LONG-TERM RELIABILITY OF ENDOSCOPIC THIRD VENTRICULOSTOMY

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OBJECTIVE: To describe the short-term operative success and the long-term reliability of endoscopic third ventriculostomy (ETV) for treatment of hydrocephalus and to examine the influence of diagnosis, age, and previous shunt history on these outcomes.

METHODS: We retrospectively analyzed 203 consecutive patients from a single institution who had ETV as long as 22.6 years earlier. Patients with hydrocephalus from aqueduct stenosis, myelomeningocele, tumors, arachnoid cysts, previous infection, or hemorrhage were included.

RESULTS: The overall probability of successfully performing an ETV was 89% (84–93%). There was support for an association between the surgical success and the individual operating surgeon (odds ratios for success, 0.44–1.47 relative to the mean of 1.0, $P = 0.08$). We observed infections in 4.9%, transient major complications in 7.2%, and major and permanent complications in 1.1% of 203 procedures. Age was strongly associated with long-term reliability. The longest observed reliability for the 13 patients 0 to 1 month old was 3.5 years. The statistical model predicted the following reliability at 1 year after insertion: at 0 to 1 month of age, 31% (14–53%); at 1 to 6 months of age, 50% (32–68%); at 6 to 24 months of age, 71% (55–85%); and more than 24 months of age, 84% (79–89%). There was no support for an association between reliability and the diagnostic group (n = 181, $P = 0.168$) or a previous shunt. Sixteen patients had ETV repeated, but only 9 were repeated after at least 6 months. Of these, 4 procedures failed within a few weeks, and 2 patients were available for long-term follow-up.

CONCLUSION: Age was the only factor statistically associated with the long-term reliability of ETV. Patients less than 6 months old had poor reliability.

KEY WORDS: Endoscopic, Hydrocephalus, Surgical procedure, Ventriculostomy

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Endoscopic third ventriculostomy (ETV) is an established treatment for hydrocephalus. High success rates have been reported for patients with aqueduct stenosis (5, 11, 20, 23, 24, 33). Lower success rates have been reported for patients with hydrocephalus from other causes, such as postinfection, posthemorrhage, or myelomeningocele, and for patients with previous ventricular shunt failure (14, 20, 23, 38, 40). ETV is less effective in pediatric populations, but the minimum age to attempt ETV is controversial (2, 20, 23, 37). We performed a retrospective analysis of the operative success and long-term reliability of ETV in 203 patients with follow-up for up to 22.6 years. We investigated the effects of age, previous shunting, and the pathogenesis of hydrocephalus on these outcomes.

PATIENTS AND METHODS

Patient Population

Between April 1979 and December 2001, 203 consecutive patients underwent ETV at The Sydney Children's Hospital initially and later also at The Prince of Wales Hospital, Sydney, Australia. The ages of the patients ranged from 2 days to 78 years, and 51% were male. Initially successful procedures were performed for 181 patients, and 22 patients had initially unsuccessful procedures. Sixteen patients had ETV procedures repeated. Of the 181 patients with initially successful procedures, 79 (44%) had previous shunt insertions. The previous shunts had been present for between 6 days and 41 months before ETV (median, 2 mo). Sixteen patients had previous shunts left in place when ETV was performed. We grouped patients into the following diagnostic categories: aqueduct stenosis (n = 86), myelomeningocele (n = 37), tumors (n = 38), status postinfection or posthemorrhage (n = 30), arachnoid cysts (n = 5), and other diagnoses (n = 7). The last group included Chiari malformations (n = 3), tuberosclerosis (n = 1), fourth ventricular cyst (n = 1), cerebral cyst (n = 1), and posttraumatic hydrocephalus (n = 1). A classification of the patients treated successfully and unsuccessfully, by age and diagnosis, is shown in *Table 1*.

Indications

When this series was started in 1979, the following criteria were used for selecting patients for ETV: triventricular hydrocephalus on computed tomographic scan, third ventricles wider than 7 mm, patients older than 2 years, and no previous intracerebral infections or radiotherapy. From approximately 1988 on, the age threshold was generally reduced to 6 months of age, although there were younger exceptions. Patients with a history of cerebrospinal fluid (CSF) infection with triventricular hydrocephalus were also offered ETV. From approximately 1992 on, the threshold for the width of the third ventricle was reduced to 4 mm. From approximately 1995 on, any patients more than 6 months of age with triventricular hydrocephalus were considered for ETV. It should be noted that preoperative studies were used to select noncommunicating forms of hydrocephalus. These included computed tomographic scans, frequently with ventriculography, until approximately 1990, when magnetic resonance imaging (MRI) was increasingly used instead.

Operations

Seven different surgeons performed the procedures. Under general anesthesia, the patient's head was slightly flexed. A burr hole was made approximately 1 cm in front of the coronal suture and 3 cm from the midline. A rigid endoscope was passed into the lateral ventricle and then the third ventricle via the foramen of Monro. The floor of the third ventricle was perforated between the infundibular recess of the pituitary stalk and the anterior border of the mammillary bodies. The interpeduncular cistern was entered as close to the clivus as possible to avoid injury to the basilar artery. Blunt fenestration is usually employed, using either the endoscope, a deflated balloon catheter, or closed forceps. The method of fenestration was not always recorded. Forceps were occasionally used to tear a small hole in the membrane. The rigid endoscope or a balloon catheter was then used to expand the fenestration to an approximate width of 5 mm. Ventricular access reservoirs were not routinely placed.

