years of age at the time of ETV surgery, the patient received 1 point. If the patient had a documented IVH as a neonate, a history of meningitis or ≥ 1 VP shunt infection, the patient also received 1 point. Thus, the patients received a preoperative score of 0, 1, or 2 based on the presence of these identified risk factors (Table 1).

The operative notes were then judged on 3 distinct criteria. The first was the presence of unusual anatomy. This included obvious intraventricular scarring intraventricular synechiae or leptomeningeal tumor dissemination. The presence of a mass, if distinct from the floor of the third ventricle, such as within the pineal recess, was not in itself a criterion for receiving 1 point in this category. The second criterion garnering 1 point was the presence of scarring or adhesions within the prepontine subarachnoid space. The final point was scored at the conclusion of the case when the endoscope was within the third ventricle and the irrigation was briefly held. If the CSF pulsations transmitted from the cardiac cycle were not adequate to create a generous movement of CSF through the newly created defect, then the procedure received a point (see Video Clip 1).

This created a maximum intraoperative score of 3 and a maximum complete score of 5 at the conclusion of the procedure (Table 1). Of the 112 patient operative notes reviewed 16 (14%) failed to mention the presence/absence of third ventricular floor pulsations, and 1 (0.8%) failed

Patient Population

A retrospective chart review using endoscopic and third ventriculostomy was performed on the operative records of one surgeon (M.M.S.) from New York Presbyterian Hospital and Memorial Sloan-Kettering Cancer Center. A total of 109 patients who had undergone 112 ETVs between March 1996 and March 2006 were identified within a 10-year period. Follow-up ranged from 1 to 10 years. A nonblinded reviewer assessed preoperative risk factors from patient histories. Operative notes were reviewed for specific intraoperative criteria. Postoperative MR images, when available, were reviewed in a blinded fashion by a neurosurgeon and neuroradiologist independently and evaluated for adequacy of the third ventricular fenestration as judged by the presence of flow signal in the third ventricle or prefontine cistern. In addition, the use of an EVD was noted. Failure of the ETV procedure was judged as the necessity of the patient to undergo a definitive shunting procedure within a 3-month postoperative period.

Grading of Surgical Procedures

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### TABLE 1

<table>
<thead>
<tr>
<th>Assessment criteria for scoring based on preoperative history and intraoperative findings</th>
<th>Value*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Parameter</td>
<td>Value*</td>
</tr>
<tr>
<td>preop history</td>
<td></td>
</tr>
<tr>
<td>age &lt;2 yrs</td>
<td>1</td>
</tr>
<tr>
<td>neonatal hemorrhage, meningitis, or VP shunt revision for infection</td>
<td>1</td>
</tr>
<tr>
<td>intraop findings</td>
<td></td>
</tr>
<tr>
<td>abnormal 3rd ventricular anatomy</td>
<td>1</td>
</tr>
<tr>
<td>thickened or scarred membranes in the subarachnoid space</td>
<td>1</td>
</tr>
<tr>
<td>absence of pulsation of 3rd ventricle floor at ETV completion</td>
<td>1</td>
</tr>
<tr>
<td>total grade</td>
<td>5</td>
</tr>
</tbody>
</table>

* A maximum of 2 points can be assigned for preoperative risk factors, and a maximum of 3 points can be assigned for intraoperative findings for a total maximum grade of 0–5.
to identify the presence/absence of scarred membranes; however, all 112 notes did mention whether the anatomy was normal or abnormal. Therefore, of 336 potential variables, 94.9% of the variables were noted in the operative dictations.

Statistical Analysis

Descriptive statistics were calculated to describe patient demographics and preoperative and intraoperative patient characteristics. The relationship between the 5-point score, as well as the 3-point intraoperative score, and ETV success/failure rate was assessed by the chi-square test or the chi-square test for trend, as appropriate. All probability values were 2-sided with statistical significance evaluated at the 0.05 alpha level. All analyses were performed in SAS Version 9.1 (SAS Institute, Inc.).

Results

Of the 109 patients who underwent ETV, 60 were male and 49 were female (Fig. 1A). Twenty-eight percent of the patients were < 2 years of age, 37% were between 2 and 18 years, and 35% were > 18 years (Fig. 1B). The most common indication for the procedure was obstructive hydrocephalus secondary to neoplasm. Of these patients, a diencephalic/third ventricular mass was the most common indication (30%), followed in decreasing frequency by masses in the tectum (24%), pineal region (14%), brainstem (12%), and posterior fossa (12%) (Fig. 1C). Of nonneoplastic causes (Fig. 1D), idiopathic aqueductal stenosis was the primary diagnosis in 41% of patients followed by 10% with Chiari malformations and 9% with nonneoplastic cystic pathological entities. An ETV was attempted in 11 patients with malfunctioning shunts in whom an underlying cause for the initial shunt placement could not be retrospectively determined.

