Long-term results of endoscopic third ventriculostomy: an outcome analysis

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OBJECT Endoscopic third ventriculostomy (ETV) is the procedure of choice in the treatment of obstructive hydrocephalus. The excellent clinical and radiological success rates are well known. Nevertheless, very few papers have addressed the very long term outcomes of the procedure in very large series. The authors present a large case series of 113 patients who underwent 126 ETVs, and they highlight the initial postoperative outcome after 3 months and long-term follow-up with an average of 7 years.

METHODS All patients who underwent ETV at the Department of Neurosurgery, Mainz University Hospital, between 1993 and 1999 were evaluated. Obstructive hydrocephalus was the causative pathology in all cases.

RESULTS The initial clinical success rate was 82% and decreased slightly to 78% during long-term follow-up. Long-term success was analyzed using Kaplan-Meier curves. Overall, ETV failed in 31 patients. These patients underwent a second ETV or shunt treatment. A positive impact on long-term success was seen for age older than 6 months, and for obstruction due to cysts or benign aqueductal stenosis. The complication rate was 9% with 5 intraoperative and 5 postoperative events.

CONCLUSIONS The high clinical success rate in short-term and long-term follow-up confirms ETV’s status as the gold standard for the treatment of obstructive hydrocephalus, especially for distinct pathologies. The patient’s age and underlying pathology may influence the outcome. These factors should be considered carefully preoperatively by the surgeon.

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KEY WORDS endoscopic third ventriculostomy; hydrocephalus; long-term results; brain; neuroendoscopy

The technique of endoscopic third ventriculostomy (ETV) has been under close evaluation as a treatment option for obstructive hydrocephalus. Although early on the procedure was associated with a very high, unacceptable complication rate, more recent publications have reported success rates of about 70% and low complication rates, including mortality, around 0.5%–1.0%. Nowadays, ETV is accepted as the gold standard for treatment of obstructive hydrocephalus. In comparison with ventriculoperitoneal shunting, a significantly lower complication rate and reoperation rate in the long term is expected. Nevertheless, topics such as the prediction of ETV success, period of highest failure rate, and late deterioration after ETV are still topics of discussion. However, current data are scarce, and the long-term efficacy of ETV is often under debate, since most studies have reported a rather short follow-up period, e.g., 8 months or a few years. Very few studies exist with a significantly longer follow-up, e.g., 4 years. This study investigates very long term success rates, up to 16 years, and the incidence of failures in the early and long-term postoperative periods after ETV.

Methods

Study Design

The long-term outcome of ETV was evaluated through a retrospective analysis of all patients who underwent an
ETV procedure at the Department of Neurosurgery at Mainz University Hospital between 1993 and 1999. ETV had been introduced to this department and was further developed under the guidance of its former chairman, Prof. Dr. Axel Perneczky (1946–2008). An initial presentation of a portion of the patients in this study has been performed earlier. Inclusion criteria for the present study were complete patient records, including preoperative history and evaluation, preoperative CT or MRI images, detailed surgical records, and postsurgical follow-up data. After data collection was complete, all patients were contacted for a final follow-up interview via telephone or post mail. The questionnaire contained detailed questions concerning current complaints and clinical symptoms.

Surgical Technique
The applied surgical technique was determined by analysis of the surgical records, video recordings, and pre- and postoperative imaging studies. During the observation period from 1993 to 1999, there was no significant evolution of the surgical technique. For a detailed description of the technique, please refer to Hopf et al. or Grunert et al. In 23 early ETVs, frame-based stereotactic guidance was used; later, the surgical technique slightly changed and ETVs were performed using frameless navigation and then freehand. This change in surgical technique occurred in accordance with the growing experience of the surgeons, standard entry points, and defined anatomical landmarks.

Clinical Evaluation
The following patient characteristics were analyzed: clinical symptoms (including alteration of consciousness), age, sex, etiology of hydrocephalus, prior surgical procedures, intraoperative complications, postoperative complications, postoperative improvement, subsequent shunting, and additional ventriculostomy. ETV was considered successful when no other procedure followed and the patient remained alive. Initial success of ETV was evaluated after 3 months. The long-term success of ETV was analyzed with the aid of Kaplan-Meier curves. Etiology of hydrocephalus, age at the time of surgery, and prior shunting procedures were investigated as potential influential factors. Results of re-ETVs were evaluated separately.

Statistical Analysis
The long-term success was analyzed using Kaplan-Meier curves. The impact of distinct influencing factors was calculated using the log-rank test. An explorative analysis with a descriptive observation of the p values was performed using SPSS 17 statistics (SPSS Inc.).

