

Endoscopic third ventriculostomy for post-inflammatory hydrocephalus in pediatric patients: is it worth a try?

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Abstract Hydrocephalus is a very common disease in developing countries. Congenital aqueductal obstruction and post-inflammatory hydrocephalus come on the top of the list of causes of hydrocephalus. Till the recent introduction of cranial endoscopy and despite their frequent complications, shunts were considered as the mainstream treatment for this disease. Endoscopic third ventriculostomy (ETV), especially for obstructive hydrocephalus, introduced a new era of treatment that is free of lifetime shunt dependency. This study was done to assess the efficacy of ETV for treating post-inflammatory hydrocephalus in a unique group of patients thus preventing—if possible—the lifetime shunt dependency and suffering. ETV was tried as a first-line therapy in 35 children (23 males and 12 females) with hydrocephalus proved to be secondary to intracranial infection. Mean age was 9.2 months (4–15). Twenty-four patients (68.6 %) were below the age of 6 months while 11 patients (31.4 %) were above 6 months. Twenty-five patients (71.4 %) had a head circumference of 3 cm and 10 patients (28.6 %) had a 5 cm or more increase in the head circumference above the 95th percentile. All the patients included were followed postoperatively with regular clinical, computerized tomography (CT), and magnetic resonance imaging (MRI) examinations as well as cerebrospinal fluid (CSF) analysis and culture. The overall success of ETV was 55.9 % (19/34). Nine (81.9 %) out of the 11 patients that were endoscopically documented to have aqueductal obstruction showed improvement. While out of the 23 patients with patent aqueduct, only 10 patients (43.4 %) had improved. Procedure-

related complications were not encountered. CSF leakage from the surgical wound occurred in three patients and mild CSF infection occurred in one patient. ETV is a simple, safe, and effective method in treating not only obstructive hydrocephalus due to non-inflammatory etiology, but also post-inflammatory hydrocephalus especially when the aqueduct is obstructed. An overall 50 % improvement in our study and even more in other series encourage the trial of getting rid of the lifetime shunt complications and suffering.

Keywords Hydrocephalus · Intracranial infection · Pediatric · Cranial endoscopy · Third ventriculostomy

Introduction

Infection (specific and nonspecific) is one of the common causes of post-inflammatory hydrocephalus. This infection is usually diagnosed by cerebrospinal fluid (CSF) analysis and isolation of organism. Other etiologies for post-inflammatory hydrocephalus include subarachnoid hemorrhage, intraventricular hemorrhage, trauma, and mucopolysaccharidosis in which inflammation results in fibrosing arachnoiditis, meningeal fibrosis, and subependymal gliosis [19]. Post-inflammatory hydrocephalus following infection is a very common pediatric disease in developing countries. For decades, shunts were the sole method for the management of all types of hydrocephalus. The use of shunts presents unique problems in the context of pediatric patients. The diminished immunity renders them more susceptible for the known shunt complications more than older patients. Lifetime shunt dependency under these circumstances has an evident conflict on both the family and the community [4]. Cranial infection in pediatrics usually results in hydrocephalus with preserved ventricular morphology. In a minor percentage, the hydrocephalus is complex due to variable intraventricular septations

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and distorted ventricular anatomy. The overall standard of care for patients with hydrocephalus appear to have greatly improved over the last 10 years with the advent of better facilities for investigations, new approaches for treatment, and the greater awareness for the need for adequate follow-up [14]. Endoscopic third ventriculostomy (ETV) provides an alternative option to potentially treat hydrocephalus in a permanent way without the use of a shunt device with its attendant expenses, risks of infection and malfunction, together with the need for lifetime maintenance. The usefulness of this technique has been clearly demonstrated in adults and older children [7, 9]; however, the results in hydrocephalus due to infection, Chiari malformation, or the age of below 2 years were questionable [2, 3, 10, 13]. In this work, endoscopic third ventriculostomy was tried as a first-step management for pediatric cases with hydrocephalus secondary to intracranial infection. Our aim was to assess the efficacy of this simple procedure for treating this specific disease entity in a unique group of patients thus preventing—if possible—the lifetime shunt dependency and suffering.

