Predicting success of endoscopic third ventriculostomy: validation of the ETV Success Score in a mixed population of adult and pediatric patients

Moujahed Labidi, MD; Pascale Lavoie, MD, MSc, FRCSC; Geneviève Lapointe, MD, FRCSC; Sami Obaid, MD; Alexander G. Weil, MD, FRCSC; Michel W. Bojanowski, MD, FRCSC; and André Turmel, MD, MSc, CSPQ

OBJECT Endoscopic third ventriculostomy (ETV) has become the first line of treatment in obstructive hydrocephalus. The Toronto group (Kulkarni et al.) developed the ETV Success Score (ETVSS) to predict the clinical response following ETV based on age, previous shunt, and cause of hydrocephalus in a pediatric population. However, the use of the ETVSS has not been validated for a population comprising adults. The objective of this study was to validate the ETVSS in a “closed-skull” population, including patients 2 years of age and older.

METHODS In this retrospective observational study, medical charts of all consecutive cases of ETV performed in two university hospitals were reviewed. The primary outcome, the success of ETV, was defined as the absence of reoperation or death attributable to hydrocephalus at 6 months. The ETVSS was calculated for all patients. Discriminative properties along with calibration of the ETVSS were established for the study population. The secondary outcome is the reoperation-free survival.

RESULTS This study included 168 primary ETVs. The mean age was 40 years (range 3–85 years). ETV was successful at 6 months in 126 patients (75%) compared with a mean ETVSS of 82.4%. The area under the receiver operating characteristic curve was 0.61, revealing insufficient discrimination from the ETVSS in this population. In contrast, calibration of the ETVSS was excellent (calibration slope = 1.01), although the expected low numbers were obtained for scores < 70. Decision curve analyses demonstrate that ETVSS is marginally beneficial in clinical decision-making, a reduction of 4 and 2 avoidable ETVs per 100 cases if the threshold used on the ETVSS is set at 70 and 60, respectively. However, the use of the ETVSS showed inferior net benefit when compared with the strategy of not recommending ETV at all as a surgical option for thresholds set at 80 and 90.

In this cohort, neither age nor previous shunt were significantly associated with unsuccessful ETV. However, better outcomes were achieved in patients with aqueductal stenosis, tectal compressions, and other tumor-associated hydrocephalus than in cases secondary to myelomeningocele, infection, or hemorrhage (p = 0.03).

CONCLUSIONS The ETVSS did not show adequate discrimination but demonstrated excellent calibration in this population of patients 2 years and older. According to decision-curve analyses, the ETVSS is marginally useful in clinical scenarios in which 60% or 70% success rates are the thresholds for preferring ETV to CSF shunt. Previous history of CSF shunt and age were not associated with worse outcomes, whereas posthemorrhagic and postinfectious causes of the hydrocephalus were significantly associated with reduced success rates following ETV.


KEY WORDS third ventriculostomy; neuroendoscopy; minimally invasive neurosurgery; hydrocephalus

Endoscopic third ventriculostomy (ETV) represents an alternative to shunts in most cases of obstructive hydrocephalus. This procedure allows the CSF to be internally diverted to the basal cisterns and eventually be reabsorbed by arachnoid granulations, avoiding the need to implant exogenous material. The success rate of ETV is variable among series, with reported rates between 50% and 94%. In an exclusively adult population, the success rate seems to be somewhat higher, with 55% to 83% of the patients having satisfactory outcomes. However, relative-
ly few studies report on the adult population and there is significant variation, both in patient characteristics and outcome definition.

In adults, previous studies have established an association between success of ETV with age at surgery, cause of hydrocephalus, and previous history of shunt. In the pediatric population, Kulkarni et al. recently proposed a clinical prediction rule allowing for the approximation of operative success (ETV Success Score [ETVSS], Table 1) based on these same 3 clinical factors. This model has been validated in several pediatric series. However, no adult data have been used in the derivation or validation of the ETVSS, and consequently its use and predictive ability in the adult population is unknown. Moreover, the population from which this clinical prediction rule was derived was composed of a high percentage of very young children. Still, age is the most important predictive factor, accounting for 50% of the model variability. It therefore seems reasonable to hypothesize that calibration of this prediction rule will be slightly inadequate for a mixed population.

