Multiple studies describe classification systems for ETV success and failure based on preoperative, intraoperative, and postoperative findings. Such classification systems help predict in which patients an ETV may fail, and who therefore may require subsequent shunting procedures. Ideally, preoperative factors help select the best candidates for ETV.

For example, age at ETV and history of infection or hemorrhage have an impact on ETV outcome. Additionally, the cause and therefore presumably the type of hydrocephalus also affects ETV outcome. As stated by investigators who have extensively examined the pathophysiology and dynamics of hydrocephalus, “all hydrocephalus is obstructive.”

Terminology used in the literature categorizes hydrocephalus as “noncommunicating” (intraventricular obstructive hydrocephalus) and “communicating” (intraventricular obstructive hydrocephalus).

Preoperative third ventricular bowing as a predictor of endoscopic third ventriculostomy success

Clinical article

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Object. Patients with hydrocephalus often present with both intraventricular obstructive and communicating components, and determination of the predominant component is difficult. Other investigators have observed that third ventricular floor deformation, or “bowing” of the third ventricular floor, is a good indicator of intraventricular obstructive hydrocephalus, resulting in higher success rates with endoscopic third ventriculostomy (ETV). However, additional third ventricular bowing assessment and statistical evidence demonstrating a difference in ETV outcome with third ventricular bowing is needed. The authors hypothesized that patients with preoperative bowing of the third ventricle would exhibit greater long-term success rates after ETV and that lack of bowing would result in increased failure rates after ETV.

Methods. The authors determined success and failure for 59 ETVs performed in 56 patients, and recorded patient age, time to failure, and preoperative third ventricular anatomy, as well as history of infection, intraventricular hemorrhage, and previous shunt. Third ventricular anatomy was assessed on MR imaging for bowing, which was classified as any of the following: depression of the third ventricular floor, enlargement of the supraoptic recess, anterior curvature of the lamina terminalis, dilation of the proximal aqueduct to a greater extent than the distal aqueduct, and blunting or posterior bowing of the suprapineal recess. Univariate and multivariate analyses of ETV failure and the time to failure were performed using logistic regression and the Cox proportional hazards model, respectively.

Results. After adjusting for patient age and history of infection, there was a significant association between lack of anterior third ventricular preoperative bowing (either lamina terminalis, supraoptic recess, or third ventricular floor) and ETV failure (adjusted HR 2.79, 95% CI 1.08–7.20). Of the patients with bowing, 70.5% experienced success with ETV, as did 33.3% of the patients without bowing. Among the individual structures, absence of bowing in the anterior aspect of the third ventricular floor was significantly associated with censored time to ETV failure (multivariate HR 2.59, 95% CI 1.01–6.66; final model including age and history of infection).

Conclusions. The presence of preoperative third ventricular bowing is predictive of ETV success, with nearly a 3-fold likelihood of success compared with patients treated with ETV in the absence of such bowing. Although bowing is predictive, 33% of patients without bowing were also treated successfully with ETV.

Key Words • intraventricular obstructive hydrocephalus • prognosis • communicating hydrocephalus • noncommunicating hydrocephalus • predictive value • shunt

Abbreviations used in this paper: ETV = endoscopic third ventriculostomy; IVH = intraventricular hemorrhage; NPV = negative predictive value; PPV = positive predictive value.
or “communicating” (extraventricular obstructive hydrocephalus), depending on the location of the obstruction of CSF flow and/or absorption.28,34,36 Determining where the obstruction occurs defines the type of hydrocephalus and therefore the proper treatment.25 However, many patients may have both components of hydrocephalus.29 Prior to the wide use of ETV, these descriptions were mostly academic, because CSF was simply shunted to areas outside the brain for absorption. With ETV, there is a reliance on CSF absorption within the neuraxis, and therefore hydrocephalus classification becomes much more important for surgeons and their preoperative counseling of patients and patients’ families in deciding whether to perform an ETV or a shunt insertion. It is classically thought that a third ventriculostomy would only alleviate intraventricular obstructive hydrocephalus. This is demonstrated with much higher rates of ETV success in clearly intraventricular obstructive cases. Yet ETV is known to help cases of extraventricular obstructive hydrocephalus.12