Study Design

Clinical data were collected retrospectively to describe a consecutive series of patients. Hospital and clinic medical records were reviewed, and patients or their relatives were contacted by telephone. Data included preoperative clinical findings, investigation results, operation details, and postoperative findings. MRI scans were not uniformly performed postoperatively.

Outcomes

There were three outcome measures: 1) the surgical success of the initial operation when there was a successful perforation of the ventricular floor, 2) the reliability of ETV, and 3) the reliability of ETV revisions. We used the term reliability to describe the duration of the successful control of symptoms

TABLE 1. Age and diagnosis for 203 endoscopic third ventriculostomy procedures[a]

Age group	Aqueduct stenosis	Myelomeningocele	Tumors	Infection/ hemorrhage	Arachnoid cyst	Other	Total
0–1 mo	6	5 (4)		1	1		13 (4)
1–6 mo	3 (1)	10 (1)	1	5			19 (2)
6–24 mo	1 (1)	15	1	3	2		22 (1)
2–15 yr	11 (2)	17	18 (2)	2 (2)		2	50 (6)
15–30 yr	8 (3)	17 (1)	6 (1)	5 (1)	1	(1)	37 (7)
>30 yr	1	15 (1)	9	10 (1)	1	4	40 (2)
Total	30 (7)	79 (7)	35 (3)	26 (4)	5	6 (1)	181 (22)

[a] Figures in parentheses represent the initially unsuccessful operations.

after a surgically successful ETV. Ventriculostomies were presumed to have failed when a shunt was inserted, when the ETV was revised, or when the patient died as a result of proven hydrocephalus.

Comparisons

The following were factors investigated as covariates for statistical analysis: age at the time of ETV, the pathogenesis of hydrocephalus, the individual surgeon, and the history of previous shunt insertion or shunt infection. Further factors included the previous number of ETV cases performed at this institution and by the individual surgeon at this institution.

Statistical Methods

Statistical analysis was performed by use of bayesian methods and Gibbs sampling methods using the software package Winbugs, version 1.4 (45). The age of the patients and the previous number of ETV cases (surgical experience) were used as covariates after logarithmic transformation because their distributions were skewed to the right. The success of ETV was analyzed by use of a logistic regression model using a hierarchical normal distribution for the effects of the individual surgeon and the diagnosis. The analysis of reliability was performed by use of a log-normal survival analysis model. Patients without ETV failure were treated as censored observations at the time of last follow-up. A latent variable approach was used for the censored failure times. We attempted a Weibull model, but this fitted the data poorly because of the proportion with long-term cure. A hierarchical normal distribution was used for the effects of the diagnosis. Statistical associations were assessed by the posterior distribution of regression coefficients. Categorical factors were assessed for statistical association by simulating multiple similar models with random ordering of the categorical factor. The likelihood of the model with the observed data was compared with the distribution of likelihood of the model with simulated data. After statistical significance had been assessed, age was categorized into groups that we thought would be most clinically useful for expressing results and predictive modeling (see *Figs. 1* and *4* below). For this purpose, age was modeled as a categorical factor with a hierarchical normal distribution.

RESULTS

Surgical Success

The overall probability of successfully performing an ETV was 89% (95% confidence interval [CI], 84–93%). There was no support for an association between the operative success of the surgery and the following factors: the age of the patient, the experience of the surgeon, the technique used, and the diagnosis of the patient. There was support for an association between the individual operating surgeon and the success of the operation ($P = 0.078$; the estimated odds ratios for success for individual surgeons ranged from 0.44 to 1.47 relative to a mean of 1.0). The surgical success and the numbers of cases for the individual surgeons were 100% (n = 2), 87% (n = 75), 95% (n = 39), 89% (n = 44), 100% (n = 1), 90% (n = 10), 25% (n = 4), and 96% (n = 28). Technical factors that prevented successful operation included hemorrhage, toughened ventricular floor, and anatomic abnormalities such as interthalamic fusions before preoperative use of MRI.

Analysis of Long-term Reliability

The reliability of ETV is shown in *Figure 1*, stratified according to age groups. Age was very strongly associated with reliability. The coefficient describing the linear relationship between the logarithm of the age in months and the logarithm of the survival in years was 0.81 (95% CI, 0.52–1.14). The reliability is shown in *Figures 2* and *3*, stratified according to diagnostic groups. The reliability of ETV for the 0- to 1-month age group was so low that we could not meaningfully examine this group stratified according to diagnosis. The longest observed reliability for this group was 3 years. There was no statistical support for an association between reliability and the diagnostic group (n = 181, $P = 0.168$) or having a previous shunt insertion (coefficient for the effect of previous shunt on the logarithm of the reliability in years was 0.12 [95% CI, −1.4 to 1.6]). The predicted reliability of ETV is shown in *Figure 4*. The statistical model predicted the following reliability at 1 year after insertion: at 0 to 1 month of age, 31% (95% CI, 14–53%); at 1 to 6 months of age, 50% (95% CI, 32–68%); at 6 to 24 months of age, 71% (95% CI, 55–85%); and at more than 24 months, 84% (95% CI, 79–89%) (*Fig. 4*).