The primary objective of the present study is to validate the ETVSS in a mixed population, including adults and children. Discriminative properties and score calibration for our population will be assessed. Clinical parameters susceptible of being associated with positive outcome following ETV in this population will also be studied.

Methods

A retrospective observational study of all consecutive cases of ETVs was conducted at two tertiary care university hospitals, the CHU de Québec—Hôpital de l’Enfant-Jésus and the CHUM—Hôpital Notre-Dame between 1998 and 2011 through medical chart review. Data collection was done in an anonymized fashion and approval was obtained from the CHU de Québec’s and CHUM—Hôpital Notre-Dame’s research ethics committee. Two methods of patient identification were used: medical archives were queried for all ventricular endoscopy cases, and personal surgical logs of the senior authors (A.T. and M.W.B.) were reviewed to identify all ETV cases. Previous authors have described the operative technique for ETV used in both our centers. All the operative reports were reviewed to verify that a stoma was created in the floor of the third ventricle, which was the minimal criterion for inclusion.

Inclusion and Exclusion Criteria

All patients 2 years and older who underwent an ETV in our institutions during the study period were included. After 2 years of age fontanelles are closed in most children, allowing for a more homogeneous group in terms of CSF physiology. ETVs performed for conditions of a temporary nature (e.g., hydrocephalus preceding surgical treatment of a tumor) or palliation and redo ETVs were excluded from the analyses. Patients with a clinical follow-up of less than 6 months, unless they were treated surgically for a problem related to hydrocephalus, were also excluded.

Data Collection and Outcome Measures

Demographic, preoperative, and postoperative variables were collected through medical chart review. Patients lost to follow-up were contacted by telephone to arrange a clinic visit and MRI when possible, and if not, their outcome was assessed at the time of the phone interview. Two independent reviewers collected data (M.L. and S.O.); one reviewer in each center. Data were compiled in a single database, and both reviewers used the same definitions for independent variables and outcomes. The cause of hydrocephalus was recorded as per the surgeon’s preoperative assessment. The operative note was reviewed for surgical details, including opacity of third ventricular floor, occurrence of significant bleeding, opening of the Liliequist membrane, concurrent biopsy, and the decision to leave an external ventricular drain (EVD) at the end of the surgery. Postoperative complications that occurred in the first 30 days following the ETV and were documented by the treating physician were also recorded. They were divided into the following categories: “new neurologic deficit,” “seizure,” “fistula,” “infection,” “hypotension,” “diabetes insipidus,” and “systemic.” Postoperative Day 1 imaging reports, either CT scan or MRI, were reviewed for any new hemorrhage, excluding only small hemorrhagic sediments in the occipital horns.

The primary outcome, the success of ETV, was defined as the absence of reoperation or death attributable to hydrocephalus at 6 months, in accordance with the ETVSS derivation study. The secondary outcome is the reoperation-free survival.

Statistical Analysis

To validate the ETVSS in our population, the score was calculated for each patient included in our study. The predicted success rate from the ETVSS was then compared with the actual success rate of ETV at 6 months (primary outcome) in our population. To that end, included patients were categorized in 9 subgroups, according to their ETVSS results. Actual success rates were determined for each of these strata. The receiver operating characteristic (ROC) curve (equivalent to the c-statistic in dichotomized outcomes) was used to assess the discriminative properties of the score. A result superior to 0.7 is usually satisfactory for a clinical prediction rule.

A Hosmer-Lemeshow test (formal goodness-of-fit test) was conducted to study the ETVSS calibration for the different strata. The calibration slope was also obtained through a linear regression, weighted according to size (number) of each ETVSS stratum, testing the correlation between observed and predicted success for each score category. A calibration slope close to 1.0 usually indicates a good calibration of the score, whereas a score less than 0.8 is generally unsatisfactory.

