SAMJ FORUM

CLINICAL PRACTICE

Intracranial endoscopy

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In modern neurosurgery there has been a strong trend towards the use of minimally invasive techniques, one of which is intracranial endoscopy. Endoscopic third ventriculostomy (ETV) is the commonest procedure performed; it is used to treat hydrocephalus caused by an obstruction to the ventricular system anywhere distal to the mamillary bodies of the third ventricle. The obstruction is bypassed by a stoma created in the floor of the third ventricle, allowing cerebrospinal fluid (CSF) to flow freely into the subarachnoid space. Endoscopy can also be used for the fenestration of various intracranial cysts, intraventricular biopsy, the placement and retrieval of ventricular catheters, the removal of small intraventricular lesions, and improved visualisation in microsurgical operations.

At Red Cross Children's Hospital and Groote Schuur Hospital endoscopy has become an indispensable tool in the management of a wide range of neurosurgical conditions. As experience has accumulated worldwide, a better understanding of the benefits and limitations of endoscopy in diverse circumstances has emerged.

Methods and materials

Data were extracted from a prospective institutional database containing all cases operated on consecutively from April 1999, when endoscopy was first introduced, to March 2005. Evaluation of the success of ETV was based on clinical and radiographical outcome; shunt independence was the primary criterion for success, as is described in most reports.[1] Cases with inadequate clinical or radiographic follow-up were excluded from further analysis, including those followed up for less than 1 month.

Because the success of ETV depends on the patient having non-communicating hydrocephalus with patent subarachnoid spaces and adequate CSF absorption, patients were divided into two groups for analysis. Group 1 consisted of patients in whom the obstruction to CSF flow could be clearly visualised on preoperative computed tomography (CT) scans, magnetic resonance imaging (MRI) or air encephalography (AEG). Group 2 consisted of patients in whom there was some uncertainty about the level of CSF obstruction, where ETV was performed on suspicion of non-communicating hydrocephalus or as a salvage attempt to avoid a prolonged course of external ventricular drainage or repeat shunt infection in patients with probable communicating hydrocephalus.

AEG was employed as part of a defined protocol in selected patients to assist in identifying the level of CSF obstruction where the underlying pathophysiology was unclear on conventional imaging. Biopsy procedures were analysed according to the representativeness of the sample obtained. Fenestration procedures were evaluated in a manner similar to that employed for ETV.

Endoscopic equipment

A selection of rigid Storz (Karl Storz, Tuttlingen, Germany) and Aesculap (Tuttlingen, Germany) endoscopes was used during this series. The scope was passed through a rigid endoscopy sheath or a peel-away catheter. Both 0º and 30º angled endoscopes were used.

ETV technique

Typically, ETV is performed through a right-sided burrhole placed immediately anterior to the coronal suture, 2 - 3 cm from the midline. The endoscope is advanced into the lateral ventricle, identifying the typical anatomy of the foramen of Monro, through which the endoscope is carefully navigated to enter the third ventricle. The floor of the third ventricle is identified by the mamillary bodies and the infundibular recess. A bluish, translucent area between the basilar artery, which lies beneath the floor and immediately anterior to the mamillary bodies, and the infundibulum is identified as the site for the stoma creation, which is accomplished by blunt pressure from a balloon catheter or rigid instrument. The stoma is enlarged with a figure-of-eight balloon (St Rose balloon, Integra Neuroscience, New Jersey, USA). Technical success of the procedure is confirmed by inspection of the subarachnoid cisternal space beyond the stoma. Any venous bleeding is controlled by copious irrigation with warmed Ringer's lactate solution.