Material and methods

Between May 2008 and September 2011, thirty-five pediatric cases with established hydrocephalus due to a history of intracranial infection underwent attempted endoscopic third ventriculostomy. Patients were the subject of detailed history taking and neurologic examination. Hydrocephalus was diagnosed by the progressive features of the disease during the regular follow-up and the positive imaging studies. The post-inflammatory etiology was diagnosed on the basis of the absence of the disease during the regular and complete prenatal follow-up together with the history of immediate postnatal incubation or the occurrence of late severe febrile illness that was diagnosed as meningitis. CSF analysis and culture were used for the establishment of the inflammatory etiology. Magnetic resonance imaging (MRI) was obtained with sagittal thin cuts to visualize the aqueduct of Sylvius.

Inclusion criteria

The inclusion criteria for this study were patients with established diagnosis of post-inflammatory hydrocephalus after subsidence of active intracranial infection confirmed by serial CSF analysis and culture.

Exclusion criteria

The exclusion criteria for this study were patients with non-settled inflammatory etiology, those with complex septated hydrocephalus, patients with active intracranial infection, and patients with CNS tuberculosis.

Operative technique

Under general anesthesia in the supine position with the head flexed about 30°, a right frontal incision was made at the site of the Kocher's bur hole. In all cases, the anterior fontanel was opened. In patients with wide fontanel, no bur hole was made and direct entry through the fontanel was done. If the fontanel was not that wide to go through, the most medial and posterior part of the right frontal bone was cut by scissors and reflected anteriorly to be returned to its position at the end of the procedure. Bur hole was made for older children. CSF sample was always taken after cannulation of the right frontal horn. Navigation through the right lateral and third ventricles for identification of the normal anatomical landmarks and assessment of the patency of the aqueduct was done. Third ventriculostomy was done by the fenestration of the floor of the third ventricle in the midline, midway between the mammillary bodies and the dorsum sellae. We used the Decq ventriculostomy forceps for fenestration. Once the stoma was done, it was augmented by the inflation of a 4-F Fogarty balloon catheter. The scope was then introduced to the interpeduncular cistern and any secondary membranes were cut when possible. The scope was then withdrawn after being sure that there was no intraventricular bleeding. Irrigation was needed in cases where bleeding occurred or turbid CSF was found. The rigid GAAB 2 scope was used in all our cases. We did not have a flexible scope to steer through the aqueduct.

Postoperative follow-up

Patients were discharged home in the first postoperative day. Patients were then seen on the 4th, 10th, and 21st days, then every 2 months till the end of the first year. During the follow-up, symptoms, neurologic examination, and developmental progress were assessed. A follow-up computerized tomography (CT) scan of the brain was done at the end of the third week and after 3 months on routine basis and then, if needed. MRI follow-up was also performed when needed.

Assessment of success

Both clinical and radiologic evaluations were considered during the assessment of procedure success. The procedure was considered clinically successful when ultimately a ventriculoperitoneal shunt (VPS) was avoided. This was based on the criteria that included a shift in the head circumference growth to normal rates as plotted on the standard growth charts, normal anterior fontanel, relief of manifestations of increased intracranial pressure (e.g., irritability, engorged scalp veins), resolution of eye manifestations (e.g., sunset appearance and sixth nerve palsy), and improved milestones. Radiologic improvement was considered when the periventricular haze gradually diminished till it

disappeared during regular follow-up CT and MRI, together with the reopening of the basal cisterns, reformation of the evident interhemispheric fissure, and in some cases, bone overlap. Reduction in ventricular size may not be always seen on radiology as a sign of neurological improvement [12].

Results

Demographic and clinical data

Thirty-five patients underwent endoscopy for attempted third ventriculostomy. Twenty-three patients (65.7 %) were males and 12 (34.3 %) were females. The age ranged between 4 and 15 months with a mean of 9.2 months. Twenty-four patients (68.6 %) were below the age of 6 months while 11 patients (31.4 %) were between 6 and 15 months. Twenty-five patients (71.4 %) had a head circumference of 3 cm and 10 patients (28.6 %) had a 5 cm or more increase in the head circumference above the 95th percentile for their corresponding age.

Imaging findings

Evan's ratio was more than 50 % in all cases. The cortical mantle ranged between 0.8 and 3.1 cm (mean 1.8 cm). MRI examination of the patients revealed aqueductal obstruction in 14 cases (Fig. 1); all of them had a normal-sized fourth ventricle. Patent aqueduct was seen in 21 patients; the fourth ventricle was of an average size in 9 patients and dilated in 12 of them.