The results of the 112 procedures were first analyzed to assess whether the intraoperative score alone could predict outcome. Of the 83 patients who received a grade of 0 for having no intraoperative risk factors, 88% had a successful ETV and avoided having to undergo VP shunt placement (Fig. 2a). Of the 14 patients with a single intraoperative finding, the procedure failed in 10 (71%), and of the 15 patients with ≥ 2 intraoperative findings, none (0%) had a successful outcome. Thus, there was an 86% failure rate for patients with at least 1 negative intraoperative finding compared with 12% for patients with no negative intraoperative findings (chi-square test, p < 0.0001).

Using univariate analyses, predictors for failure include age < 1 year (OR 4.52 [95% CI 1.57–12.98], p = 0.0051); age < 2 years (OR 3.64 [95% CI 1.48–8.91], p = 0.0048); a history of IVH or infection (OR 7.51 [95% CI 2.39–23.59], p = 0.0006); presence of scarring (OR 16.03 [95% CI 4.16–61.79], p < 0.0001); and presence of distort-

Fig. 1. Pie graphs showing the study design and demographics. Sex (A), age (B), tumor classification (C), and non-tumorous origins (D) of the 109 patients undergoing attempted ETV for obstructive hydrocephalus. AS = idiopathic aqueductal stenosis; CMI = Chiari malformation Type I; Hydro = hydrocephalus.
Assessing ETV success

An OR could not be calculated for third ventricular floor pulsation independently because there were no patients with “no pulsation” who were listed as “successes.” All of the aforementioned 5 variables were strong univariate predictors of failure and were therefore considered in the multivariate model. Age < 1 year was found to be a stronger predictor of failure in the univariate and multivariate models compared with age < 2 years. As a result, age < 1 year was included in the final model.

Within the multivariate analysis, predictors for failure include: age < 1 year (adjusted OR 2.59 [95% CI 0.63–10.62], p = 0.1860); history of IVH or meningitis (adjusted OR 3.24 [95% CI 0.70–14.95], p = 0.1315); intraventricular scarring (adjusted OR 9.00 [95% CI 1.96–41.28], p = 0.0047); and distorted anatomy (adjusted OR 5.72 [95% CI 1.75–18.72], p = 0.0040). After multivariate analysis, all of the variables have strong ORs, although 2 of them are not significant. This is likely due to the small number of patients < 1 year, or with a history of IVH or infection when each is crossed with the success/failure variable. However, the 95% CIs for these 2 variables do reveal a strong trend toward an increased risk of failure, so they are still likely to be important. The strongest predictors of failure in the multivariate model were intraventricular scarring or distorted intraventricular anatomy.

When the preoperative risk factors were included in the analysis, patients with Grade 0 and no preoperative risks or intraoperative findings (59 patients), had a 95% ETV success rate (Fig. 2b). Conversely, patients with Grades 3, 4, or 5 had a 100% failure rate (15 patients). Of the intermediate-grade patients, patients receiving a grade of 1 or 2 had success rates of 59 and 45%, respectively (p < 0.0001 by trend test for increasing failure rate with increasing grade). Subset analysis revealed that of the 21 patients with Grade 1 or 2 who had successful procedures, 81% had perfect intraoperative scores (Grade 0), suggesting that even with a history of meningitis or IVH, intraoperative criteria are crucial to predicting outcome.

At the conclusion of the 112 surgeries, 48 ventriculostomies were placed and 64 were not. Of the 48 patients receiving an EVD, the procedure failed in only 17 (35%) and these patients required placement of a VP shunt. Of the 64 patients who did not receive an EVD, the procedure failed in 18 patients (28%) (p = 0.41). Thus, ~65% of the EVDs may have been unnecessary and in 25% of patients in whom the ETV attempt failed, ICP monitoring was not used (Fig. 3). Magnetic resonance imaging was performed in 89 of the 112 patients. Of surgeries, 65 were successful and 24 were not. Of the 65 successes, MR imaging predicted success with radiographic evidence of flow in 77% of cases (Fig. 4). Thus, no flow was recognized radiographically in 23% of patients who clinically had successful outcomes. Conversely, of the 24 patients with MR images in whom the procedure failed clinically,
14 demonstrated flow on their MR images and 10 lacked flow, suggesting that MR imaging has limited predictive capacity in those patients in whom the procedure fails clinically.

**Discussion**

In the century subsequent to Dandy’s publication introducing the field of neuroendoscopy, refinements in neuroendoscopy have revolutionized the management of hydrocephalus. Today, ETV is the procedure of choice for the care of nonurgent obstructive hydrocephalus at the level of the cerebral aqueduct. Idiopathic aqueductal stenosis, or tectal or pineal region masses may create CSF outlet obstruction, which may be managed by attempting an ETV when alleviation of the obstruction via resection is not technically feasible. However, despite advancements in instrumentation and patient selection, neurosurgeons experienced in endoscopy can successfully manage obstructive hydrocephalus without using a ventricular shunt in only 75–85% of patients.