Combining age, cause of hydrocephalus, and history of a previous shunt, the ETV Success Score models ETV success and failure in the treatment of childhood hydrocephalus.21–23 However, patient history is not always clear at the time of presentation. Additionally, it is not proven yet that the ETV Success Score is applicable to adult patients with hydrocephalus. Finally, the cause of hydrocephalus is difficult to assess, because there is often a combination of intraventricular and extraventricular obstructive components, thereby limiting the usefulness of these factors. Therefore, there is a clear need for other objective preoperative classification systems for both children and adults with hydrocephalus to predict success or failure prior to performing ETV, since another surgical alternative (that is, shunting) exists.

Other investigators have observed third ventricular floor deformation or “bowing” of the third ventricular floor and lamina terminalis as indicators of intraventricular obstructive hydrocephalus resulting in higher success rates with endoscopic third ventriculostomy.8,18,29,30,36 Bowing or “ballooning” of the third ventricle is believed to indicate a pressure differential between this structure and the intracranial subarachnoid space and therefore serves as a manifestation of intraventricular obstructive hydrocephalus. A lack of bowing of the third ventricle may indicate equivalent pressures between the ventricular system and the subarachnoid space and may therefore suggest communicating hydrocephalus. Although others have examined the third ventricular floor and lamina terminalis, analysis of other third ventricular wall bowing is needed.

Based on these observations, we hypothesized that patients with preoperative bowing of the third ventricle would exhibit higher long-term success rates after ETV than those treated with ETV whose third ventricle did not exhibit preoperative bowing. To test this hypothesis, we retrospectively examined all patients treated with ETV at our institution for a heterogeneous group of hydrocephalic conditions, to evaluate whether preoperative third ventricular MR imaging anatomical findings, and specifically preoperative bowing or non-bowing of the third ventricle, correlated with ETV success or failure in a multivariate statistical model.
ina terminalis and optic chiasm and posteriorly by the suprapineal recess and pineal gland. It is bordered inferiorly by structures surrounding and constituting the third ventricular floor that include, from anterior to posterior, the optic chiasm, the infundibulum of the hypothalamus, the tuber cinereum, the mamillary bodies, the posterior perforated substance, and the part of the tegmentum of the midbrain located above the medial aspect of the cerebral peduncles.

We considered the third ventricle “bowed” if any of the following imaging features were present on the mid-sagittal preoperative MR imaging study (Fig. 1): depression of the anterior or posterior third ventricular floor below a reference line; enlargement of the supraoptic recess (indicated by downward or anterior displacement of the chiasm and/or the presence of a downward curvature in the chiasm itself); anterior curvature of the lamina terminalis (instead of its usual posterior concavity); dilation of the proximal aqueduct to a greater extent than the distal aqueduct; and enlargement of the suprapineal recess (Fig. 1 right). We used a reference line drawn from the middle of the optic chiasm to the superiormost aspect of the tegmentum of the midbrain, at its junction with the mamillary body. We considered the floor “flat” if this reference line overlaid the floor or if the floor resided superiorly to this line.

For this report, we further subdivided the third ventricular floor into an anterior section (between the optic chiasm and the posterior aspect of the infundibulum) and a posterior section (between the posterior aspect of the infundibulum and the junction of the mamillary bodies and the tegmentum of the midbrain). To assess bowing of the lamina terminalis, we used a reference line drawn from the middle of the optic chiasm to the anterior commissure. We considered the lamina terminalis flat if this reference line overlaid the lamina terminalis or if the lamina terminalis was posterior to this line, or bowed if the lamina was anterior to this line. We considered the suprapineal recess bowed if it overlaid the pineal gland inferiorly to any extent.