Kaplan-Meier plots of ETV reliability, shown in *Figure 3*, indicate some effects of diagnosis on the pattern of reliability. Adults with infection/hemorrhage have a high immediate and short-term failure rate of 40%. After this, the reliability was very high. The remaining diagnoses, in contrast, had a higher late failure rate. Despite these differences, there were no overall conventionally statistically significant differences among the diagnostic groups.

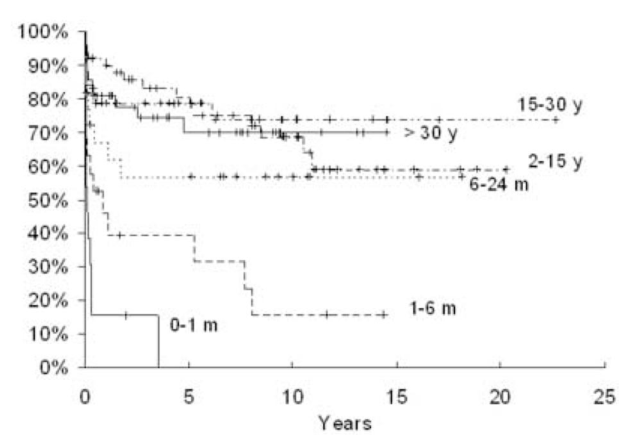

FIGURE 1. *Kaplan-Meier plots of the reliability of 181 surgically successful ETV procedures stratified according to age groups.* Cross points *represent censored observations.*

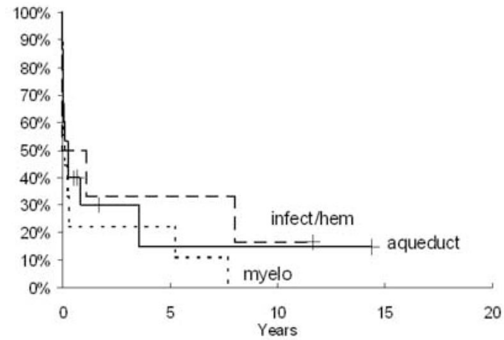

FIGURE 2. *Kaplan-Meier plots of the reliability of ETV procedures for patients age 0 to 6 months stratified according to diagnostic group. One patient with arachnoid cyst and one with tumor are omitted for clarity.* myelo, *myelomeningocele;* infect/hem, *infection and hemorrhage;* aqueduct, *aqueduct stenosis.* Cross points *represent censored observations.*

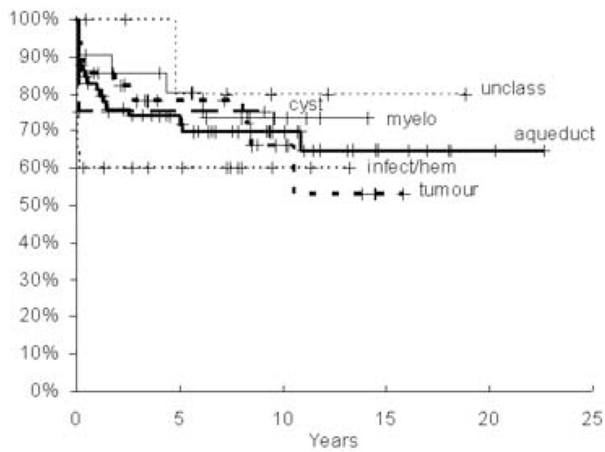

FIGURE 3. *Kaplan-Meier plots of the reliability of ETV procedures for patients more than 6 months old stratified according to diagnostic group.* myelo, *myelomeningocele;* infect/hem, *infection and hemorrhage;* aqueduct, *aqueduct stenosis;* cyst, *arachnoid cyst;* unclass, *unclassified.* Cross points *represent censored observations.*

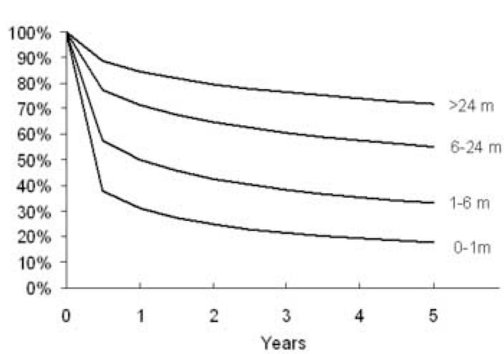

FIGURE 4. *Model predictions for the effect of selected ages on the reliability of ETV. Confidence limits at 1 year are provided in the text.*

Shunts were left in place in 16 of the 181 patients with successfully performed ETVs. The shunt valves used were Heyer-Schulte (NeuroCare Group, Pleasant Prairie, WI) with an antisiphon device (Portnoy's; AV Integra Neurosciences, Plainsboro, NJ) that was clinically obstructed at the time of ETV. In two of these patients, the ETV failed, and new shunts were placed. Two more patients had postoperative infection, and the shunts were removed without ETV revision becoming necessary.

