Endoscopic third ventriculostomy in the management of obstructive hydrocephalus: an outcome analysis

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Object. The purpose of this paper is to elucidate the safety and efficacy of, and indications and outcome prognosis for endoscopic third ventriculostomy (ETV) in 58 patients with obstructive hydrocephalus.

Methods. Between September 1999 and April 2003, 58 ETVs were performed in 58 patients with obstructive hydrocephalus (36 male and 22 female patients) at the authors’ institution. The ages of the patients ranged from 5 to 67 years (mean age 35 years) and the follow-up period ranged from 3 to 41 months (mean duration of follow up 24 months). Patients were divided into four subgroups based on the cause of the obstructive hydrocephalus: 21 with intracranial tumors; 11 with intracranial cysts; 18 with aqueductal stenosis; and eight with intracranial hemorrhage or infection. Both univariate and multivariate statistical analyses were performed to assess the prognostic relevance of the cause of the obstructive hydrocephalus, early postoperative clinical appearance, and neuroimaging findings in predicting the result of the ETV.

The survival rate was 87% at the end of the 1st year and 84% at the end of the 2nd year post-ETV. One month after ETV an overall clinical improvement was observed in 45 (77.6%) of 58 patients. If we also consider the successful revision of ETV in two patients, a success rate of 78.3% (47 of 60 patients) was reached. The ETV was successful in 17 (81%) of 21 patients with intracranial tumors, nine (82%) of 11 with cystic lesions, 16 (88.9%) of 18 with aqueductal stenosis, and three (38%) of eight with intracranial hemorrhage or infection. A Kaplan–Meier analysis illustrates that the percentage of functioning ETVs stabilizes between 75 and 80% 1 year after the operation. In a comparison of results 1 year after ETV, the authors found that the aqueductal stenosis subgroup had the highest proportion of functioning ETV (89%). The proportions of the tumor and cyst subgroups were 84 and 82%, respectively, whereas the proportion was only 50% in the intracranial hemorrhage subgroup (strata log-rank test: $\chi^2 = 7.93, p = 0.0475$).

In the present study, ETV failed in eight patients (13.8%) and the time to failure after the procedure was a mean of 3.4 months (median 2 months, range 0–8 months). The logistic regression analysis confirmed an early postoperative improvement (within 2 weeks after ETV, significance [Sig] of log likelihood ratio [LLR] < 0.0001) and a patent stoma on cine phase–contrast magnetic resonance (MR) images (Sig of LLR = 0.0002) were significant prognostic factors for a successful ETV. The results demonstrated the multivariate model ($B = -53.7309$, standard error = 325.1732, Wald = 0.0273, Sig = 0.8688) could predict a correct result in terms of success or failure from ETV surgery in 89.66% of observed cases. The Pearson chi-square test demonstrated that little reliance could be placed on the finding of a reduced size of the lateral ventricle ($\chi^2 = 5.305, p = 0.07$) on neuroimaging studies within 2 weeks after ETV, but it became a significant predictive factor at 3 months ($\chi^2 = 8.992, p = 0.011$) and 6 months ($\chi^2 = 10.586, p = 0.005$) post-ETV. Major complications occurred in seven patients (12.1%), including intraoperative venous bleeding in three, arterial bleeding in one, and occlusion of the stoma in three patients. The overall mortality rate was 10.3% (six patients). One of these patients died of pulmonary infection and another of ventriculitis. Four additional patients died of progression of malignant tumor during the follow-up period.

Conclusions. The results indicate that ETV is a most effective treatment in cases of obstructive hydrocephalus that is caused by aqueductal stenosis and space-occupying lesions. For patients with infections or intraventricular bleeding, ETV has considerable effects in selected cases with confirmed CSF dynamic studies. Early clinical and cine phase–contrast MR imaging findings after the operation play an important role in predicting patient outcomes after ETV. The predictive value of an alteration in ventricle size, especially during the early stage following ETV, is unsatisfactory. Seventy-five percent of ETV failures occur within 6 months after surgery. A repeated ventriculostomy should be considered to be a sufficient treatment option in cases in which stoma dysfunction is suspected.