**Fig. 1.** Drawings showing so-called bowing and non-bowing of the third ventricle. **Left:** Diagram of the third ventricle without bowing. A reference line drawn from the middle of the optic chiasm to the superior aspect of the tegmentum of the midbrain demonstrates a flat third ventricular floor. A reference line drawn from the middle of the optic chiasm to the anterior commissure reveals that the line sits anterior to the posteriorly curved lamina terminalis. **Right:** Diagram of a bowed third ventricle. A line drawn from the middle of the optic chiasm to the superior aspect of the tegmentum of the midbrain demonstrates depression of the anterior (b) and posterior (a) aspects of the third ventricular floor. The deformation and elongation of the optic chiasm is indicative of suprachiasmatic recess bowing (c). A line drawn from the middle of the optic chiasm to the anterior commissure reveals the anterior bowing of the lamina terminalis (d). The proximal aqueduct is larger than the distal aqueduct (e). The suprapineal recess overlies the pineal gland inferiorly (f).
Preoperative third ventricular bowing and ETV success

The preoperative third ventricular anatomy analysis and classification of each structure as bowed or not bowed/flat was assessed in the midsagittal plane on MR imaging studies by independent observers, with interobserver reliability greater than 90%.

Statistical Analysis

To test the main hypothesis of the association of preoperative third ventricular bowing (either complete or partial) with ETV failure, 2 algorithms were used. In Algorithm I we considered 6 third ventricular structures (posterior floor, anterior floor, suprachiasmatic recess, lamina terminalis, suprapineal recess, and the proximal aqueduct). Because we analyzed a heterogeneous patient population, several patients had posterior third ventricular or pineal region masses (Fig. 2), which prevented visualization of the suprapineal recess and proximal aqueduct. Therefore, we used a second statistical model (Algorithm II), which included only the anterior aspects of the third ventricle that were consistently visualized on the preoperative MR imaging studies (posterior floor, anterior floor, suprachiasmatic recess, and lamina terminalis), even in the presence of posteriorly situated tumors.

Both algorithms compared ETV outcome (successful or failed) stratified by the presence or absence of preoperative bowing, and used a time-to-failure analysis model. For the primary analysis, we considered bowing as the presence of third ventricular distortion in any of the visible areas on the sagittal MR imaging study, using the criteria described above. Furthermore, for this initial analysis, bowing could be complete (every visible structure showing distortion) or partial (as few as a single structure showing distortion). No bowing was defined as the absence of all anatomical third ventricular distortion based on the criteria outlined above.

Univariate and multivariate analyses of ETV failure and time to failure were performed using logistic regression and the Cox proportional hazards model, respectively. Bowing, patient age at time of surgery, history of infection, and history of a previous shunt were initially examined in a series of univariate analyses, followed by a multivariate regression analysis incorporating variables that showed some evidence of univariate association (p < 0.20). Interactions were also tested. The final model was defined with a manual backward selection.

Descriptive statistics were performed to analyze the patient demographics. The chi-square or Fisher exact test was used to investigate the association of third ventricular anatomy and ETV success or failure. Kaplan-Meier curves for ETV failure were generated, with the log-rank test used for intergroup comparison. Statistical analyses were conducted with the help of SAS version 9.2 software (SAS Institute, Inc.).

Results

A total of 56 patients who met all inclusion criteria underwent 59 ETVs for a heterogeneous group of hydrocephalic conditions (Table 1). The average age of patients at time of ETV was 30.6 years (range 9 months–80 years). Of these 56 patients, 19 were less than 18 years old, and 37 were 18 or older at the time of ETV. The maximum time that patients did not experience an ETV failure was 5.6 years. The average length of follow-up was 1.5 years (1.3 years for the success group and 1.9 years for the failure group). There were 14 patients with previous shunts, 8 patients with a history of intracranial infection or shunt infection, and 4 patients with history of IVH. Of the 59 ETVs performed, 38 were successful and 21 were unsuccessful, for an overall 64% success rate. Three patients underwent a second procedure after initial ETV failure. For these 3 patients, only their initial presentation and outcome was used in the statistical modeling.