ETV

The procedure was aborted in four patients. In two patients, a purulent CSF came from brain cannula and navigation by the endoscope was impossible due to the very turbid CSF despite having no manifestations of active intracranial infection. External drainage was done for both of them till clearance of the CSF. VPS was inserted in one of the patients (excluded from the study) and the other underwent ETV. The other two patients in whom the procedure was aborted had a very tough third ventricular floor that was very difficult to perforate, and fear of vascular injury obliged termination of the procedure. CSF sample was sent for examination for all patients undergoing endoscopic third ventriculostomy. Culture and sensitivity revealed negative results in all patients even in the two cases with purulent CSF. High protein content in the CSF was obtained in 31 patients. No abnormal cells were identified in 17 patients while in 18 cases, there were abnormal cells; 6 of them had more than 10 neutrophils/HPF. Atrophic fenestrated septum pellucidum was identified in 12 cases. The aqueduct was seen by the endoscope for patency. Eleven patients out of the 14 with evidence of aqueductal obstruction in the MRI showed actual obstruction; while in the remaining three, the aqueduct was seen to be patent by the endoscope. Patent aqueduct in the MRI images was established in all cases by the endoscope.

Success of ETV

The overall success of ETV was 55.9 % (19/34). Thirty-two patients out of the selected 35 patients underwent endoscopic third ventriculostomy. In one case, the CSF was purulent and the parents deferred their child from the study and preferred VPS insertion. In the remaining two cases, the ETV was not



Fig. 1 **a** CT scan (axial view) showing post-inflammatory dilated ventricular system. **b** MRI (sagittal view) of the same patient showing dilated supratentorial ventricular system with normal fourth ventricle due to aqueductal stenosis. **c** Postoperative follow-up CT scan (axial view) of

the same patient after endoscopic third ventriculostomy showing improvement of the pressure manifestations with widening of the sulci, opening of the Sylvian and the interhemispheric fissures without a significant reduction in the ventricular size

performed because of the tough floor of the third ventricle. A variable degree of arachnoid thickening and second membrane was found in all cases. Failure to establish good communication in the interpeduncular cistern due to marked arachnoid thickening and cementing around the basilar artery and the brain stem occurred in four cases. Out of the remaining 28 patients, 19 (67.9 %) were cured from the hydrocephalus. Eight patients showed progression of their manifestations and a VPS was inserted after 3 weeks from the day of surgery. One patient showed primary improvement till the third week, evidenced by lax fontanel and improved milestones. Follow-up CT showed marked subdural hygroma (Fig. 2). In time, recurrence of the manifestations mandated the insertion of a VPS by the end of the second month.

Success of ETV in relation to aqueductal obstruction

Nine (81.9 %) out of the 11 patients that were endoscopically documented to have aqueductal obstruction showed improvement. While out of the 23 patients with patent aqueduct, only 10 patients (43.4 %) had improved (Table 1).

Success of ETV in relation to the size of the fourth ventricle

Twenty-three patients had normal-sized fourth ventricle, improvement occurred in 13 of them (56.6 %). Improvement occurred in 6 (54.6 %) out of 11 patients with dilated fourth ventricle (Table 1).

Mortality and morbidity

The case deferred from the study died 6 months later due to shunt infection and virulent ventriculitis. CSF leakage from

the surgical wound occurred in three patients. The leakage and persistence of manifestations of increased intracranial pressure were considered a sign of failed ETV and required the insertion of a VPS. The CSF leakage eventually stopped after the VPS. Mild CSF infection occurred in one patient and was controlled by antibiotics before the insertion of VP shunt. No procedure-related complications were encountered.

Follow-up imaging

The follow-up imaging (CT, MRI) by the third week documented the improvement or the failure in all cases. Improvement was judged by the widening of the sulci, opening of the Sylvian and the interhemispheric fissures, reappearance of the basal cisterns, reduction of the transependymal permeation, and bone overlapping. The reduction in the ventricular size was not seen in all cases.