Revision ETV

Sixteen patients had ETV procedures repeated. Seven were performed between 3 days and 3 months after the initial procedure. Five of these failed within 2 weeks, and the remaining 2 provided long-term treatment. The remaining 9 repeat procedures were performed at least 6 months after the initial procedure. The reliability of these procedures is shown in *Figure 5*. Four procedures failed within a few weeks, and 2 were available for long-term follow-up.

Complications

There were five cases of intraoperative bleeding that settled with irrigation. Of these five cases, four failed at less than 6 weeks and the other at 3 years, 7 months. There were nine cases of postoperative infection, of which one ventriculostomy remained patent, whereas the remainder failed at 7, 8, and 15 days; 1, 2, and 7 months; and 3 and 8 years, respectively. Of these nine patients, four had previous shunts, two of which were removed at ETV, and two were tied off. There were two major and permanent complications. A 61-year-old patient with hydrocephalus from meningitis developed hemiparesis; ataxia and diplopia after the endoscope traumatized the midbrain. A 45-year-old woman sustained a traumatic basilar aneurysm with rupture caused by the endoscope. The aneurysm was successfully clipped, but the patient was permanently cognitively impaired.

Deaths

There was one ETV-related death. A boy with congenital hydrocephalus had a shunt inserted as a neonate. At 4 years of

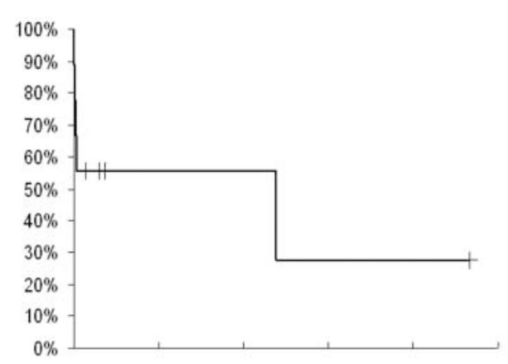

FIGURE 5. *Kaplan-Meier plot of the reliability of repeat ETV procedures performed more than 6 months after the initial procedure.* Cross points *represent censored observations.*

age, he had an ETV. He was subsequently well for 5 years. He became suddenly drowsy and then unconscious before presenting to a peripheral hospital, where resuscitation failed. Autopsy confirmed that death was caused by acute hydrocephalus and failure of the ventriculostomy. There were six unrelated deaths, including two patients with acute subarachnoid hemorrhage.

DISCUSSION

Main Findings

We performed a long-term follow-up study of ETV. The main findings were that the overall probability of operative success was 89%, but this tended to be influenced by the individual surgeon. Thereafter, reliability was strongly dependent on age. At less than 1 month of age, the maximum reliability we observed was 3 years. The proportions of patients presumed to have a functioning ETV after 5 years were 41% at age 1 to 6 months, 58% at age 6 to 24 months, and above 70% for ages greater than 24 months. The following factors did not have a clinically significant or observable influence on reliability: a previous history of shunt insertion or intraoperative shunt removal, previous shunt infection, surgeon, or the pathogenesis of hydrocephalus. After 203 patients, the rate of transient major complications was 7.2%, and the rate of permanent major complications was 1%. One ETV-related death was recorded from a presumed late acute hydrocephalus.

Study Limitations

Our study was subject to several limitations inherent in a retrospective study. The selection criteria for the operation were not rigidly applied in a prospective manner. There are no data on the patients with hydrocephalus who were not treated with ETV. The selection criteria for ETV at our institution changed over time by a gradual evolution. Deviations from blunt operative technique were not reliably recorded. We used revision surgery or placement of a shunt as outcomes for reliability. A well-designed prospective study will use functional outcome measures assessed both before and after surgery.

Only 89 of the 181 patients with initially successful procedures had postoperative MRI of their ventriculostomies. The remainder were clinically successful. MRI demonstration of aqueduct flow voids or resolving ventriculomegaly does not always mean a good clinical outcome (9, 42). Some patients with large ventricles improve, and some patients with smaller ventricles do not. Some of the patients with apparently successful ETV may have become independent of their ventriculostomies by resolution of their hydrocephalus. Examples of this include treatment of benign tumors or arachnoid cysts. These cases may have biased the estimation of reliability.

Shunts were left in place in 16 of the 181 successfully performed ETVs. Two of these were removed because of infection without ETV revision being necessary. The remaining 14 patients may have had a functioning shunt despite clinical and radiological signs of hydrocephalus from a blocked shunt. The clinical condition of these patients improved with ETV, so it is unlikely that ETV reliability was confounded by functioning shunts.

Our series included only a small number of ETV revisions. Revision ETV performed within 3 months failed in five patients (70%). Only nine revisions were performed after more than 6 months (*Fig. 5*).

Despite these limitations, this study includes some of the earliest patients to receive ETV (as early as 1979). This study is a large consecutive series with a long follow-up period (up to 22.6 yr), and it includes a range of ages and diagnoses. Finally, we have provided statistical modeling for the predicted long-term reliability for selected ages (*Fig. 4*).