Preoperative risk factors for ETV failure have been suggested to confer a higher rate of ETV failure. These factors include a history of IVH from the germinal matrix—often associated with premature birth, a history of neonatal meningitis or intracranial or shunt infection or malfunction, along with an age of either a hemorrhage or an infection. These criteria likely contribute to some degree to reclosure of the fenestration site, scarring in the subarachnoid space, and scarring at the arachnoid granulations creating a multifactorial environment within which CSF diversion via shunting will be the only adequate current solution. Intraoperative hemorrhage during ETV has never been suggested as an independent variable affecting ETV, unlike perinatal hemorrhage and thus was specifically excluded from being an independent variable in our analysis. In addition, we did not note any intraoperative hemorrhage as defined by aborting the procedure or needing an external drain due to hemorrhage. Nevertheless, neurosurgeons, older patients, and the parents of younger patients often are willing to accept the comparatively high failure rate for ETV in some of these situations because the potential to treat their hydrocephalus without implanted shunt hardware is so enticing.

Postoperative evaluation of ETV success is based on clinical assessment, ICP monitoring with EVDs, and MR imaging to evaluate for stoma patency, ventricular size, and the presence of a flow void. Cine MR imaging has been used with increasing frequency to document bidirectional flow of CSF across a patent stoma between the third ventricle and the preoptic cistern. Although clinical assessment should remain the cornerstone of assessing patients post-ETV, the usefulness of ICP monitoring and postoperative MR imaging with their associated risks and costs has never definitively been addressed in this population despite widespread use.

The concept of intraoperative assessment is not a new tool. Any neuroendoscopist determining when an adequate fenestration has been created is performing an intraoperative assessment. Recently other groups have tried to identify individual factors that may predict the outcome of the surgery. We have introduced a grading scale that takes into account several criteria, which independently have been used by neurosurgeons to rate the likelihood of the procedure achieving a successful outcome. The patient’s grade will help guide the surgeon’s decision in several ways. The first decision will be to determine if there is any chance at long-term patency. If the patient has a grade of 5 at the conclusion of an ETV procedure, it may cause less morbidity and be more cost-effective to place a VP shunt at the time of the initial surgery. This practice has recently been introduced as the standard of care in Uganda where children with postmeningitic hydrocephalus and excessive scarring identified on endoscopy are immediately treated with shunts. Although our findings would suggest shunt insertion in the same anesthesia session, we are awaiting forthcoming results of an ongoing prospective study. One important distinction between our management from that of the Ugandan experience is that our population is expected to have more reliable follow-up; thus, we currently prefer an individualized critical analysis rather than a uniform policy that runs the risk of overtreatment. In addition, the limitations and possible bias introduced into our retrospective study are well appreciated, although they have been minimized as much as possible. To better analyze the possible usefulness of intraoperative criteria, we have initiated an institutional board-review–approved prospective study in which we use a planned review of now-archived video files to eliminate reviewer bias.

In cases with limited resources and in which patient follow-up or late ETV failures are a concern, this practice may be particularly warranted. With respect to late ETV failures within this study, we identified 4 patients who experienced clinical failure after 3 months. The ETV failed in a 2-year-old girl after 7 months (Grade 5); she underwent a repeated ETV that failed as well, and then she underwent shunt treatment. The ETV failed in a 3-year-old boy 12.5 months later (Grade 1) due to diffuse disseminated pineoblastoma; he then underwent a palliative ETV. The ETV failed in a 3-month-old boy 4 months after the procedure (Grade 4), and a VP shunt was placed. The ETV failed in a 10-year-old girl 10 years after the procedure (Grade 1), but she underwent a successful repeated ETV.

Postoperative EVD placement may be warranted for reasons such as excessive procedural hemorrhage; however, the results from this study indicate that routine ventricular monitoring and MR imaging is not contributory in patients with a grade of 0 or those with a grade of 3–5. With respect to ICP monitoring postoperatively, we did not record any tracing or retrospectively review actual ICP measurements because this paper is meant to address only intraoperative assessment of ETV functionality. Our data can be interpreted to suggest that surgeon’s judgment about the need for an EVD has less of a predictive value than expected. Patients with a grade of 1 or 2 may remain a subset in which some degree of postoperative monitoring or imaging may be helpful as an adjunct to the intraoperative findings, although the intraoperative score should still strongly guide the management.
Assessing ETV success

Conclusions

Endoscopic third ventriculostomy has become more routine as neurosurgeons become more comfortable with endoscopy. This procedure is frequently the treatment of choice for noncommunicating hydrocephalus. Our experience suggested that common criteria might help explain why certain patients had successful outcomes from the procedure whereas others did not. We reviewed 112 procedures and created a scoring scale to judge the intraoperative success of the procedure. Combined with some well-accepted preoperative risk factors, a 5-grade scale emerges as a highly predictive scoring measure with which neurosurgeons can evaluate their patients’ conditions at the time of surgery. This scale may help prevent unnecessary returns to the operating room, help guide postoperative management, reduce the dependency on external ventricular monitoring and MR imaging, and assist surgeons communicating about their patients undergoing endoscopy.

Disclosure

Dr. Souwedaine is a consultant for Aesculap.

References