Key Words • endoscopic third ventriculostomy • hydrocephalus • complication • outcome

Since the development of valve-regulated shunts in the 1950s,35 shunt surgery has widely been used to treat hydrocephalus. Nevertheless, high failure rates and numerous complications have been reported.47,56,57,65 With the introduction of neuroendoscopic methods, ETV has become the preferred treatment for obstructive hydrocephalus because the approach is minimally invasive and offers the surgeon brilliant visual control of the maneuver.5,6,26,29,31,40,58,71 In the present study, we retrospectively analyzed the indications for ETV, the surgical technique itself, and outcomes in a consecutive group of 58 patients who underwent ETV for obstructive hydrocephalus.
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Clinical Material and Methods

Patient Population

Fifty-eight ETVs were performed in 58 patients (36 male and 22 female patients) for the treatment of obstructive hydrocephalus at our institution between September 1999 and April 2003. The mean age of the patients was 35 years (range 5–67 years). Symptoms of obstructive hydrocephalus included headaches (42 patients), nausea (38 patients), vomiting (33 patients), seizures (three patients), blurred vision (25 patients), memory disturbances (41 patients), gait disturbances (16 patients), urinary incontinence (three patients), and reduction of physical power (seven patients).

Patient selection was based on findings of CT and MR imaging studies, which indicated the presence of obstructive hydrocephalus with the obstruction located in the posterior aspect of or distal to the third ventricle. In selected cases, cine phase–contrast MR imaging was performed before or after surgery. Patients who experienced meningitis, ventriculitis, and intraventricular or subarachnoid hemorrhage who met the aforespecified criteria were also included. It was determined that the obstructive hydrocephalus was caused by space-occupying lesions in 32 patients (including 21 with intracranial tumors and 11 with intracranial cysts), aqueductal stenosis in 18 patients, and intracranial hemorrhage or infection in eight patients. The follow-up period lasted between 3 and 41 months (mean duration of follow-up 24 months).

Outcome of ETV was evaluated according to patients' follow-up data or patients' status before they were lost to follow-up. The treatment was recorded as a success or failure (the latter includes no change and a deterioration in the condition). Success of the ETV was defined as partial or complete relief of symptoms; unchanged outcome was defined as neither significant relief from nor progression of symptoms; and deterioration was defined as progression of symptoms. Any patient who died as a direct result of the ETV procedure or had to undergo a shunt implantation operation after the ETV procedure was described as having treatment failure. Considering the potential predictive role of the early clinical appearance after ETV, we defined it as clinical presentation in the first 2 weeks after ETV and classified it with the same criteria as those used for the ETV outcome evaluation. Repeated CT or MR images (the initial study was completed within 2 weeks after ETV) were obtained in each patient to evaluate the results of surgery and during the follow-up period, including 29 patients in whom cine phase–contrast MR images were obtained to verify the patency of the stoma.

Endoscopic Maneuver

Endoscopic third ventriculostomy was performed using the freehand method in all 58 cases while the patient was in a state of general anesthesia. In each case we used a rigid endoscope (Clarus Medical, Minneapolis, MN) with a working length of approximately 21.6 cm and an outer diameter of 4.5 mm, which was equipped with three channels for instruments, suction, and irrigation, and a 2.3-mm optic. Observation and flexible endoscopes were applied in some cases for confirmation of anatomical orientation and for tumor biopsy. Before surgery, the relationship between the floor of the third ventricle and the tip of basilar artery was carefully evaluated on sagittal MR images to reduce injury to the basilar artery and its branch.