Decision-analytical measures were conducted to assess the clinical utility of the ETVSS in this population. These measures are based on the relative impact of the true positives (benefits) and false positives (harms) relative to the threshold on the ETVSS. This threshold may be defined as the score at which the expected benefit of ETV is equal to the expected benefit of avoiding ETV. Different thresholds were tested because the benefit may
Validation of the ETV Success Score in a mixed population

### TABLE 1. ETV Success Score*

<table>
<thead>
<tr>
<th>Variable</th>
<th>ETVSS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0</td>
</tr>
<tr>
<td>Age</td>
<td>&lt;1 mo</td>
</tr>
<tr>
<td>Etiology</td>
<td>Postinfectious</td>
</tr>
<tr>
<td>Previous shunt</td>
<td>Yes</td>
</tr>
</tbody>
</table>


IVH = intraventricular hemorrhage.

Results

During the study period, 205 ETVs were performed in both institutions. Following application of the exclusion criteria, 168 patients were included in the final analysis (Fig. 1). Eight patients were lost to follow-up at 6 months postsurgery. There were 86 female patients (51.2%) and the mean age was 40 years. Only 12 patients (7.1%) were younger than 10 years, and 137 (81.5%) were 18 years or older. The most common indications were aqueductal stenosis with 59 patients (35.1%), and tectal tumor with 39 patients (23.2%). Patients’ characteristics are detailed in Table 2.

At 6 months, 126 patients (75%) achieved the primary outcome, while the mean ETVSS was 82.4%. Table 3 depicts actual success rates and predicted success according to the ETVSS. A higher ETVSS was correlated with higher success rate (p = 0.045). However, the area under the ROC curve (c-statistic) for the score was 0.61 (95% CI 0.52–0.71), which was under the 0.7 mark for adequate discrimination (Fig. 2). A logistic regression was used to assess calibration of the ETVSS model in this cohort (Fig. 3). The calibration slope was 1.01, implying excellent calibration for this population. The Hosmer-Lemeshow test was composed of 3 strata (23, 72, and 73 patients). The test results were not significant (p = 0.89), which indicates good calibration of the model (Table 4).

Because approximately 5–10 predicted events per independent predictor are usually required to have an adequate sample for statistical inference,22 a sample size allowing detection of a total of 30 failures of ETV was required. A pilot study on 41 primary ETV cases performed in the last 2 years in a single institution (CHU de Québec) revealed a failure rate of 17%. Assuming that the failure rate of approximately 17% will be maintained throughout the series, a sample size of 200 procedures is needed to obtain the minimum absolute number of 30 failures required to achieve the ratio events/predictor.
The majority (77.8%) but not all of the ETV failures occurred in the first 6 months after the surgery. Of the 52 patients with ETV failures, 13 had a redo ETV at the time of failure, with the remainder treated by CSF shunt implantation. Figure 5 represents a Kaplan-Meier analysis of the reoperation-free survival, which corroborates the finding that most failures occurred early in the follow-up period.

In this series the overall complication rate at 30 days was 11.9% (Table 6), and major complications occurred in 6 patients (3.6%). Two fatalities following ETV occurred in the study population (1.2%). One patient had an ETV following a high-grade subarachnoid hemorrhage with intraventricular hemorrhage, but later succumbed to pneumonia and sepsis. The second patient had hydrocephalus associated with cerebellar lymphoma and was treated by ETV and EVD placement, but experienced upward herniation in the immediate postoperative period.