ETV Reliability

We observed success rates at 5 years of between 58 and 78%. This is similar to the findings in the few studies that attempted survival analysis in which there were reported patency rates of 75% at 1 year (mean follow-up, 24 mo) in 58 patients (13), 80% at 3.1-year mean follow-up in 63 patients (7), 72% at 6 years in 213 children (no failures after 5 yr) (11), 61.7% at 5.3 years in 89 patients (40% of failures at 2 wk, 40% between 2 wk and 10 mo, and 10% after 6 mo) (14), and 56% at 3.5 years in 32 patients (43). A further group of studies, without formal survival analysis, demonstrated similar success rates of 78% at 6 months, declining to 50% at 12 months in 64 patients (42), and 71.3% in 150 patients over 8 years (17).

It is clear that 20 to 30% of ETVs fail within the first few years (5, 9, 11, 20). Our results in *Figures 1* and *3* show that beyond this, ETV reliability plateaus to between 60 and 75% in the long term. Clinical follow-up over the first few postoperative years is important.

It has been suggested that early failures may result from failure of CSF absorption despite a patent stoma (5, 7, 42). Other explanations have been offered, including inadequate size of the initial fenestration (7), unnoticed second membranes (9), reduced flow through the stoma (20), subsequent closure of the fenestration (7, 44), bleeding around the ventriculostomy site (10), increased concentration of protein and fibrinogen (20), infection causing obliteration of CSF pathways (14), and finally, in some patients, progression of tumor to block the ETV (7). Routine performance of postoperative MRI scans may have shown the cause of some of our early failures.

Delayed failures have been attributed to obstruction of the third ventriculostomy stoma by gliotic tissue, arachnoid membrane, or reduced resistance to CSF absorption in the ventricular system compared with the subarachnoid space leading to increased transependymal absorption (5, 42). Nevertheless, it is still not clear why some patients with patent ventriculostomies exhibit deterioration after months of control of hydrocephalus (42).

Early failures were more common in children, particularly those less than 6 months old (*Fig. 1*). It has been suggested that these patients have immature and poorly functioning arachnoid granulations (23). It has also been suggested that adults can generate higher pressure gradients to overcome higher resistance at the arachnoid granulations (7, 29). The reliability of ETV can be difficult to assess in children less than 6 months old, who may continue to have an increasing head circumference before eventually stabilizing.

For patients between 6 and 24 months old, 58% of the ETV remained effective at 5 years of age. This contrasts with other reports that ETV was unlikely to be successful for patients younger than 2 years (10, 19, 20, 25, 28, 37), and particularly those younger than 1 year (20, 26, 27, 34). However, one recent study on 36 patients younger than 1 year of age reports a 64% success rate, with a mean follow-up of 47.4 months (15). It has also been reported that ETV can be successful in patients younger than 2 years of age, but only with careful assessment and selection (principally exclusion of intraventricular hemorrhage) (2, 9, 11, 12, 16, 21). In our study, excluding patients with previous hemorrhage would not have improved outcomes for these young patients.

We did not find that ETV was more successful or reliable in any particular diagnostic group. We expected poor reliability for ETV in patients with hydrocephalus from infection or hemorrhage (10, 12, 34, 37, 38). We could not show this statistically, but this group did seem to have more early failures. Even so, the reliability was 60% after 10 years. This was similar to the 10-year long-term success rate of 64.3% after infection and 60.9% after hemorrhage described by Siomin et al. (38). Previous shunt insertion and malfunction did not affect reliability in our study. This is similar to previously reported observations (4, 20, 38).

Other studies have described increased long-term success for patients with late-onset idiopathic or acquired CSF obstruction (14, 34). Factors previously associated with poor long-term success but not apparent in our study include the following: an infected shunt at presentation, a history of shunt infection, a history of three or more shunt revisions, preexisting Chiari malformation, and postoperative meningitis (5, 12, 14, 42). Although we selected patients who were likely to have obstructive hydrocephalus, obstructions may be subtle or incomplete. The dichotomy based on obstruction may not be appropriate in all patients.

Myelomeningocele

Patients with myelomeningocele did not have lower success rates than other diagnostic groups in our study (*Fig. 3*). When these patients have previous shunts and are more than 6 months of age, success rates of 63 to 92% have been described (32, 40). In contrast, reduced success has also been described for these patients (10). We previously reported a reduced success with myelomeningocele among patients less than 6 months old, but this difference was not observed in the larger current series (23). Anatomic abnormalities such as interthalamic fusions were an occasional cause of operative failures in the period before preoperative MRI was used. We did not specifically investigate the association between anatomic abnormalities and the selection of patients and the success of ETV.

Revision ETV

There were only nine patients who had ETV repeated at least 6 months after a previous ETV. For up to 4 years, the reliability was 58%. This is similar to the success rate of 65% at a median of 20 months of follow-up described by Siomin et al. (39). ETV revision may still be successful after a late failure.