The patient was placed supine with the head supported by a horseshoe frame. A coronal burr hole was placed approximately 3 cm lateral from the midline and just anterior to the coronal suture. For patients undergoing endoscopic biopsy for a tumor in the posterior portion of the third ventricle, the burr hole was modified on the basis of MR imaging findings (usually 3–5 cm anterior to the coronal suture). After incision of the dura mater, the endoscope was advanced into the lateral ventricle through the peel-away sheath. After identification of the foramen of Monro, the operating sheath and endoscope were passed into the third ventricle. After close inspection of the floor of the third ventricle, the tuberculum sellae was identified as the site of perforation. Blunt forceps and a Fogarty balloon catheter were used in most cases for perforation and widening of the stoma whose diameter was usually larger than 5 mm. Bipolar coagulation was only used in cases in which there was a tough or floating floor. The endoscope was advanced through the stoma to the cistern and the prepontine cistern for confirmation of a free communication between the third ventricle and the subarachnoid space. The Liliequist membrane acts as a barrier between them in some cases; thus it was essential to combine a Liliequist membranostomy with all the aforementioned procedures to reduce the incidence of failure. After a final inspection, the operating sheath was withdrawn with the endoscope inside so that we could look for active bleeding at the foramen of Monro and in the puncture channel. External ventricular drains were not routinely inserted. The burr hole was packed with a gelatin sponge and the galea was tightly sutured to prevent a subgaleal CSF accumulation and fistula. The skin was closed using a running atraumatic suture.

Statistical Analysis

Statistical analyses (Kaplan–Meier Survival analysis, logistic regression, and the Pearson chi-square test) were conducted using statistical software (SPSS, Inc.; Chicago, IL).

Results

Fifty-eight ETVs were performed in 58 patients. There were 36 male and 22 female patients among whom 87% survived the 1st year and 84% the 2nd year after ETV (Fig. 1). One month after ETV an overall clinical improvement was observed in 45 (77.6%) of 58 patients. If we consider successful revision of ETV, which was performed in two patients, the success rate reached 78.3% (47 of 60 patients). A Kaplan–Meier analysis illustrated that the proportion of functioning ETVs became stable at rates of 75 to 80% after the 1st year and 84% the 2nd year after ETV (Fig. 1). One month after ETV an overall clinical improvement was observed in 45 (77.6%) of 58 patients. If we consider successful revision of ETV, which was performed in two patients, the success rate reached 78.3% (47 of 60 patients). A Kaplan–Meier analysis illustrated that the proportion of functioning ETVs became stable at rates of 75 to 80% after the 1st year and 84% the 2nd year after ETV (Fig. 1). Initially the procedure failed in eight patients (13.8%). Cases of treatment failure included two cases of aqueductal stenosis, one of third ventricular ependymoma, two of giant suprasellar arachnoid cyst, and three of ventriculitis or intracranial hemorrhage. In these eight patients, five failures (62.5%) occurred within 3 months, six (75%) within 6 months, and all within 9 months after surgery. Time to failure after ETV for the whole group was a mean of 3.4 months (median 2 months, range 0–8 months). Two patients underwent second successful ETVs because membranes of Liliequist or occlusion...
of the fenestration were identified on postoperative MR images. Thus overall there were six failures (10.3%) in 58 patients. Five patients had previously received shunts; among these there were three successes. Fifty-three patients had not received previous treatment; of these there were five failures.

The proportion of functioning ETVs between separated groups was analyzed using a Kaplan–Meier curve (Fig. 3; log-rank test: $\chi^2 = 4.6$, $p = 0.0319$). In a comparison of the results 1 year after ETV, the aqueductal stenosis subgroup had the highest rate of functioning ETVs (89%). In the tumor and cystic subgroups the rates of functioning ETVs were 84 and 82%, respectively. This rate was only 50% in the ventriculitis/intracranial hemorrhage subgroup (strata log-rank test: $\chi^2 = 7.93$, $p = 0.0475$). In the largest sub-