**Discussion**

In our cohort of 168 patients 2 years and older, discrimination of the ETV success score was low (c-statistic = 0.61), whereas calibration appeared excellent (calibration slope = 1.01). In addition, results of the Hosmer-Lemeshow test were not significant, also suggesting good calibration. Interpretation of this test and of the calibration slope result are limited, however, by the small number of patients who have low scores on the ETVSS. Although this is the first appraisal of the ETVSS in a mixed adult and pediatric population, external validation of this scoring system has been assessed by a few studies in pediatric populations. In contrast to our results, Naftel et al. reported, in their cohort of 136 pediatric patients, a c-statistic at 0.74 (95% CI 0.65–0.83) with the mean ETVSS score (76.5% ± 12.5%) predicting very closely the actual success rate (68.4%).24 It seemed, however, that the ETVSS slightly overestimated success in scores ≤ 70.

**TABLE 2. Characteristics in 168 patients who underwent ETV**

<table>
<thead>
<tr>
<th>Variable</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of patients</td>
<td>168</td>
</tr>
<tr>
<td>Age ≥10 yrs</td>
<td>156 (92.9%)</td>
</tr>
<tr>
<td>Sex Female</td>
<td>86 (51.2%)</td>
</tr>
<tr>
<td>Etiology</td>
<td></td>
</tr>
<tr>
<td>Aqueductal stenosis</td>
<td>59 (35.1%)</td>
</tr>
<tr>
<td>Nontectal tumor</td>
<td>23 (13.7%)</td>
</tr>
<tr>
<td>Posthemorrhagic</td>
<td>20 (11.9%)</td>
</tr>
<tr>
<td>Tectal tumor</td>
<td>39 (23.2%)</td>
</tr>
<tr>
<td>Myelomeningocele</td>
<td>12 (7.1%)</td>
</tr>
<tr>
<td>Postinfectious</td>
<td>5 (3.0%)</td>
</tr>
<tr>
<td>Other</td>
<td>10 (6.0%)</td>
</tr>
<tr>
<td>Previous shunt</td>
<td>48 (28.6%)</td>
</tr>
<tr>
<td>Follow-up (mean ± SD)</td>
<td>799 ± 848 days</td>
</tr>
</tbody>
</table>

**TABLE 3. Predicted and actual success of ETV**

<table>
<thead>
<tr>
<th>ETV Success</th>
<th>ETVSS 40</th>
<th>ETVSS 50</th>
<th>ETVSS 60</th>
<th>ETVSS 70</th>
<th>ETVSS 80</th>
<th>ETVSS 90</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. predicted</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>17</td>
<td>72</td>
<td>73</td>
</tr>
<tr>
<td>Actual success (%)</td>
<td>1 (50.0%)</td>
<td>1 (50.0%)</td>
<td>0 (0.0%)</td>
<td>11 (64.7%)</td>
<td>53 (73.6%)</td>
<td>60 (82.2%)</td>
</tr>
</tbody>
</table>
Likewise, Breimer et al. reported a c-statistic of 0.82 for the ETVSS in their group of 104 children, with a mean ETVSS of 66.2 ± 17.0, accurately approximating a success rate of 70.2% at 6 months. However, in a population of pediatric patients with hydrocephalus undergoing ETV in Uganda, Warf et al. have shown inadequate calibration (Hosmer-Lemeshow p < 0.0001) and insufficient discrimination (c-statistic = 0.57). In their large series of 979 patients, choroid plexus coagulation replaced previous history of shunt placement in the prediction rule, whereas age and cause of hydrocephalus remained significant predictive factors. Others have examined the utility of the ETVSS in predicting longer-term (> 6 months) success or reported good prediction of ETV success, but have not reported on the score’s discriminative properties in their population.

From a statistical standpoint, the low discrimination of the ETVSS in our study, in contrast to the pediatric literature, may be explained by the facts that 50% of the model variability depends on age and that > 30% of patients in the initial training set were < 1 year old. Hence, a group like ours, comprising mostly adult patients (92.9% ≥ 10 years, 81.5% ≥ 18 years), has a considerably reduced distribution of patients in the different categories of the ETVSS. We conducted analyses exploring the impact of age in our cohort, and these showed that exclusion of patients younger than 10 years of age as a factor in the ETVSS did not result in different discrimination or calibration metrics. These analyses further emphasize that the variability conferred by age to the ETVSS is practically negated in our cohort. However, this may have been offset by the better outcomes obtained following ETV among adults, although there is conflicting evidence to this effect in the literature. A higher success rate may also explain in part the excellent calibration of the model in our population.