Operation Technique

Blunt perforation of the ventricular floor was routinely used for the 203 ETV procedures in this study, although the perforation technique was not always recorded. There were two major hemorrhagic complications. These were a subarachnoid hemorrhage and a subdural hemorrhage at the entry site. Specific treatment was not required for these hemorrhages. Blunt perforation has been associated with fewer complications than sharp perforation (5, 44). Sharp perforation has been a factor in vascular complications, including fatal and nonfatal subarachnoid hemorrhage, cerebral infarction, and subdural hemorrhages (1, 3, 6, 28, 31, 36, 44). Although blunt perforation is less likely to injure blood vessels below the ventricular floor, increased traction on the lateral walls of the third ventricle may cause transient hypothalamic complications (41).

Failure to achieve perforation occurred in 9.3% of operations in this study. Most studies do not describe this proportion. Failure rates of 1 to 3% have been described, and one study reported 26% (5, 10, 20, 35). Reasons for failure include excessive blood loss or hematoma, thickening of the ventricle floor preventing fenestration, or unfavorable anatomy (5, 10, 20). In this study, the operating surgeon was detected statistically as a preoperative factor influencing success. Although the cases were not randomly distributed, this suggests that training and skill are important factors that are not overcome by individual or institutional previous experience with the procedure.

Complications and Deaths

Infections occurred in nine (4.9%) of the ETV operations. Of these, four had previous shunts that were revised at the same time. Revision of an existing shunt may have been a risk factor for infection, although there were not enough patients to examine this association statistically. In this study, there was one death as a result of delayed failure of ETV. Deaths as a result of this cause have been reported after 4 and 8 months and 2, 3, and 7 years (18, 22). Placement of a ventricular catheter attached to a subcutaneous reservoir may reduce this risk (30). We did not observe any deaths related to the procedure, but mortality rates of 1 to 5% have been observed in other series (7, 11, 35)

Clinical Implications

Age was the most important factor influencing the outcome of ETV. Patients less than 6 months of age have low reliability, but this must be balanced with the expected outcome of ventricular shunts (11). Patients less than 6 months old and patients with revision ETV should be followed up closely. We found a low complication rate associated with the predominant use of blunt perforation of the ventricle floor, but our major and permanent complications were associated with trauma caused by the endoscope itself.

Further Research

In future studies, MRI scans and CSF flow studies performed before and after operation and when the ETV fails will provide useful information on the mechanism for ETV failure. In turn, this will enable better patient selection. Further observational studies will define which subgroups of hydrocephalus patients should be selected to compare ETV with ventricular shunts in controlled trials.