Results
Patient Collective
One hundred fifty patients underwent ETV between April 1993 and November 1999. Of these 150 patients, 37 were excluded because of incomplete data. One hundred thirteen patients (58 males, 55 females; mean age 35 years, age range 8 days to 77 years) who underwent a total of 126 ETV procedures were evaluated in this study. One-third of the patients were children; therefore, this was a mixed population. Twenty-nine patients presented with shunt malfunction and/or had a history of previous shunt revisions. These 29 patients were shunt dependent for 3–291 months prior to ETV (median 48 months, mean 77 months). Table 1 provides a detailed overview of the patient characteristics and distribution of underlying etiologies. Preoperative symptoms mainly consisted of cephalgia (61%), gait ataxia (47%), and nausea/vomiting (40%). A preoperative decrease in consciousness was observed in 18 patients (16%) with 11 patients being somnolent, 4 being soporous, and 3 being comatose. Preoperative symptoms are detailed in Table 2.

Complications
Intra- and postoperative complications occurred in 10 procedures (8%). In 5 (4%), an intraoperative complication occurred: 2 injuries of the thalamostriate vein, 2 intraventricular hemorrhages without identification of their origin, and 1 intermittent paroxysmal tachyarrhythmia during surgery.

Intraoperative bleeding was controlled with prolonged irrigation. In cases of intraoperative bleeding, an external ventricular drain was inserted. The intermittent paroxysmal tachyarrhythmia during surgery was controlled conservatively. The procedure could be completed appropriately.

Five (4%) postoperative complications within the hospital stay were observed: 1 case each of trochlear nerve pal-
sy, bacterial meningitis, wound infection including brain abscess, phlebothrombosis, and pneumonia. All occurred within 6 days after surgery. All complications were transient. In the first 4 cases, no compromise of the long-term ETV result was identified. Only the last patient (i.e., the patient with pneumonia) suffered from ETV closure, which required reventriculostomy at 2 months after surgery.

**Early Postoperative Evaluation**

Within the hospital stay, 98 patients (87%) improved clinically. The remaining 15 patients showed unchanged or progressing clinical symptoms: 10 required shunt implantation within 5–55 days after ETV, 2 underwent another ETV (3 and 13 days after surgery), and 3 others were followed because of very mild symptoms. The decision to perform shunt implantation or re-ETV was based on the surgeon’s preference. Two patients died during the hospital stay (one of cardiac arrest and the other of tumor progression). All patients who had a preoperative decrease in consciousness improved, with 17 of 18 (94%) becoming asymptomatic.

After discharge from the hospital, 6 patients showed signs of ETV failure within the first 3 months. Five of these patients underwent shunt placement and 1 underwent reventriculostomy. Treatment for these 6 patients was again based on the surgeon’s preference. The initial success rate of primary ETV was 82% (93 of 113 procedures) within 3 months after surgery (Fig. 1). Overall, 18 patients (15.9%) suffered from early ETV failure and underwent additional surgery, whether re-ETV or shunting.

**Long-Term Evaluation**

Long-term evaluation was only performed for patients with significant ETV success within 3 months postoperatively. Eighteen patients were excluded from long-term evaluation since they suffered an early ETV failure, and 17 other patients were excluded because of incomplete or too short follow-up. Finally, 78 patients were followed up further. Follow-up time ranged from 4 months to 16 years (mean 7 years). During this period, 13 failures occurred. Based on Kaplan-Meier analysis, long-term success of ETV in this patient series was 97% after 1 year, 91% after 3 years, 82% after 5 years, and 78% after 8 years, and stayed stable until the end of long-term follow-up of 16 years (Fig. 2).

**Influence Factors on Long-Term Outcome**

The influence of etiology of hydrocephalus, age at surgery, and preoperative shunt dependence was evaluated.

Regarding the underlying pathology of obstructive hydrocephalus, intraventricular cysts were associated with the best long-term outcome with a 91% success rate after 5 years, followed by benign aqueductal stenosis with a success rate of 67%. Patients with tumors or history of infection/bleeding achieved fewer good outcomes with 56% and 46%, respectively. There was a negative impact for these etiologies after 5 years (Fig. 3).

Infants younger than 6 months had a high risk of re-closure. Four infants younger than 6 months of age underwent ETV, and 3 of these 4 infants became shunt dependent in the first 3 months. Age younger than 6 months had a significant impact (p ≤ 0.001) on the long-term ETV success. The best outcomes were seen in patients between 6 months and 2 years old (n = 4) with a success rate of 67%, followed by patients older than 18 years with a 66% success rate (n = 84). A slightly worse success rate (64%) was seen in patients between 2 years and 18 years (n = 21) (Fig. 4).

There was no statistically significant association between previous shunt implantation and long-term outcome after ETV (p = 0.403), but patients with preoperative existing shunt dependence showed a worse long-term success than patients with no history of shunt dependence (Fig. 5).