group of patients, 21 (36.2%) had tumors in or adjacent to the third ventricle, which caused obstructive hydrocephalus. By performing endoscopic biopsy or craniotomy, pathological diagnoses were confirmed for two ependymomas, two medulloblastomas, eight pineocytomas, three thalamic astrocytomas, and four hemangioblastomas. In these cases of tumor ETV was successful in 17 (81%) of 21 patients. Eleven patients had cystic lesions (four suprasellar cysts, three third ventricular arachnoid cysts, and four fourth ventricular cysts); successful ETVs were completed in nine (82%) of these patients. Sixteen (88.9%) of the 18 patients with aqueductal stenosis improved after ETV. The improvement was most striking and rapid in the 11 patients who had symptoms of acute increased ICP, including severe headaches and vomiting. The conditions of two other patients deteriorated after ETV. These two patients both belong to our early phase of ETV procedures. One patient was removed from the study because of severe intraventricular venous bleeding and the other one because of early occlusion of the stoma. Both of these patients underwent shunt placement surgery, which was successful. Five patients with IVH received ETV. Only two patients improved and became shunt free after the operation. Two other patients received shunts 1 month later and a third died 2 months after surgery of a severe pulmonary infection. Only one of three patients with ventriculitis benefited from ETV and became shunt free after surgery. In the other two patients the condition remained unchanged and shunts were required.

Neuroimaging evaluation within 2 weeks after ETV demonstrated an improvement in the conditions of 29 patients (50%), including 10 patients in whom ventricle size remained unchanged, but a definite CSF flow void was observed on MR images and there were no imaging signs of ICP. All 10 patients experienced clinical improvement. Correlations between ETV outcome and the postoperative size of the lateral ventricle, a patent stoma on cine phase–contrast MR images, and an early postoperative clinical re-
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**TABLE 1**

<table>
<thead>
<tr>
<th>Size of Ventricle</th>
<th>Successful ETV†</th>
<th>Failed ETV†</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 wks postop</td>
<td></td>
<td></td>
</tr>
<tr>
<td>smaller</td>
<td>11</td>
<td>2</td>
</tr>
<tr>
<td>unchanged</td>
<td>29</td>
<td>6</td>
</tr>
<tr>
<td>larger</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>3 mos postop</td>
<td></td>
<td></td>
</tr>
<tr>
<td>smaller</td>
<td>23</td>
<td>2</td>
</tr>
<tr>
<td>unchanged</td>
<td>18</td>
<td>2</td>
</tr>
<tr>
<td>larger</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>6 mos postop</td>
<td></td>
<td></td>
</tr>
<tr>
<td>smaller</td>
<td>31</td>
<td>2</td>
</tr>
<tr>
<td>unchanged</td>
<td>10</td>
<td>2</td>
</tr>
<tr>
<td>larger</td>
<td>2</td>
<td>3</td>
</tr>
</tbody>
</table>

* Alteration in the size of the ventricle was evaluated according to the frontal and occipital horn ratio, a reliable and valid measure of ventricular size (see Matsuno, et al.).
† Pearson chi-square test: \( \chi^2 = 5.305, p = 0.07 \) for 2 weeks; \( \chi^2 = 8.992, p = 0.011 \) for 3 months; \( \chi^2 = 10.586, p = 0.005 \) for 6 months.

Response was documented in 58 patients. Although the Pearson chi-square test demonstrated that little reliance could be placed on a reduced size of the lateral ventricle (\( \chi^2 = 5.305, p = 0.07 \)) on neuroimages within 2 weeks after ETV as a sign of success, because this ventricle remained unchanged in 35 patients and enlarged in 10 patients 2 weeks after surgery (Table 1), ventricle size became a significant predictive factor 3 months (\( \chi^2 = 8.992, p = 0.011 \)) and 6 months (\( \chi^2 = 10.586, p = 0.005 \)) after ETV.