REFERENCES

1. Abtin K, Thompson BG, Walker ML: Basilar artery perforation as a complication of endoscopic third ventriculostomy. **Pediatr Neurosurg** 28:35–41, 1998.
2. Beems T, Grotenhuis JA: Is the success rate of endoscopic third ventriculostomy age dependent: An analysis of the results of endoscopic third ventriculostomy in young children. **Childs Nerv Syst** 18:605–608, 2002.
3. Beni-Adani L, Siomin V, Segev Y, Beni S, Constantini S: Increasing chronic subdural hematoma after endoscopic third ventriculostomy. **Childs Nerv Syst** 16:402–405, 2000.
4. Boschert J, Hellwig D, Krauss JK: Endoscopic third ventriculostomy for shunt dysfunction in occlusive hydrocephalus: Long-term follow up and review. **J Neurosurg** 98:1032–1039, 2003.
5. Brockmeyer D, Abtin K, Carey L, Walker ML: Endoscopic third ventriculostomy: An outcome analysis. **Pediatr Neurosurg** 28:236–240, 1998.
6. Buxton N, Punt J: Cerebral infarction after neuroendoscopic third ventriculostomy: Case report. **Neurosurgery** 46:999–1001, 2000.
7. Buxton N, Ho KJ, Macarthur D, Vloeberghs M, Punt J, Robertson I: Neuroendoscopic third ventriculostomy for hydrocephalus in adults: Report of a single unit's experience with 63 cases. **Surg Neurol** 55:74–78, 2001.
8. Buxton N, Macarthur D, Mallucci C, Punt J, Vloeberghs M: Neuroendoscopic third ventriculostomy in patients less than 1 year old. **Pediatr Neurosurg** 29:73–76, 1998.
9. Buxton N, Vloeberghs M, Punt J: Liliequist's membrane in minimally invasive endoscopic neurosurgery. **Clin Anat** 11:187–190, 1998.
10. Choi JU, Kim DS, Lim SH: Endoscopic surgery for obstructive hydrocephalus. **Yonsei Med J** 40:600–607, 1999.
11. Cinalli G, Saint-Rose C, Chumas P, Zerah M, Brunelle F, Lot G, Pierre-Kahn A, Renier D: Failure of third ventriculostomy in the treatment of aqueductal stenosis in children. **J Neurosurg** 90:448–454, 1999.
12. Elbabaa S, Steinmetz M, Ross J, Moon D, Luciano M: Endoscopic third ventriculostomy for obstructive hydrocephalus in the pediatric population: Evaluation of outcome. **Eur J Pediatr Surg** 11[Supp 1]:S52–S54, 2001.
13. Feng H, Huang G, Liao X, Fu K, Tan H, Pu H, Cheng Y, Liu W, Zhao D: Endoscopic third ventriculostomy in the management of obstructive hydrocephalus: An outcome analysis. **J Neurosurg** 100:626–633, 2004.
14. Fukuhara T, Vorster SJ, Luciano MG: Risk factors for failure of endoscopic third ventriculostomy for obstructive hydrocephalus. **Neurosurgery** 46:1100–1111, 2000.
15. Gorayeb RP, Cavalheiro S, Zymberg ST: Endoscopic third ventriculostomy in children younger than 1 year of age. **J Neurosurg Spine** 100:427–429, 2004.
16. Grant JA, McLone DG: Third ventriculostomy: A review. **Surg Neurol** 47:210–212, 1997.
17. Grunert P, Charalampaki P, Hopf N, Filippi R: The role of third ventriculostomy in the management of obstructive hydrocephalus. **Minim Invasive Neurosurg** 46:16–21, 2003.
18. Hader WJ, Drake J, Cochrane D, Sparrow O, Johnson ES, Kestle J: Death after late failure of third ventriculostomy in children: Report of three cases. **J Neurosurg** 97:211–215, 2002.
19. Hirsch JF, Hirsch E, Saint-Rose C, Renier D, Pierre-Khan A: Stenosis of the aqueduct of Sylvius: Etiology and treatment. **J Neurosurg Sci** 30:29–39, 1986.
20. Hopf N, Grunert P, Fries G, Klaus, Resch K, Perneczky A: Endoscopic third ventriculostomy: Outcome analysis of 100 consecutive procedures. **Neurosurgery** 44:795–804, 1999.
21. Javadpour M, Mallucci C, Brodbelt A, Golash A, May P: The impact of endoscopic third ventriculostomy on the management of newly diagnosed hydrocephalus in infants. **Pediatr Neurosurg** 35:131–135, 2001.
22. Javadpour M, May P, Mallucci C: Sudden death secondary to delayed closure of endoscopic third ventriculostomy. **Br J Neurosurg** 17:266–269, 2003.
23. Jones RF, Kwok BC, Stening WA, Vonau M: The current status of endoscopic third ventriculostomy in the management of non-communicating hydrocephalus. **Minim Invasive Neurosurg** 37:28–36, 1994.
24. Jones RF, Kwok BC, Stening WA, Vonau M: Neuroendoscopic third ventriculostomy: A practical alternative to extracranial shunts in non-communicating hydrocephalus. **Acta Neurochir (Wien) Suppl** 6:79–83, 1994.
25. Kamikawa S, Inui A, Kobayashi N, Kuwamura K, Kasuga M, Yamadori T, Tamaki N: Endoscopic treatment of hydrocephalus in children: A controlled study using newly developed Yamadori-type ventriculoscopes. **Minim Invasive Neurosurg** 44:25–30, 2001.
26. Kim SK, Wang KC, Cho BK: Surgical outcome of pediatric hydrocephalus treated by endoscopic third ventriculostomy: Prognostic factors and interpretation of postoperative neuroimaging. **Childs Nerv Syst** 16:161–168, 2000.
27. Koch D, Wagner W: Endoscopic third ventriculostomy in infants of less than 1 year of age: Which factors influence the outcome? **Childs Nerv Syst** 20:405–411, 2004.
28. McLaughlin M, Wahlig J, Kaufan A, Albright A: Traumatic basilar aneurysm after endoscopic third ventriculostomy: Case report. **Neurosurgery** 41:1400–1404, 1997.
29. Milhorat TH: Hydrocephalus: Pathophysiology and clinical features, in Wilkins RH, Rengachary SS (eds): *Neurosurgery*. London, McGraw-Hill, 1996, ed 2, pp 3625–3631.
30. Mobbs RJ, Vonau M, Davies M: Death after late failure of endoscopic third ventriculostomy: A potential solution. **Neurosurgery** 53:384–386, 2003.
31. Mohanty A, Anandh B, Reddy MS, Sastry KV: Contralateral massive acute subdural collection after endoscopic third ventriculostomy. **Minim Invasive Neurosurg** 40:59–61, 1997.
32. Natelson SE: Early third ventriculostomy in myelomeningocele infants: Shunt independence. **Childs Brain** 8:321–325, 1981.
33. Saint-Rose C, Chumas P: Endoscopic third ventriculostomy. **Tech Neurosurg** 1:176–184, 1995.
34. Scarrow AM, Levy EI, Pascucci L, Albright AL: Outcome analysis of endoscopic III ventriculostomy. **Childs Nerv Syst** 16:442–444, 2000.
35. Schroeder HW, Niendorf WR, Gaab MR: Complications of endoscopic third ventriculostomy. **J Neurosurg** 96:1032–1040, 2002.
36. Schroeder HW, Warzok RW, Assaf JA, Gaab MR: Fatal subarachnoid hemorrhage after endoscopic third ventriculostomy. **J Neurosurg** 90:153–155, 1999.
37. Schwartz TH, Yoon SS, Cutruzzola FW, Goodman RR: Third ventriculostomy: Postoperative size and outcome. **Minim Invasive Neurosurg** 39:122–129, 1996.
38. Siomin V, Cinalli G, Grotenhuis A, Golash A, Oi S, Kothbauer K, Weiner H, Roth J, Beni-Adani L, Pierre-Kahn A, Takahashi Y, Mallucci C, Abbott R, Wisoff J, Constantini S: Endoscopic third ventriculostomy in patients with cerebrospinal fluid infection and/or haemorrhage. **J Neurosurg** 97:519–524, 2002.
39. Siomin V, Weiner H, Wisoff J, Cinalli G, Pierre-Kahn A, Saint-Rose C, Abbott R, Elran H, Beni-Adani L, Ouaknine G, Constantini S: Repeat endoscopic third ventriculostomy: Is it worth trying? **Childs Nerv Syst** 17:551–555, 2001.
40. Teo C, Jones R: Management of hydrocephalus by endoscopic third ventriculostomy in patients with myelomeningocele. **Pediatr Neurosurg** 25:57–63, 1996.
41. Teo C, Rahman S, Boop FA, Cherny B: Complication of endoscopic neurosurgery. **Childs Nerv Syst** 12:248–253, 1996.
42. Tisell M, Almstrom O, Stephenson H, Tullberg M, Wikkelson C: How effective is endoscopic third ventriculostomy in treating adult hydrocephalus caused by primary aqueductal stenosis? **Neurosurgery** 46:104–109, 2000.