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Table I. Analysis of ETV results per aetiology

Aetiology	Total cases (*N*)	Succeeded (*N*)	Failed (*N*)	Inadequate data or lost to follow-up (*N*)	Percentage of successful cases among patients with adequate follow-up
Postinfectious	27	14	12	1	53.8
Posthaemorrhagic	13	6	5	2	54.5
Congenital	22	11	8	3	57.9
Myelomeningocele	19	9	9	1	50.0
Posterior fossa tumour	13	10	3	0	76.9
Before resection					
After resection	8	7	1	0	87.5
Pineal tumour	10	9	1	0	90.0
Thalamic tumour	8	7	0	1	100.0
Midbrain lesion	7	6	1	0	85.7
Intracranial cyst	3	2	0	1	100.0
Posterior fossa abscess	3	2	1	0	66.7
Chiari 1 malformation	2	1	0	1	100.0
Craniosynostosis	1	0	1	0	0.0
Dandy-Walker syndrome	2	1	1	0	50.0
Structural anomaly	1	0	0	1	N/A
Unknown	7	5	1	1	83.3
Total	146	90	44	12	67.2

For operations other than ETV, the approach is determined by the pathology encountered. In this series, pathological findings included a variety of arachnoid cysts, paraventricular tumours, and septated ventricles. The approaches were contralateral, low frontal, occipital, temporal, and posterior fossa.

Results

From April 1999 to March 2005, 263 operations were performed on 219 patients. In some operations more than 1 endoscopic procedure was performed, giving a total of 302 individual procedures. Of these, there were 164 ETVs, 46 fenestration procedures, 27 endoscopic biopsies, and 39 'other' procedures. In 26 cases the procedure could not be completed for various reasons, most commonly because of abnormal anatomy or poor endoscopic visualisation. The median age of the patients in the series was 6 years (range 5 days - 67 years). Follow-up data were inadequate in 12 patients and were excluded from further analysis.

ETV

One hundred and forty-six patients were treated with ETV and there were 18 re-do procedures. Hydrocephalus was treated successfully with ETV alone in 67% of cases, all of which were shunt-free at follow-up. The median follow-up for successful cases was 23 months (range 1 - 61 months). Shunt insertion was required for failed cases. Fig. 1 illustrates a successful case.

Most ETV failures were apparent early – the outcome was evident by 1 month in 67% and by 3 months in 86% of failed cases. The median time to shunt insertion was 1 month after ETV failure. The results for ETV with regard to aetiology of the hydrocephalus are summarised in Table I. The success rate for patients in group 1 was 88% and in group 2, 58%. These data are shown in Table II.

Table II. Analysis of success rates for groups 1 and 2 (patients with inadequate follow-up excluded)

Total	Total number	Successful (*N*)	Failed (*N*)	% success
Group 1	41	36	5	87.8
Group 2	93	54	39	58.06
Total	134	90	44	67.16

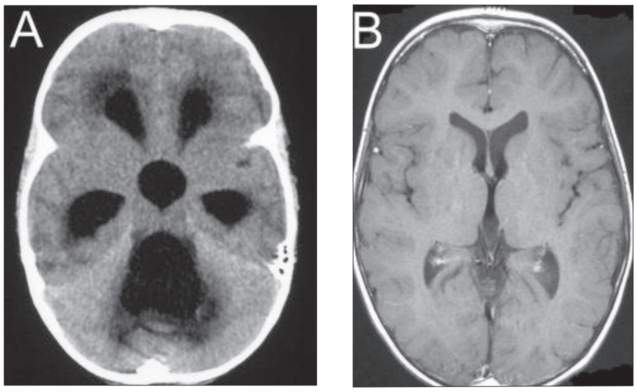

Fig. 1. A: Axial CT scan demonstrating the occurrence of marked hydrocephalus after resection of an ependymoma in the fourth ventricle. B: T1-weighted MRI scan showing resolution of hydrocephalus after ETV.