**Discussion**

ETV is the procedure of choice in the treatment of obstructive hydrocephalus. Its safety and efficacy are well known; recent literature has reported a 70%–90% success rate.13,20,23,27,31,35 These publications that have evaluated the long-term outcome of ETV have reported excellent and

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**TABLE 2. Distribution and frequency of preoperative symptoms**

<table>
<thead>
<tr>
<th>Preop Symptoms</th>
<th>No. of Cases (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cephalgia</td>
<td>69 (61)</td>
</tr>
<tr>
<td>Gait ataxia</td>
<td>53 (47)</td>
</tr>
<tr>
<td>Nausea/vomiting</td>
<td>45 (40)</td>
</tr>
<tr>
<td>Visual disturbances</td>
<td>41 (36)</td>
</tr>
<tr>
<td>Cognitive deficits</td>
<td>40 (35)</td>
</tr>
<tr>
<td>Decreased consciousness</td>
<td>16 (16)</td>
</tr>
<tr>
<td>Dizziness</td>
<td>27 (24)</td>
</tr>
<tr>
<td>Urinary incontinence</td>
<td>17 (15)</td>
</tr>
<tr>
<td>Increased head circumference</td>
<td>16 (14)</td>
</tr>
<tr>
<td>Aphasia</td>
<td>10 (9)</td>
</tr>
</tbody>
</table>

**Fig. 1.** Kaplan-Meier curve showing the initial success rate of primary ETV scored 93 of 113 procedures (82%) within 3 months after surgery. There were 18 early failures of ETV within the first 3 months. Figure is available in color online only.
stable ETV success rates after several years and favor this technique as the procedure of choice, as shunt procedures are associated with higher complication and reoperation rates. The goal of this study was to add further data about the very long term outcome, behavior of ETV failure over time, and the possible role of known factors and their impact on the long-term success.

ETV was considered successful when clinical success was seen after 3 months postoperatively without the need for re-ETV or shunting. Initial success reached 82% after 3 months and was in agreement with current literature that reports success rates of 61% up to 87%. The success rate seems to be influenced by patient age and etiology of hydrocephalus. Siomin et al. reported a reduced success rate of 61% in a series of patients with infection or hemorrhage as the cause of hydrocephalus. Other authors such as Sacko et al. and senior author Oertel previously reported similar findings. Our data in this series and the resulting success rates are in agreement with other reported “mixed” populations with different ages and underlying pathologies. Most ETV failures and worse long-term outcomes occur in patients with pathologies such as hemorrhage or bleeding that are not ideally treated with ETV.

In our opinion, the postoperative time range after which an ETV is considered successful is very important. We chose a time interval of 3 months and found that the majority of ETV failures (58%) happened within this short interval, as already reported by other authors. Feng et al. reported that 75% of all failures occur in the first 6 months; Sacko et al. saw 97% of all failures in the first 2 months and Siomin et al. reported 91% of failures in the first 3 months. Kulkarni et al. developed the ETV Success Score, which was designed for pure pediatric series to predict the 6-month success rate of ETV in hydrocephalus patients. A high ETV Success Score predicts a high chance of early ETV success. These authors found similar results with a higher initial failure rate within the first 3 months; however, over time the failure rate becomes lower. Our data are based on a mixed patient population with widespread distribution of ages and underlying pathologies but show the same behavior of ETV failure. Reasons for this early failure could be CSF hyporesorption after surgical CSF intervention, with fundamental changes in this liquid system.

ETV success can be delayed in the early postoperative period, and ETV failure could be erroneously supposed. Ventricular size after ETV could increase, decrease, or be unchanged, and is therefore a poor indicator, and it must be taken in context with clinical findings and signs of raised intracranial pressure. Potentially, it could be of value to leave an external drain after an ETV procedure for several days to overcome this initial nonspecific phase. It would be of interest to determine whether this approach reduces the early failure rate; this possibility was not analyzed in this work. In addition, there is no fixed point of time when an ETV is assumed to be completely functional. As stated above, underlying pathologies such as hemorrhage, infection, and tumor may lead to ETV failures caused by their nature themselves, with progression of tumor size, a tendency to form new membranes, and closure of stoma by gliosis and scarring. This could affect the early postoperative course or the long-term period.

There are few data concerning the long-term success of ETV. Only a few studies have regarded the postoperative course and success after a period of 3 years. As already noted, ETV malfunction happens most often in the early postoperative course, but failures may still occur after several months, even years. Some authors have reported ETV failures after 5 or 6 years. It seems to be necessary to follow the patients’ clinical course over a long period; this was our aim in this study. Our goal was to provide an overview of a large postoperative period to draw more specific conclusions regarding the long-term success of ETV and time of failures. After 18 events of early ETV failure, 13 additional failures occurred in the long term, with an average occurrence at 7 years, with the most de-
Late failure of ETV could be explained by very late reclosure of the stoma due to normal physiological conditions or infectious causes. Also possible is an intensification of hydrocephalus due to tumor growth or simple creation of arachnoid adhesions in the prepontine cisterns.