43. Tuli S, Alshail E, Drake J: Third ventriculostomy versus cerebrospinal fluid shunt as a first procedure in paediatric hydrocephalus. **Pediatr Neurosurg** 30:11–16, 1999.
44. Walker ML, Petronio J, Carey CM: Ventriculostomy, in Cheek WR, Marlin AE, McLone DG, Reigel DH, Walker ML (eds): *Paediatric Neurosurgery*. Philadelphia, W.B. Saunders Co., 1994, pp 572–581.
45. http://www.mrc-bsu.cam.ac.uk/bugs. Accessed 4/7/05.

COMMENTS

This is a retrospective review of 203 patients who underwent endoscopic third ventriculostomy (ETV) at a single institution over a 23-year period. The patients had a wide range of ages, ranging from neonates to 78 years, and came from a wide range of etiologies. Inability to surgically create the ventriculostomy was uncommon; 89% were successful. Long-term success (reliability, as termed by the authors) was a function of age, increasing from 31% in neonates younger than 1 month to 84% in patients older than 24 months. There was some variability among the success rates of the individual surgeons, but the authors were unable to find any effect of etiology or the presence of a previous shunt on long-term outcome. Sixteen patients had repeat ETV (nine, four of which failed after 6 months). In terms of complications there was a 4.9% infection rate, the rate of transient major complications was 7.2%, and the rate of permanent major complications was 1%. There was one delayed death from acute hydrocephalus 5 years after the procedure.

Although this is a retrospective review, it is well conducted. The authors use appropriate statistical techniques which they describe along with a discussion of the shortcomings of the study. The effect of age is very interesting, as is the absence of any effect of etiology. These findings are at odds with other retrospective studies, which suffer from the same limitations (i.e., limited numbers of patients operated on over a prolonged time period). Multi-center and prospective studies would sort the issues of age and etiology which relate very much to patient selection and outcome.

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This is one of the largest series of ETVs reported with the longest follow-up period. The results reported are better than those reported by others regarding long-term functioning of the ETV. The major findings of the study were that, with triventricular hydrocephalus (radiographic obstruction at the aqueduct), the etiology of the hydrocephalus did not really predict success, and that age was a major predictor, an age less than 24 months at the time of the procedure carried a relatively poor success rate, and an age of under 6 months a much lower success rate. The procedure had some major complications, but these only occurred in 3 out of the 203 patients.

Our experience with this technique is not as favorable as that reported here. It is also difficult at times to determine when success has been achieved, because imaging after this procedure often shows little or no decrease in ventricular size. Until these excellent results can be achieved by others, I fear that shunts will remain an important component of pediatric neurosurgical practice.

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Kadrian et al. describe the long-term reliability of ETV for the treatment of hydrocephalus. To examine the influence of diagnosis, age, and previous shunt history on the reliability of ETV, the authors retrospectively analyzed 203 consecutive patients who were treated over a period of 22.6 years. Patients presented with hydrocephalus from aqueductal stenosis, myelomeningocele, tumors, arachnoid cysts, previous infection, or hemorrhage.

The overall probability of successfully performing an ETV was 89% (84 to 93%). There was support for an association between the surgical success and the individual operating surgeon. Patient age was also associated with reliability. They conclude that age was the only factor statistically associated with the long-term reliability of ETV.

I always have difficulty understanding why abnormalities of cerebrospinal fluid circulation which result in reduced reabsorption of cerebrospinal fluid would respond to ETV. It is obvious why ETV would work in cases of true obstruction. Despite this, an ever-growing literature is suggesting the contrary in certain scenarios. The inclusion of age as a significant variable further contributes to our understanding on how to manage hydrocephalus (obstructive or others), while clarifying an additional reason that patients with reduced reabsorption of cerebrospinal fluid may be candidates for ETV.

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