In our study, the early clinical response (within 2 weeks after surgery) and the patent stoma on cine phase–contrast MR images provided a high correlation with overall ETV success (Tables 2 and 3). The logistic regression analysis confirmed that the early postoperative improvement (B = 11.3453, SE = 65.037, Wald = 0.0304, Sig = 0.8615, LL = –30.032, –2 LLR = 47.019, Sig of LLR < 0.0001) and a patent stoma on cine phase–contrast MR images (B = 20.3881, SE = 130.0631, Wald = 0.0246, Sig = 0.8754, LL = –13.354, –2 LLR = 13.662, Sig of LLR = 0.0002) were significant prognostic factors for a successful ETV. Our results demonstrated that the multivariate model (B = –53.7309, SE = 325.1732, Wald = 0.0273, Sig = 0.8688) could be used to predict a correct result in terms of the success or failure of ETV surgery in 89.66% of observed cases (–2 LL = 13.045, goodness of fit = 12). If the predicted probability was less than 0.25, the chance for success was 93.75%; if the predicted probability was greater than 0.75, the chance for success was 0%.

Major complications occurred in seven patients (12.1%). Complications included intraoperative venous bleeding in three patients. In one of these patients thalamic infarction developed but improved successfully. Arterial bleeding from a small perforating vessel occurred in one patient; it was treated successfully by extensive irrigation and shunt placement 3 weeks later. Three patients experienced occlusion of the stoma after ETV. In one this occurred in the early stage and in the other two a delay (maximum time 13 months after ETV). Other minor complications included transient fever and vomiting in six patients. No infection was related to intervention with ETV in this group. The overall mortality rate was 10.3% (six patients). One patient died of pulmonary infection and another of ventriculitis. An additional four patients died of progression of malignant tumor during the follow-up period. No death was directly caused by the ETV.

**TABLE 2**

<table>
<thead>
<tr>
<th>Clinical Response</th>
<th>Successful ETV</th>
<th>Failed ETV</th>
</tr>
</thead>
<tbody>
<tr>
<td>W/in 2 Wks Postop</td>
<td></td>
<td></td>
</tr>
<tr>
<td>improved</td>
<td>32</td>
<td>2</td>
</tr>
<tr>
<td>unchanged</td>
<td>7</td>
<td>5</td>
</tr>
<tr>
<td>deteriorated</td>
<td>6</td>
<td>6</td>
</tr>
</tbody>
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* Pearson chi-square test: \( \chi^2 = 13.152, p = 0.01 \) (asymptotic significance [two sided]).
† Failed ETV includes unchanged and deteriorated conditions.

**TABLE 3**

<table>
<thead>
<tr>
<th>Cine Phase–Contrast MRI</th>
<th>Successful ETV</th>
<th>Failed ETV</th>
</tr>
</thead>
<tbody>
<tr>
<td>positive</td>
<td>12</td>
<td>4</td>
</tr>
<tr>
<td>negative</td>
<td>5</td>
<td>8</td>
</tr>
</tbody>
</table>

* Pearson chi-square test: \( \chi^2 = 3.948, p = 0.047 \) (asymptotic significance [two sided]).

**Discussion**

Endoscopy has changed neurosurgical treatment in many ways. Obstructive hydrocephalus represents the most important indication for endoscopic intervention. Endovascular third ventriculostomy has been considered to be an effective and safe treatment for occlusive hydrocephalus by many authors, but indications, surgical techniques, and outcomes related to different pathological findings are still under intensive investigation.

**Consideration of the Endoscopic Technique**

Although flexible fiberscopes have been used for ETV, they offer a considerably inferior image quality and there is difficulty with their orientation, guidance, and fixation. In our series, except in the first few cases, most ETVs were performed using rigid endoscopes for freehand procedures. We applied a stereotactic technique in three ETV operations, but failed to observe any benefits to the procedure. Instead it was time consuming and provided inadequate accuracy for the stoma perforation. When ETV and a biopsy needed to be performed simultaneously, we routinely adjusted the burr hole site for the convenient use of a rigid endoscope according to preoperative MR imaging studies. If necessary, a “mother-and-daughter” method can be used to perform biopsy and ETV. A variety of methods have been described for perforation of the floor of the third ventricle, including manipulation of the endoscope itself, blunt probes or catheters, monopolar coagulation, la-