Discussion

Considering the anatomical point of view, post-inflammatory hydrocephalus could be either of the communicating or the obstructive type, the former being more common. In both instances, the cause is the inflammatory exudates that occupy the subarachnoid space or part of the ventricular pathways. Pathologically, intracranial infection can cause hydrocephalus by increased CSF secretion due to inflammation of the choroid plexus in early stage of the disease, obstruction of the CSF pathways inside or outside the ventricular system, thus resulting into obstructive or communicating hydrocephalus or also by diminished CSF absorption due to blocking of the

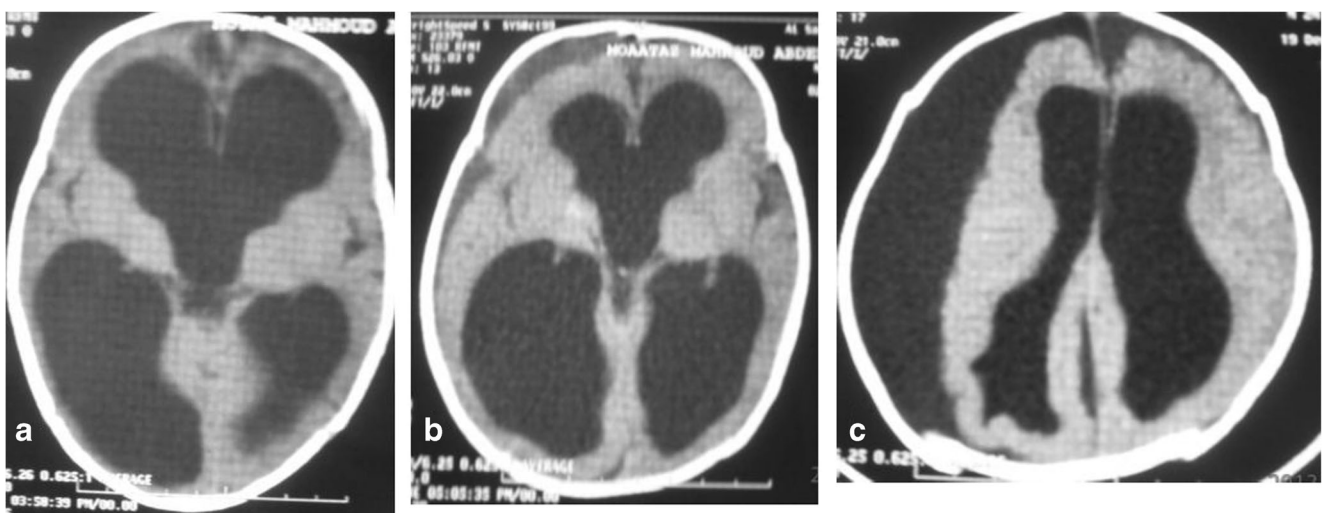


Fig. 2 **a** CT scan (axial view) showing post-inflammatory hydrocephalus. **b** Postoperative follow-up CT scan (axial view) of the same patient showing thin rim right frontoparietal subdural hygroma. **c** Late

postoperative follow-up CT scan (axial view) of the same patient showing marked progression of the subdural hygroma which required insertion of shunt

Table 1 The success of ETV in relation to the endoscopic finding of the aqueduct and the size of the fourth ventricle

Group	Group A (11)	Group B (23)	Group C (23)	Group D (11)
Improved	9 (81.9 %)	10 (43.4 %)	13 (56.6 %)	6 (54.6 %)
Not improved	2 (18.1 %)	13 (56.6 %)	10 (43.4 %)	5 (45.4 %)

Group A with aqueductal obstruction. *Group B* with patent aqueduct. *Group C* with normal fourth ventricle. *Group D* with dilated fourth ventricle

arachnoid granulations by inflammatory exudates. The intracranial inflammatory process can subside completely leaving behind no marks whatsoever. On the other hand, simple communicating or obstructive hydrocephalus can occur, or more severe is the complex septated hydrocephalus with totally distorted ventricular anatomy is the extreme dramatic outcome of the disease [5]. For a long time, the only treatment for post-inflammatory hydrocephalus was the insertion of VPS. The incidence of shunt complications was even estimated to be higher in this kind of hydrocephalus when compared to that in hydrocephalus due to other causes [6]. Meanwhile, the previously reported experiences treating post-meningitic hydrocephalus by ETV was disappointing to the degree of considering the history of meningitis or ventriculitis in a patient with hydrocephalus a negative predictor of success [2, 3, 6]. More recent studies of ETV including patients with post-inflammatory hydrocephalus were encouraging [17, 20].