Pure long-term success (i.e., long-term outcomes with the cases of early failure removed) of ETV reached 78% and reflected established success rates in the current literature, which are reported as 60%–90%.3,6,17,35 The influence of age at the time of ETV on the long-term success should be mentioned. There are reports of low long-term success rates, e.g., 35% and 53%, in patient series comprised exclusively of children younger than 2 years. It can be stated that children younger than 2 years have lower long-term success rates.6,25,33 Again, the underlying pathology influences the long-term success rate. Etiology has almost always been discussed intensively; however, most reports involve pediatric series. A large patient series regarding children who underwent ETV was presented by Cinalli et al.6 They found an ETV success rate of 72% at 6 years with a mean follow-up period of 45.5 months. Sacko et al. reported a long-term success rate of 69% in their series of 350 patients with mixed age distribution and mixed underlying pathology, similar to our data.35

Di Rocco et al.8 displayed the success rates of ETV of selected studies5,6,14–16,21,39 with Kaplan-Meier curves to visualize the long-term success of ETV in hydrocephalus treatment of pediatric patients. The results showed homogeneous and stable rates of 70%–85% after 5 years. We have included our findings (blue curve in Fig. 6), which is in line with the current literature. Only Tuli et al.39 reported a 44% failure rate in a group of pediatric patients with obstructive hydrocephalus. This might be a product of their different definition of failure of ETV, which is defined according to the guidelines of the shunt design trial by Drake et al.11 Di Rocco et al. defined ETV failure as the need for shunt implantation. According to our findings, the Kaplan-Meier curves showed that ETV failure happens frequently within the 1st year after surgery; very few late failures have been described after the 5th year from ETV (Fig. 6).

The long-term success in our study is only insignificantly lower than the early success, which again underlines the importance of the 3-month time frame in judging the early success of ETV. The last point we want to address is the influence of preoperative shunt procedures. In this large patient series, we found no significant impact for preexisting shunt dependence on the long-term success. Reviewing the literature revealed the same results with no or minimal influence of shunt history on ETV success.3,17,23,30 Hader et al. reported a higher complication rate for patients with shunt malfunction, but with no effect on ETV success rate.19 This fact appears logical. Patients who have undergone previous shunt surgery (maybe with additional revisions) often suffer from anatomical abnormalities, such as slit ventricles, thick third ventricle floors, or tissue defects after catheter removal. On the other hand, shunt-related complications and failures in the long term are well known and are associated with high morbidity and economic disadvantages. Stone et al.38 presented a recent retrospective analysis of 64 pediatric patients treated with ventriculoperitoneal shunt and an average follow-up time of 20 years. They found that 84.5% of the patients required 1 or more shunt revisions and 4.7% required 10 or more.38 Reddy et al. presented a retrospective review of 683 adult patients with shunts and found an overall shunt failure rate of 32%.34

By this account we recommend and support the attempt of endoscopic CSF restoration in patients with shunt failure and concomitant proof of obstructive hydrocephalus. As mentioned above, there is a risk of sudden ETV failure in the long term. Therefore, a sudden unpredictable intracranial pressure increase with clinical deterioration must be kept in mind and treated immediately.

We recognize some limitations to our study. The present study has a retrospective design with a mixed population in terms of age, endoscopic treatment, and underlying pathology. The ETV success was judged retrospectively.
on the basis of clinical records. There was not always a detailed description of ETV success in the clinical records. The failures and the treatment of several failures were determined by individual surgeons.

Conclusions

ETV is an effective and safe alternative to shunt implantation for the treatment of obstructive hydrocephalus. The complication rate is moderate, and mortality rate is minimal. Even in a mixed population, excellent short-term and long-term results were achieved with thorough patient selection and sophisticated surgery. In most cases of ETV failure, the failure occurred early, within the first 3 months. Age and etiology are significant factors and predictors of surgical success. In contrast, preoperative shunt dependence had no significant impact. The results of this study with a large, mixed population and follow-up of several years confirm ETV as the procedure of choice for obstructive hydrocephalus.

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Author Contributions
Conception and design: Oertel, Vulcu. Acquisition of data: Eickele, Wagner. Analysis and interpretation of data: all authors. Drafting the article: Vulcu, Wagner. Critically revising the article: Oertel, Cinalli. Reviewed submitted version of manuscript: Oertel, Cinalli. Administrative/technical/material support: Vulcu, Wagner. Study supervision: Oertel, Vulcu, Wagner.

Supplemental Information
Previous Presentation
Portions of this work were presented in abstract form at the Jahrestagung der DGNC, June 14–16, 2013, in Leipzig, Germany, and VI World Congress of Neuroendoscopy, December 8–12, 2013 in Mumbai, India.

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