The discrepancy between the low discrimination and excellent calibration obtained in the present study leaves unanswered the question of how to apply the ETVSS in our population. In fact, even in validation studies in which both calibration and discrimination measures are in accord, they do not translate easily into the clinical realm. Decision curve analysis conducted for the ETVSS in our population allowed us to better define the role of this clinical prediction rule in our population. When comparing the strategy of treating all eligible patients who have undergone ETV (those with obstructive hydrocephalus) with a more selective approach using the ETVSS as a tool to identify candidates with a better chance of clinical success, the results of these analyses indicate that the benefit conferred by the ETVSS is marginal. If the minimally acceptable success rate is 70% for ETV, the prediction model allowed for the detection of only 4 avoidable ETVs per 100 cases, and if the threshold is 60%, that figure was

<table>
<thead>
<tr>
<th>TABLE 4. Partition for the Hosmer-Lemeshow test*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group</td>
</tr>
<tr>
<td>-------</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>1</td>
</tr>
<tr>
<td>2</td>
</tr>
<tr>
<td>3</td>
</tr>
</tbody>
</table>

* Details of the partitions and sample sizes used for the Hosmer-Lemeshow test. The result of the test was not significant (p = 0.89), indicating good calibration of the model.
reduced to 2 avoidable ETVs per 100 cases. In other words, in clinical scenarios in which 30% or 40% failure rates are acceptable, treating all communicating hydrocephalus with ETV may yield comparable clinical results as would decision-making based on the use of the ETVSS. If the clinician or the patient considers that an acceptable failure rate should be lower, however; say 10% or 20% (scores of 80 or 90 on the ETVSS), the use of the ETVSS showed an inferior net benefit when compared with the strategy of not recommending ETV at all as a surgical option.

In addition to the loss of variability due to age, the low generalizability of the ETVSS to our cohort may also be due to factors related to study design or outcome definition and, possibly more importantly, to etiology definition. For example, an ETV done in the immediate posthemorrhagic setting may have a lower chance of succeeding than one undertaken for a shunt malfunction in a patient with posthemorrhagic hydrocephalus. This introduces confusion bias in the ETVSS when applied to adult patients. It may also reflect the different pathophysiological mechanisms of hydrocephalus in this population. One hypothesis that might explain this discrepancy is the underdevelopment of CSF absorption capacity in patients with long-term shunt treatment, although previous CSF shunt was not associated with worse outcomes in our series or those of others (see below). A second mechanism by which one can explain the different outcomes, especially when comparing the very young children (< 1 year) with older ETV candidates, is altered CSF hydrodynamics in a “closed-skull” environment. In fact, closure of the fontanelles probably plays a role in allowing the establishment of a pressure gradient between the ventricles and the subarachnoid space, thus favoring stoma patency and CSF absorption through the arachnoid villi. However, CSF physiology continues to evolve after closure of the fontanelles, and this alone cannot explain the different results obtained after ETV, or CSF shunting for that matter.

In the univariate and multivariate analyses, only etiology was significantly associated with outcome at 6 months postsurgery. In fact, the worst outcomes were achieved in posthemorrhagic and postinfectious hydrocephalus. Both age and previous history of shunt placement did not adversely influence the success of ETV in our series. This is in keeping with the majority of previous series reporting on prognostic factors following ETV in mixed or exclusively adult populations. The literature is divided, however, on the prognostic significance of the cause of hydrocephalus; there are some studies indicating lower success rates in postinfectious and posthemorrhagic hydrocephalus, and others reporting no such association. The prognostic significance of the factors used in the ETVSS in this