In our study, all cases with preoperative MRI showing patent aqueduct was documented by the endoscope to have a non-obstructed aqueduct; however, three cases with preoperative MRI evidence of aqueduct obstruction was found to have a patent aqueduct by the endoscope. The preoperative diagnosis of aqueduct obstruction is good predictor of success of ETV in patients with post-inflammatory hydrocephalus [2]. False results of aqueduct obstruction may arise from wide MRI cuts that may escape the aqueduct or slightly oblique cuts. The stress on requesting thin strict sagittal midline cuts can reduce these fallacies. Moreover, the conventional MRI imaging can provide direct or indirect signs suggesting aqueduct obstruction, these signs are hardly validated and seem to be difficult to use especially in postoperative outcome evaluation [18]. Many reports suggested the complementary use of the rapid, easy and non-invasive cine phase contrast MR imaging sequences to prove the obstruction of the CSF circulation at the aqueductal level [1, 16].

We aborted the procedure in four cases; two due to purulent CSF and two due to tough third ventricular floor. Despite the lapse of enough time between the subsidence of the cranial infection and the surgical procedure in the two cases with purulent CSF, the turbid CSF made navigation with the endoscope too dangerous with high risk of complication. Their preoperative CSF examination was within normal; however, the pediatricians who helped in the management of our cases preferred obtaining a spinal

sample rather than a cranial one. That is why a preoperative cranial CSF analysis in patients with opened fontanel can be considered mandatory.

In our series, failure of perforation of third ventricular floor happened in two cases due to tough membrane. Chronic intraventricular increased pressure leaves usually thinned out and stretched third ventricular floor; however, infection with its resultant granulation tissue can render the floor thick and rubbery. Most vascular injuries reported in the literature were due to the combined perforation of tough floor and the use of cauterization for perforation [8]. For this reason, the surgeons who participated in the study preferred abortion of the procedure over jeopardizing the life of the patients. There is a steep learning curve before full competence in performing ETV in post-inflammatory cases. Distorted ventricular anatomy, tough third ventricular floor, and arachnoid thickening are true challenges. Therefore, appropriate endoscopic training is mandatory as the procedure is more demanding than in non-inflammatory cases.

CSF culture was negative for the presence of any organism in all cases. Apart from the two patients with purulent CSF, nearly all patients had a high CSF protein content that can be ascribed to the stagnant state of the CSF. In patients with CSF containing neutrophils, we relied on their negative cultures and a longer period of parenteral broad-spectrum antibiotic to cover our surgical procedure.

Post-inflammatory hydrocephalus, till recently, was considered a contraindication for ETV. These patients also reported to have shunt-related complications more than that with hydrocephalus due to other causes. We got an overall success in 55.9 % of cases (19/34) and 81.9 % improvement in patients with definite aqueductal stenosis. Despite the small number to get a definite significant data, the results are encouraging and even the overall 55 % improvement deserves the trial of the procedure and avoiding the lifetime shunt complications and dependency. Many recent reports support the use of the ETV even with patients with post-tuberculous meningitis [5, 15].

Tuberculous hydrocephalus, however, is more difficult to treat endoscopically especially in the acute phase. This is due to the thickened opaque third ventricular floor and obliteration of the normal subarachnoid space in the interpeduncular and prepontine cisterns with thick tuberculous exudate. The procedure is associated with a higher morbidity than in most other situations [5, 15].

The four cases with severe arachnoid adhesions in the interpeduncular cistern showed no improvement and shunts were inserted after 3 weeks. The result was expected during the procedure, but hopping improvement rendered us to be more patient to avoid shunt insertion. All these cases had patent aqueduct and dilated fourth ventricle. Reports correlating the obstructed aqueduct with the relatively good percentage improvement have been published [6, 11].