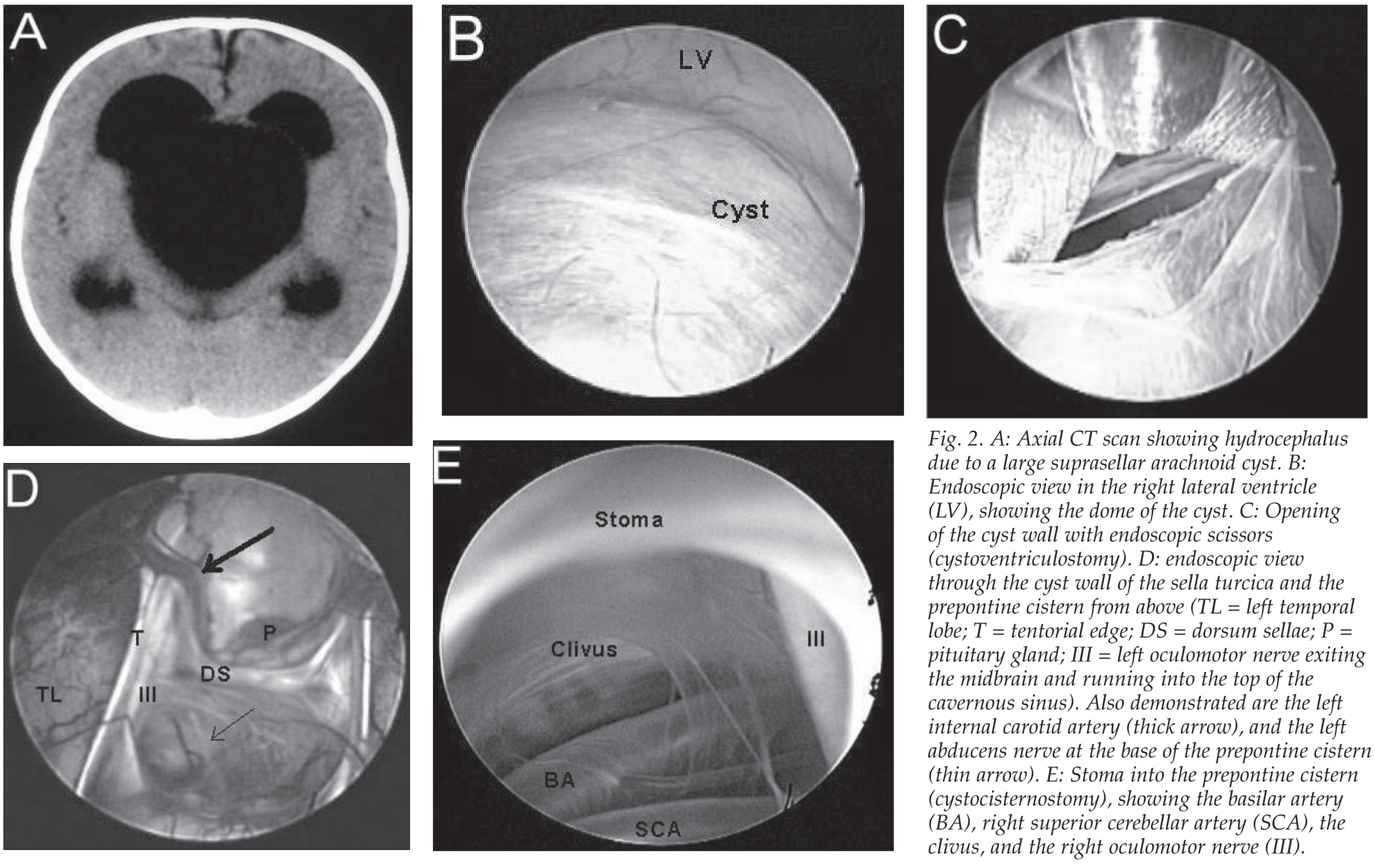

Fig. 2. A: Axial CT scan showing hydrocephalus due to a large suprasellar arachnoid cyst. B: Endoscopic view in the right lateral ventricle (LV), showing the dome of the cyst. C: Opening of the cyst wall with endoscopic scissors (cystoventriculostomy). D: endoscopic view through the cyst wall of the sella turcica and the prepontine cistern from above (TL = left temporal lobe; T = tentorial edge; DS = dorsum sellae; P = pituitary gland; III = left oculomotor nerve exiting the midbrain and running into the top of the cavernous sinus). Also demonstrated are the left internal carotid artery (thick arrow), and the left abducens nerve at the base of the prepontine cistern (thin arrow). E: Stoma into the prepontine cistern (cystocisternostomy), showing the basilar artery (BA), right superior cerebellar artery (SCA), the clivus, and the right oculomotor nerve (III).