<table>
<thead>
<tr>
<th>Variable</th>
<th>Total Success</th>
<th>p Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Surgical experience</td>
<td></td>
<td>0.5733</td>
</tr>
<tr>
<td>6/1999 to 5/2005</td>
<td>38 (22.6%) 29 (76.3%)</td>
<td></td>
</tr>
<tr>
<td>6/2005 to 8/2007</td>
<td>46 (27.4%) 35 (76.1%)</td>
<td></td>
</tr>
<tr>
<td>8/2007 to 3/2009</td>
<td>41 (24.4%) 33 (80.5%)</td>
<td></td>
</tr>
<tr>
<td>4/2009 to 2/2012</td>
<td>43 (25.6%) 29 (67.4%)</td>
<td></td>
</tr>
<tr>
<td>Liliequist opening*</td>
<td>115 (98.3%) 91 (79.1%) Not done†</td>
<td></td>
</tr>
<tr>
<td>Opaque 3rd ventricular floor‡</td>
<td>33 (36.3%) 26 (78.8%) 0.1295</td>
<td></td>
</tr>
<tr>
<td>Significant bleeding‡</td>
<td>22 (13.1%) 16 (72.7%) 0.7934</td>
<td></td>
</tr>
<tr>
<td>Biopsy</td>
<td>11 (6.5%) 8 (72.7%) 1</td>
<td></td>
</tr>
<tr>
<td>EVD left in</td>
<td>36 (21.4%) 21 (58.3%) 0.0092</td>
<td></td>
</tr>
</tbody>
</table>

* Opening of the Liliequist membrane when specified in the operative report (117 cases total).
† The p value was not calculated because of the very low number being compared (the Liliequist membrane was opened in all but 2 patients).
‡ When mentioned in the operative report.
§ The appearance of the third ventricular floor was discussed specifically in the operative reports in only 91 cases.
population was thus found to be different from that in the patient cohort used for score derivation.

In the present series, 72.9% of patients with previously implanted shunts (or “secondary ETV”) had a satisfactory outcome at 6 months after ETV, compared with 75.8% in primary ETV cases (p = 0.63). This adds data to the claim that one can achieve good outcomes in the setting of shunt malfunction.\(^2\)\(^,\)\(^6\)\(^,\)\(^23\)\(^,\)\(^25\) Furthermore, 7 of 12 patients with previously shunted myelomeningocele (58.3%) were reoperation free at 6 months following ETV. Teo and Jones have reported an even better 80% success rate in their group of previously shunt-treated patients with spina bifida when they were > 6 months old at the time of endoscopy.\(^3\)\(^,\)\(^5\) Spennato et al. have hypothesized that changes in ventricular anatomy induced by chronic shunting may actually increase the probability of ETV success by, among other mechanisms, reexpansion of the subarachnoid compartment and production of a pressure gradient between the supra- and infratentorial compartments due to secondary aqueductal stenosis.\(^3\)\(^1\)

To adapt the ETVSS to the adult population, or to devise a new prediction model altogether, the first step is to identify predictive factors that might be specific to this population. Previous studies have submitted different models of predicting ETV success, including variables not taken into account by the ETVSS. Some of these models relied on preoperative clinical factors or neuroradiological parameters,\(^2\)\(^,\)\(^13\)\(^,\)\(^27\) whereas others were built on operative findings or postoperative variables.\(^2\)\(^8\) In our series, none of the studied surgical variables (third ventricular floor opacity, significant bleeding during endoscopy, concurrent biopsy, surgeon experience, and Liliquist membrane opening) were predictive of ETV success, except for the decision by the neurosurgeon to leave an EVD at the end of the case. This association is probably due to the fact that EVDs were, in most cases, selectively inserted in those patients who were deemed poorer candidates for ETV.