The inflammatory exudates caused by intracranial infection can be totally resolved leaving behind patent CSF pathways or causes variable degrees of adhesions and synechia. Limited adhesions can obstruct the foramen of Monro causing monoventricular, the aqueduct causing triventricular, or the outlet of the fourth ventricle causing tetra ventricular hydrocephalus. Widespread basal meningitis can obstruct the whole subarachnoid space causing communicating hydrocephalus, which cannot be differentiated from fourth ventricular outlet obstruction [5, 17]. Cases with aqueduct obstruction showed better improvement (81.9 %) than cases with patent aqueduct (43.4 %). Warf BC [20] reported similar results; he studied the efficacy of ETV for post-inflammatory hydrocephalus in Uganda. The higher success in patients with obstructed aqueduct can be explained by the occurrence of limited adhesions in the aqueduct rather than wide spread affection of the whole subarachnoid space. Prior meningitis can delay absorption of CSF along the convexity in addition to the immaturity. Hence, there could be persistent raised intracranial pressure despite successful ETV. This can explain the failure of improvement in about 18 % of cases of aqueductal obstruction who required insertion of VPS later. On the other hand, improvement of cases with patent aqueduct can be also explained by obstruction at the fourth ventricular outlet or extraventricular limited intracisternal obstruction as has been recently suggested [11].

Assessment of postoperative improvement in the present series was based on both the clinical outcome and the imaging studies. The postoperative reduction in the ventricular size may not always be seen. ETV usually leaves dilated ventricles without pressure [12].

Correlation between the success of ETV and the size of the fourth ventricle showed nearly the same outcome in normal and dilated fourth ventricle. Dilatation of the fourth ventricle may not indicate a communicating hydrocephalus due to wide spread arachnoid adhesions, but limited fourth ventricular outlet obstruction may be the cause of the hydrocephalus and the benefit from ETV should be considered.

We did not experience procedure-related mortality or morbidity. The patient who died in this series did not undergo a third ventriculostomy. His death was due to virulent ventriculitis after shunt application.

Limitations of the study

The small number of cases to get significant data and short period of follow-up limited this study.

Conclusion

ETV is a simple, safe, and effective method in treating not only obstructive hydrocephalus due to non-inflammatory etiology, but also post-inflammatory hydrocephalus especially when the aqueduct is obstructed. An overall 50 % improvement in our study, and even more in other series, encourage even the trial of getting rid of the lifetime shunt complications and suffering.

Conflict of interest None.

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Comments

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The authors describe their experience in the treatment of post-inflammatory hydrocephalus in infants using the endoscopic third ventriculostomy (ETV) and conclude that the procedure can be associated to favorable results in cases where a stenosis of the aqueduct is present.

Post-inflammatory hydrocephalus remains unfortunately a common pathological condition in developing countries; consequently, the possibility of avoiding an extrathecal CSF shunt in some of the affected patients should be taken into account, especially considering the high risk of complications directly related to the presence of the CSF shunt device. The interest of the authors' results is that they further confirm the possible role of ETV in cases where a communicating hydrocephalus combines also the features of an obstructive hydrocephalus. Such an event is not uncommon in post-hemorrhagic and post-infectious hydrocephalus in which an aqueductal stenosis may aggravate an initially communicating hydrocephalus.

The experience considered here is of paramount importance for neurosurgeons in developing countries where the shunt device's cost may still be excessively high and the management of its associated complications, critical. However, the long-term efficacy of the endoscopic procedure remains to be evaluated especially in this age group as a higher incidence of secondary closure of the artificially created stoma in the floor of the third ventricle could be expected at the light of the inflammatory etiology of the hydrocephalus.

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Raouf et al. reports a study of endoscopic third ventriculostomy in 35 pediatric patients with post-inflammatory hydrocephalus. They conclude that ETV has good results in reducing intracranial pressure in post-inflammatory hydrocephalus causing aqueductal obstruction. The study design and methodology is sound. The limitations of the study have been mentioned. The manuscript is written, discussed, and referenced well. ETV has a definite role in a child with raised intracranial pressure following aqueductal stenosis. However, in cases of tubercular meningitis or any other pyogenic infection, the indications are still to be validated although few case series in literature propose it. ETV prevents the complications of shunt and hence, is more physiological. Reduction in ventricular size may not be always seen on radiology as a sign of neurological improvement. Prior meningitis can delay CSF absorption along the convexity and may contribute to persistent raised intracranial pressure despite successful ETV. It will be a different scenario than patients with only aqueductal stenosis. The learning curve in this situation is steep and adequate hands-on training is mandatory in endoscopy.