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<td>negative</td>
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</tr>
</tbody>
</table>

* Pearson chi-square test: \( \chi^2 = 3.948, p = 0.047 \) (asymptotic significance [two sided]).
ser energy, and, recently reported, reverse ETV via the cistern magna. We usually use blunt probes for perforation. In most cases of obstructive hydrocephalus, the floor is translucent. Therefore, visualization of the basal tip is possible and perforation can be safely performed.

Dilation of the stoma is completed using a balloon catheter (No. 4 French), which can be passed freely by the endoscope and can increase the size of the perforation up to 6 mm. Floating tissue on the margin of the stoma needs to be coagulated carefully in a low-energy manner to avoid the delayed closure of the stoma. In cases in which there is a tough and nontranslucent floor, blunt perforation may be inadequate and carry the risk of distortion of surrounding vital tissue. In this situation, we prefer to create a perforation by using probes with sharp tips. Other methods include ultrasonic or navigational guidance. The perforating site depends on findings on preoperative MR images. Special attention should be directed toward the preponine cistern. The nonfenestrated Liliequist membrane acts as a barrier between CSF flow from the infratentorial cisterns to the supratentorial cisterns: this membrane may be opened accidently or may require a deliberate attempt to open it, depending on its anatomical attachment. The site of inferior attachment of the Liliequist membrane is the dorsum sellae; however, the site of the superior attachment may vary (premamillary or retromamillary attachment).

In patients in whom there is preamillary attachment of the Liliequist membrane, it is essential to include Liliequist membranostomy to reduce the incidence of treatment failures. In patients in whom there is a retromamillary attachment, it is not necessary to open the Liliequist membrane because the third ventricle has been opened to the interpeduncular cistern. Considering the potential harmful effect of low ICP on ETV, postoperative drainage was not routinely applied in this series except in cases in which there was severe IVH or ventriculitis.

**Patient Selection and Outcome Evaluation**

The goal of ETV and, to date, the best objectively quantifiable measure of a successful outcome, is shunt independence. Authors of recent reports on ETV trials have claimed success rates greater than 75% (50–94%) for carefully selected patients. In the present series of 58 ETVs, overall shunt independence after ETV was achieved in 45 (77.6%) of 58 patients. If we consider the successful revision of ETV in two patients, the success rate reached 78.3% (47 of 60 patients). According to the results of the Kaplan–Meier analysis, the rate of functioning ETVs stabilized at 75 to 80% after the 1st postoperative year. Compared with this achievement, we are still struggling with shunt implantation surgery and many unsolved problems that lead to a 50% failure rate within 2 years and a 2:1 risk of shunt revision after the initial shunt insertion.

Endovascular third ventriculostomy is commonly used to treat cases of noncommunicating hydrocephalus in which there are patent subarachnoid spaces and adequate CSF absorption. Our studies have demonstrated that patients with aqueductal stenosis, cystic abnormalities, and tumors obstructing outflow from the third or fourth ventricle are good candidates for ETV. High rates of shunt independency (>80%) were achieved in these patients. The success rates were 88.9% for patients with aqueductal stenosis, 81% for those with cystic abnormalities, and 82% for those with tumors in selected series. Regarding the cause of obstructive hydrocephalus, a recent study revealed significantly poor outcomes in patients with progressive tumorous lesions, compared with patients with benign space-occupying lesions. Nevertheless, we did not find a significant difference in the proportion of functioning ETVs in patients with malignant tumors and those with benign space-occupying lesions (data not shown). We believe that the major reasons for this result may be due to the small patient population and the limited duration of follow up.