Before ETV, bowing was observed in the posterior floor of the third ventricle (22 patients), anterior floor of the third ventricle (40 patients), suprachiasmatic recess (38 patients), lamina terminalis (37 patients), proximal aqueduct (16 patients), and in the suprapineal recess (33 patients).

Illustrative cases of third ventricular bowing and no bowing are demonstrated in Fig. 3. Figure 3A demonstrates the preoperative images of a patient presenting with symptomatic hydrocephalus but without bowing of the third

![Fig. 2. Neuroimaging studies demonstrating anterior third ventricular bowing due to pineal region mass. Preoperative MR imaging of the third ventricle in the presence of a pineal region mass and hydrocephalus demonstrating anterior third ventricular bowing (the right panel shows an enlargement of the area in the left panel). a = lamina terminalis; b = suprapineal recess; c = third ventricular floor.](image-url)

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>No. of Patients (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>mean age in yrs at date of first ETV, range</td>
<td>30.6, 0.75–80</td>
</tr>
<tr>
<td>mean total follow-up in yrs, range</td>
<td>1.5, 0.06–5.6</td>
</tr>
<tr>
<td>diagnosis</td>
<td></td>
</tr>
<tr>
<td>aqueductal stenosis</td>
<td>16 (28.6)</td>
</tr>
<tr>
<td>tectal/pineal masses</td>
<td>11 (19.6)</td>
</tr>
<tr>
<td>posterior fossa masses</td>
<td>10 (17.9)</td>
</tr>
<tr>
<td>normal-pressure hydrocephalus</td>
<td>4 (7.1)</td>
</tr>
<tr>
<td>third ventricular masses</td>
<td>3 (5.4)</td>
</tr>
<tr>
<td>congenital hydrocephalus</td>
<td>3 (5.4)</td>
</tr>
<tr>
<td>intraventricular hemorrhage</td>
<td>3 (5.4)</td>
</tr>
<tr>
<td>unknown cause</td>
<td>3 (5.4)</td>
</tr>
<tr>
<td>neural tube defects</td>
<td>2 (3.6)</td>
</tr>
<tr>
<td>postmeningitis hydrocephalus</td>
<td>2 (3.6)</td>
</tr>
</tbody>
</table>
ventricle in the midsagittal plane. The ETV in this patient was technically successful; however, the patient’s symptoms persisted, and ultimately a ventriculoperitoneal shunt was placed. Conversely, in Fig. 3B, a different patient presented with complete preoperative third ventricular bowing, and ETV provided long-term symptomatic relief for this patient. Figure 2 illustrates anterior third ventricular bowing due to hydrocephalus from a pineal region mass; notice the obliteration of the suprapineal recess and aqueduct, eliminating their anatomical assessment.

Kaplan-Meier analysis of censored time to ETV failure revealed significant differences in the time to failure between patients with and without bowing (Fig. 4; log-rank Algorithm I, \( p = 0.0173 \); log-rank Algorithm II, \( p = 0.0178 \)). The improved ETV success rate in those with preoperative bowing was significantly better for both analysis algorithms.

We found that our patients who had a history of CNS infection prior to ETV had much higher rates of ETV failure (HR 7.36, range 2.53–21.41; Table 2). Likewise, the youngest and oldest age group quartiles trended toward lower ETV success rates. Therefore, these 2 variables were incorporated into a multivariate analysis. A significant association between bowing and censored time to ETV failure was observed using Algorithm II (for no bowing vs bowing: multivariate HR 2.79, 95% CI 1.08–7.20 [Model II]; Table 2) in the final model including age and history of infections. Weak evidence of an association between bowing and censored time to ETV failure was found using Algorithm I (\( p = 0.0612 \)). Patients with no bowing had 8 (Algorithm I) and 5.8 (Algorithm II) times the odds of experiencing a failure of ETV in the final logistic regression model including age group (multivariate OR 8.00 with Algorithm I, 95% CI 1.14–56.19; multivariate OR 5.76 with Algorithm II, 95% CI 1.24–26.79 [data not shown]).