In contrast to our results, Greenfield et al., in a mixed adult and pediatric population, devised a grading system that combined intraoperative findings (thickened or scarred membranes in the subarachnoid space and absence of third ventricular floor pulsatility) and preoperative variables, and these authors were able to demonstrate an increasing failure rate with increasing grade.\(^13\) Romero et al. showed a similar association between ETV failure and absence of pulsatility of the floor of the third ventricle at the end of ETV, scarring or thickening in the subarachnoid membranes, and the need for a second attempt before opening of the Liliquist membrane.\(^27\) Kehler et al. published a grading system that combined two different neuroradiological parameters (identification of an obstructive cause and downward bulging of the floor of the third ventricle) with progression in symptomatology at presentation. Grades ranged from 0 to 5, with higher grades correlating with better outcomes (40% in Grade 3 compared with 95% in Grade 5, p < 0.001).\(^19\) However, these findings were not replicated in a subsequent study\(^4\) and we were not able to analyze neuroradiological parameters in the present series, owing to an unacceptably high rate of missing data.

Among the study limitations, of note is the fact that 8 patients (4.5%) were lost to follow-up, even if this number was minimized by telephone interviews. Moreover, best-case and worst-case analyses have demonstrated their lack of impact on study results. Although the projected total number of patients was not achieved, a higher than expected failure rate allowed for adequate statistical inference. The lack of blinded reviewers in the assessment of predictive variables and outcome may have introduced an observational bias. In accordance with the outcome definition used in the derivation of the ETVSS, the outcome relied on the surgeon’s decision to reoperate, based on his assessment of the clinical and radiological evolution during the follow-up period. In most patients ETV failure is quite clear, with renewed manifestations of intracranial hypertension and ventricular dilation. Yet, in a subset of patients symptomatology is more insidious and, in others, ventricular dilation improves only partially after the ETV even if the patient is doing well clinically. Thus, in some cases of clinical successes, one may ask if a superior clinical outcome would have been achieved with shunt implantation.

### Conclusions

In this population of patients comprising mostly adults and children 2 years and older, the ETVSS did not show adequate discriminative ability. However, even in a mixed adult and pediatric population, the ETVSS showed an adequate calibration. The ETVSS is only marginally useful in clinical scenarios when 60% and 70% success rates are used as the thresholds for preferring ETV to CSF shunt. In such cases, the ETVSS can result in a reduction of 2 and 4 avoidable ETVs per 100 patients, respectively.

In our cohort, previous history of CSF shunt and age were not associated with worse outcomes, whereas posthemorrhagic and postinfectious causes of the hydrocephalus were significantly associated with reduced success rates following ETV. Surgical variables, including third ventricular floor opacity, significant bleeding during endoscopy, concurrent biopsy, surgeon experience, and Liliquist membrane opening were not associated with success of the ETV at 6 months. Further studies should focus on the predictive factors that are specific to the older population. A combination of clinical, radiological, and intraoperative findings may be necessary to devise a clinical prediction rule better suited to this group of patients.
References

40. Wasson JH, Sox HC, Neff RK, Goldman L: Clinical predic-


**Author Contributions**
Conception and design: Labidi, Bojanowski, Turmel. Acquisition of data: Labidi, Obaid, Weil, Bojanowski, Turmel. Analysis and interpretation of data: Labidi, Lavoie, Lapointe, Bojanowski, Turmel. Drafting the article: Labidi. 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: Labidi. Statistical analysis: Labidi, Lavoie. Administrative/technical/material support: Labidi, Bojanowski, Turmel. Study supervision: Labidi, Turmel.

**Supplemental Information**
**Previous Presentation**
Part of this work was presented, along with accompanying proceedings and abstracts, during the 2013 meeting of the Société de Neurochirurgie de Langue Française (SNCLF), which was held May 27–30, 2013, in Québec City, QC, Canada, and during the 2013 meeting of the Canadian Neurological Sciences Federation (CNSF), which was held June 12–14, 2013, in Montréal, QC, Canada.

**Correspondence**
Moujahed Labidi, Neurological Sciences Department, Division of Neurosurgery, CHU de Québec, Hôpital de l’Enfant-Jésus, 1401, 18e rue, Québec City, QC G1J 1Z4, Canada. email: moujahed.labidi.1@ulaval.ca.