Given that ETV has proved to be an effective and safe maneuver for occlusive hydrocephalus, the duration of functioning ETV in patients with malignant neoplasms is dependent on their length of survival. In our study, stereotactic radiosurgery or chemotherapy, which was used in patients with malignant tumors to prolong their lives, had effects on evaluation of functioning ETV when compared with that in patients with benign space-occupying lesions. Patients with a reduced CSF resorption capacity, which may be seen after IVH, meningitis, or myelomeningocele, were usually thought to have a low success rate if they underwent ETV.

According to the Kaplan–Meier analysis, the proportion of functioning ETVs in the ventriculitis/intracranial hemorrhage subgroup was significantly lower than that in the aqueductal stenosis, tumor, and cystic subgroups. A significant difference between subgroups with regard to the 1-year proportion of shunt independence was also shown. In contrast to this assumption, recent studies on ETV performed in patients with meningitis, shunt infections, and IVH demonstrated considerable success rates (>60%).

Given the relative safety of ETV and the potential chance for freedom from shunts, we performed ETV in patients in whom there was bleeding into the ventricles or ventriculitis during the early phase of the study. Unfortunately, only two of five patients with IVH and one of three patients with ventriculitis derived benefit from ETV and became shunt free after surgery. One possible explanation for this result is that a combination of obstruction and impaired CSF resorption coexisted in these patients. The adaptation of subarachnoid space to altered CSF dynamics after ETV failed to compensate the preexisting malfunction of CSF resorption.

Reliable and applicable clinical tests that can be used to predict whether ETV will be beneficial for selected patients are still pending. According to recent studies, tests of CSF dynamics and ventricle wall function will offer a resolution to these questions. Many studies have demonstrated a trend toward a more successful outcome of ventriculostomy in patients with existing shunt systems. In our study, three of five patients who had previously received shunts became shunt free after ETV.

According to recent studies, the failure rate of ETV ranged from 6 to 50%. In the present study, the procedure failed in eight patients (13.8%). Time to failure after ETV for the whole group was a mean of 3.4 months (median 2 months, range 0–8 months). Almost two thirds of failures occurred within 3 months, three fourths of failures occurred within 6 months, and all developed within 9 months after surgery. The cases of treatment failure included two patients with aqueductal stenosis, one with third ventricular ependymoma, two with giant suprasellar arachnoid cysts, and three with ventriculitis or IVH. The major cause of failure of ETV is obstruction of the stoma, which
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occurs between 2 weeks and 6 years according to the literature.38 We consider that the risk for obstruction of the stoma seems to be higher if the flow through the stoma is reduced or if there is a high concentration of protein and fibrinogen. This may be the case in patients with partially functional shunts, in those patients with extracranial drainage before ETV, and in those with intraventricular tumors, IVH, or ventriculitis.

In our series, five patients experienced partial or complete closure of the stoma. Two patients presented with low-pressure hydrocephalus caused by overdrainage and continued to require a shunt after ETV. In the other three patients the problem may have been caused by conglutination of the stoma due to a high concentration of protein in one patient with an intraventricular tumor and two with ventriculitis.

Revision of the ETV is indicated in patients in whom there are anatomical blocks such as a Liliequist membrane or occlusion of the fenestration.50 During our early experience with ETV the rate of surgical complication was obviously higher than that associated with insertion of a shunt, indicating that there was a steep learning curve. Seven patients (12.1%) experienced ETV-related complications in this study. There were no cases of permanent morbidity and none of the six deaths was a direct result of the ETV. The major complication we encountered was intraoperative bleeding. Fortunately, in most cases, intensive irrigation led to termination of the bleeding. Other complications included infarction of the thalamus, fever, and transient dysfunction of the hypothalamus.