Overall, considering Algorithm I, 33 (68.8%; PPV) of the 48 patients with bowing and 2 (25%) of the 8 patients without bowing experienced success with ETV. Conversely, 6 (75%; NPV) of the 8 patients with no bowing and 15 (31.3%) of the 48 patients with bowing experienced failure of ETV. Considering Algorithm II, 31 (70.5%; PPV) of the 44 patients with bowing and 4 (33.3%) of the 12 patients without bowing experienced success with ETV. Conversely, 8 (66.7%; NPV) of the 12 patients with no bowing and 13 (29.5%) of the 44 patients with bowing experienced failure of ETV.

To identify the third ventricular area most important in determining the difference in ETV outcome, a secondary analysis involved examination of bowing levels and bowing in individual structures. There was no significant difference between so-called partial bowing and complete bowing in patients treated using the different approaches. Among the individual structures, absence of bowing in the anterior aspect of the third ventricular floor was significantly associated with censored time to ETV failure (multivariate HR 2.59, 95% CI 1.01–6.66, final model including age and history of infection [Model III]; Table 2).
Preoperative third ventricular bowing and ETV success

![Graph showing ETV success over time for Algorithms I and II]

**Discussion**

**Evolution of the ETV**

Improvement in fiberoptics and imaging over the last 2 decades has led to tremendous advancements in the field of neuroendoscopy. Third ventriculostomy, although very old in concept, became a more feasible procedure after this neuroendoscopic advancement. With its potential to leave someone shunt free, and the low operative morbidity associated with the procedure, ETV has grown in popularity and is used in many hydrocephalic conditions in children and adults, with varying results.

**Types of Hydrocephalus and Use of ETV**

Hydrocephalus has historically been classified as noncommunicating, communicating, or a combination of both. Hydrocephalus was categorized as noncommunicating if there was a definable lack of CSF flow out of the ventricular system and enlargement of the cerebral ventricles proximal to the obstructing lesion. Hydrocephalus was categorized as communicating if there was lack of CSF outflow from the subarachnoid space; this usually results in enlargement of the entire ventricular system. Recently, studies have reminded us of the more descriptive terms of hydrocephalus classification—“intraventricular” obstructive (noncommunicating) and “extraventricular” obstructive (communicating) hydrocephalus.

The patient’s clinical history is sometimes helpful to evaluate the type of hydrocephalus. However, difficulty in hydrocephalus classification arises when the type of hydrocephalus is mixed or unclear clinically, and imaging demonstrates enlarged lateral and third ventricles without an obvious obstructing lesion within the ventricular system (Fig. 3A). As a result of this uncertainty in classification, difficulty arises when determining which patients will benefit from an ETV. It is hypothesized that given its need to rely on normal intracranial CSF absorption, a third ventriculostomy will only be maximally effective in cases of a more intraventricular obstructive nature. This has been demonstrated clinically, with much higher ETV success rates in cases of aqueductal stenosis, masses obstructing the aqueduct, and in fourth ventricular outflow obstruction compared with ETV success rates in the more classically defined communicating hydrocephalus.

However, a third ventriculostomy can be successful even in cases in which communicating hydrocephalus is expected, such as with postinfectious or posthemorrhagic hydrocephalus, or in patients with idiopathic normal-pressure hydrocephalus.

Success of an ETV in treating hydrocephalus is determined by symptomatic relief and the lack of need for additional surgery, including shunting. For most successful ETV-treated patients, there is an eventual decrease in ventricular size. Failure of ETV may occur for multiple reasons. In some cases ETV failure is due to mechanical obstruction or closure of the stoma, and in other cases the stoma appears patent, but there is a lack of CSF absorption, possibly indicating a component of extraventricular obstructive hydrocephalus. Failures can occur early or in a delayed fashion.

**Third Ventricular Bowing and ETV Success**

Third ventricular floor deformation has been sug-
gested anecdotally as predictive of more intraventricular obstructive types of hydrocephalus, resulting in higher success rates with ETV.\textsuperscript{18,30} Because the success of ETV varies widely and ETV subjects patients to potential perioperative morbidity that shunt insertion does not, there is a clear need for other objective preoperative classification systems for both children and adults with hydrocephalus to predict success or failure prior to performing an ETV.

Therefore, we used the preoperative MR imaging finding of third ventricular bowing to determine if this anatomical feature\textsuperscript{31} may be predictive of ETV success. We indeed found that those patients with bowing present prior to ETV had improved success rates compared with a cohort of patients who did not demonstrate bowing prior to surgery. The ETV was successful in 70% of patients with anterior third ventricular bowing. However, 33% of patients without bowing were also successfully treated with ETV. We further examined the individual structures of the third ventricle to determine the area most significant for ETV success and failure. As observed by others, we found that bowing of the anterior third ventricular floor was significant and predictive of ETV success.

This work complements the recent work by Foroughi et al.\textsuperscript{8} and previous work by Kehler et al.\textsuperscript{18} Foroughi et al. demonstrated that a large percentage of pediatric patients with hydrocephalus in whom preoperative convexity of the third ventricular floor and lamina terminalis was present had successful ETVs. Using the success and failure rates of ETV with and without third ventricular bowing from this previous study, we were able to compare PPVs. In the study by Foroughi et al., 96% of patients with third ventricular floor and lamina terminalis bowing experienced success with ETV, which is greater than our PPV of 70%. However, the study by Foroughi et al. analyzed the success of ETV only in pediatric hydrocephalus. Therefore, patient populations may impact the role of third ventricular bowing in predicting ETV success. Furthermore, we examined additional areas of the third ventricle for bowing in addition to the lamina terminalis and third ventricular floor. We assessed the supraoptic recess and the posterior aspect of the third ventricle because we observed that these areas can be independently enlarged. However, no other individual regions, including bowing of the lamina terminalis, demonstrated significance in our patient population. Overall, we were able to use similar third ventricular reference planes independently to demonstrate statistically in both a logistic regression and the Cox proportional hazards model a difference in ETV outcome with Algorithm II of our definition of third ventricular bowing.

It is important to consider ventricular compliance when evaluating patients for third ventricular bowing. In the slit-ventricle syndrome,\textsuperscript{35} intraventricular pressures can be elevated without a change in ventricular size and therefore indicate stiff, noncompliant ventricular walls.\textsuperscript{36} As a result, these patients would not be expected to show bowing of third ventricular structures. However, our series did not include any such patients, so we are unable to comment on the presence or absence of bowing and ETV implications in this situation.

Similarly, the timing of midsagittal MR image acquisition relative to the cardiac cycle could impact the appearance of the third ventricular floor on MR imaging. As can be seen directly intraoperatively during ETV surgery, or indirectly on midsagittal cine MR imaging sequences obtained to evaluate ETV patency after surgery, the floor