**Neuroimaging Study and Outcome Prediction**

Endovascular third ventriculostomy is considered superior to shunt implantation in patients with obstructive hydrocephalus to resolve intracranial hypertension and restore CSF dynamics to nearly normal. Nevertheless, the adjustment of CSF dynamics is sometimes time consuming when one observes the delay between the ETV operation and the decrease in ventricular size. Therefore, the challenge for neurosurgeons is to predict patient outcomes by using reliable predictors. During the early phase of our ETV procedures, we used ventriculography to evaluate the dynamics of CSF after ETV. Serial-enhanced contrast MR or CT images showed a clear patency of the stoma, but several days were needed to elucidate the observation, thus increasing the economic burden on the patient. More recently, we have assessed the patency of ETV by performing cine phase-contrast MR imaging at our center. Cine phase-contrast MR imaging has been increasingly used during the last decade to evaluate cranial and spinal flow. With the increasing frequency of neuroendoscopic procedures, cine MR imaging has been recommended to evaluate the patency of third ventriculostomy. A recent study showed that CSF flow studies might detect obstruction before symptom recurrence or clinical deterioration. According to our logistic regression model, the finding of a patent stoma on postoperative MR images had a successful ETV, whereas we also noticed that four patients in whom a positive flow void was imaged experienced treatment failure.

Magnetic resonance imaging, which can be used to detect the presence of a flow void signal through the third ventricular floor, has been reported to have a significantly high incidence of false-positive findings. We figured the reason for a false-positive finding was mainly a result of a delayed occlusion of the stoma. Five (38.5%) of 13 patients in whom postoperative cine MR images demonstrated no alleviation of the condition improved after ETV. We believe that this was due to external drainage or partial shunting, which produce a no-flow image even when there is an open orifice. Most studies have demonstrated a gradual decrease in ventricle size over months to years postoperatively, coinciding with a clinical improvement.74,70 We proved that the size of the ventricle is not a good predictor for neurosurgeons to use in the evaluation of the outcome within 3 months after surgery. In the early postoperative period, a decrease in the size of the ventricle is often minimal and not visible before 3 and 4 weeks. Nevertheless, the opposite opinion has been raised in a recent report in which the authors stated, “postoperative ventricular size reflects outcome.”69 The size of the ventricle was used as the most important factor in determining failure and requirement for surgery. In our study, five of 10 patients with an increased ventricle size after ETV achieved satisfactory results. The reason may have been because of the adaptation process of CSF absorption capacity; in three of these five patients a hemorrhage or ventriculitis was documented.

In patients who have arachnoid granulations with a decreased level of absorbability, which often occurs in these patients, we believe that a large pressure gradient may develop due to the increasing ICP and that this may overcome the partial blockage caused by the arachnoid granulations.49 A recent study showed that symptoms improved within 1 week after ETV in patients with shunt-dependent noncommunicating hydrocephalus.42 We demonstrated that the early clinical response played a important role for prediction of outcome in patients who have undergone surgery for ETV. In clinically improved cases, the success predictive value was as high as 94.1% (32 of 34), which corresponds to rates reported in the literature.6,26 Some authors considered clinical outcome to be the most important guide to success or failure. Using a reduction in the size of the ventricle as a sole indicator of success in this procedure is questionable because clinically successful cases can have no change in ventricle size. Neuroimaging outcomes alone may be misleading and reliance on them should be avoided.7

**Conclusions**

In conclusion, our results indicate that ETV is most effective in patients with obstructive hydrocephalus caused by aqueductal stenosis and space-occupying lesions. For patients with IVH or infections, ETV has a considerable effect on selected cases with confirmed CSF dynamic studies. Blunt perforation of the floor of the third ventricle is the preferred method of the procedure. Postoperative shunt placement and excess drainage should not been advocated to avoid closure of the stoma. Early clinical results and postoperative findings on cine phase-contrast MR images play a important role in predicting outcomes of ETV. The predictive value of an alteration in the size of the ventricle, especially during the early stage after ETV, is unsatisfactory. Most ETV failures occur 6 months after the operation.
Repeated ventriculostomy should be considered as a sufficient treatment option in cases of suspected stoma dysfunction. If performed correctly, ETV is a safe, simple, and effective treatment option with an acceptable level of complications.

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