\begin{table}[h]
\centering
\caption{Risk factor analysis with the Cox proportional hazards model for time to ETV failure in 56 patients\textsuperscript{*}}
\begin{tabular}{|l|c|c|c|c|c|}
\hline
Variable & No. of Patients & Bivariate HR (95% CI) & Multivariate HR (95% CI) \\
& & & Model I & Model II & Model III \\
\hline
history of infection & & & & & \\
yes & 8 & & 7.36 (2.53–21.41) & 5.86 (1.75–19.65) & 6.87 (2.13–22.16) & 7.46 (2.31–24.16) \\
no & 48 & & reference & reference & reference & reference \\
\hline
age at ETV by quartiles & & & & & \\
1–14 yrs & 14 & & 4.06 (0.85–19.32) & 5.55 (1.19–27.52) & 6.05 (1.20–30.37) & 5.46 (1.10–27.17) \\
15–25 yrs & 14 & & 2.14 (0.39–11.71) & 3.43 (0.58–20.33) & 3.13 (0.54–17.99) & 3.09 (0.54–17.76) \\
47–80 yrs & 14 & & 4.73 (0.98–22.94) & 5.19 (0.97–27.76) & 4.69 (0.93–23.76) & 4.69 (0.92–23.93) \\
bowing Algorithm I—6 structures & & & & & \\
no bowing & 8 & & 3.01 (1.16–7.80) & 2.88 (0.95–8.74) & NA & NA \\
complete or partial bowing & 48 & & reference & reference & NA & NA \\
bowing Algorithm II—4 structures & & & & & \\
no bowing & 12 & & 2.79 (1.15–6.75) & NA & 2.79 (1.08–7.20) & NA \\
complete or partial bowing & 44 & & reference & reference & NA & NA \\
\hline
anterior 3rd ventricular floor bowing & & & & & & \\
yes & 40 & & reference & NA & NA & reference \\
no & 16 & & 2.46 (1.03–5.91) & NA & NA & 2.59 (1.01–6.66) \\
\hline
\end{tabular}
\end{table}

\textsuperscript{*} NA = not applicable.
of the third ventricle generally moves with cardiac systole and diastole, depending on the thickness and compliance of the floor.13 Our imaging protocol did not use cardiac gating, because the addition of such gating significantly lengthens scanning time. Consequently, we cannot comment on the role of cardiac-gated imaging, and additional study is needed to investigate this issue.

Despite our robust statistical findings of PPVs and NPVs relating to ETV success when bowing is present, we still found that approximately one-third of patients without preoperative bowing will have successful ETVs. Although we believe that overall our findings will be helpful to both treating surgeons and their patients regarding procedural selection (ETV or shunt) and preoperative counseling, this particular observation is an indication that additional study and improved preoperative classification schema are needed to improve our decision making about hydrocephalus treatment. We intentionally included a diverse and heterogeneous hydrocephalic patient population for this initial study, so further stratification into more closely matched subgroups may improve these numbers.

We understand the retrospective nature of this paper and the limitations that such a study introduces. As with all retrospective studies, inaccurate or incomplete medical record data might alter the statistical outcomes. Unrecognized patient selection bias by treating physicians may be present when they are deciding which patients should undergo ETV or shunting. The minimum inclusion criteria of 6 weeks of follow-up is admittedly short; however, the mean follow-up for both successful and failed ETVs was well over 1 year, so it is unlikely that potential delayed failures occurred that would significantly impact our statistical results. Therefore, there is a need for further and larger prospective studies. Furthermore, we realize that our patient population comprises a heterogeneous group of hydrocephalus origins. However, even within a presumed cause, the type of hydrocephalus may differ from patient to patient. Therefore, we grouped all patients together for analysis. Future work to examine each cause and its association with third ventricular bowing may be important for further refinement of our ability to predict ETV success and failure accurately.

Conclusions

Third ventricular bowing is predictive of ETV success—nearly a 3-fold likelihood of success compared with patients treated with ETV in the absence of such bowing. Although bowing was predictive, 33% of patients without bowing were also successfully treated with ETV.

Disclosure

Dr. Greenlee is a member of the endoscopic neurosurgery advisory panel for Aesculap, Inc.

Author contributions to the study and manuscript preparation include the following. Conception and design: Greenlee, Dlouhy. Acquisition of data: Dlouhy, Madhavan. Analysis and interpretation of data: Greenlee, Dlouhy, Capuano, Torner. Drafting the article: Dlouhy. Critically revising the article: all authors. Reviewed submitted version of manuscript: all authors. Approved the final version of the manuscript on behalf of all authors: Greenlee. Statistical analysis: Dlouhy. Capuano, Torner. Administrative/technical/material support: Greenlee, Dlouhy. Study supervision: Greenlee, Dlouhy.

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J Neurosurg: Pediatrics / Volume 9 / February 2012

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