In the majority of cases investigated with AEG during this period, the investigation demonstrated communicating hydrocephalus. Patients with non-communicating hydrocephalus were referred for ETV, while those with communicating hydrocephalus had CSF shunts implanted (or medical treatment initially in the case of tuberculous hydrocephalus). In 6 patients ETV was performed on the basis of AEG which showed non-communicating hydrocephalus; all 6 cases had an infectious aetiology. Five of these cases were successfully treated and there was 1 failure.

Fenestration procedures

Forty-six endoscopic fenestration procedures were performed for isolated ventricular compartments and various intracranial cysts (Fig. 2). The most common indication was an isolated lateral ventricle secondary to shunting, infection, intraventricular haemorrhage or tumour obstruction. The indications for endoscopic fenestration are shown in Table III. Overall, fenestration procedures were successful in 31 of 34 cases (91%), although a repeat operation was required in 5 patients because of stomal closure.

Table III. Indications for endoscopic fenestration and analysis of results

Indications for fenestration (*N*)	Total	Successful	Failed
Isolated ventricular compartments			
Single	16	14	2
Multilocular	5	4	1
Arachnoid cyst			
Suprasellar	2	2	
Middle cranial fossa	1	1	
Hemispheric	1	1	
Interhemispheric	1	1	
Intraventricular	2	2	
Schizencephalic cyst	2	2	
Tumour cyst	2	2	
Dandy-Walker malformation	1	1	
Cavum septum pellucidum cyst	1	1	
Total	34	31	3

Biopsies

Twenty-seven endoscopic biopsies were performed in 25 patients. Overall, a histological diagnosis was obtained endoscopically in 20 patients. In the majority of cases (19 of 24) another procedure (ETV, fenestration or catheter placement) accompanied the biopsy. Of the lesions for which an accurate result was not obtained, 3 were thalamic, 1 pineal and 1 hypothalamic in location. Poor intraventricular visibility of abnormal tissue was associated with inconclusive results.

Other procedures

Data for these procedures are summarised in Table IV. An example of 1 of these procedures is shown in Fig. 3, a patient in whom intraventricular neurocystercercal cysts were removed endoscopically.

Table IV. Details of other procedures performed

Type of procedure	Number
Retrieval of shunt	6
Assisted shunt placement	3
Relook procedure/ inspection	12
Fenestration of lamina terminalis	2
Assisted Omayya reservoir placement	2
Removal of intraventricular neurocysts	2
Opening of foramen of Monro	2
Aqueductoplasty	1
Transphenoidal pituitary surgery	7
Endoscopic orientation in tumour craniotomy	2
Total	39

Complications

Thirty-one procedural complications were documented (11.8%), the majority of which (29 of 31) were transient and had no permanent sequelae. There were 2 major complications in the series. One patient died as a result of tumour swelling after a large pineal tumour was biopsied endoscopically, while another died as an indirect complication, the consequence of sepsis related to prolonged external ventricular drainage and shunt failure 3 months after a failed ETV. Twenty cases of CSF leak were recorded (7.6%), of which 6 were associated with CSF infection (2%). All cases of CSF infection occurred secondary to a CSF leak or external ventricular drainage; there were no cases of CSF infection directly related to the endoscopic procedure. There were 4 cases of significant venous bleeding, all of which were cleared intraoperatively with irrigation and none of which was associated with any clinical consequence. There were no cases of significant arterial injury.

Discussion

Although endoscopy was first considered as an option for the treatment of hydrocephalus in the early part of the 20th century, the practice fell into disuse because of the technical limitations at the time and the introduction of CSF shunts. The current resurgence of interest has occurred as a result of technological advances in endoscopy equipment and the more realistic long-term appraisal of CSF shunt failures in hydrocephalus treatment. The potential advantages of neuroendoscopy are many. ETV avoids many of the long-term complications associated with CSF shunts, which include obstruction, disconnection, breakage, overdrainage, sepsis and seizures. Shunt failure is extremely common and the associated mortality and morbidity are high, even with modern shunt systems.[2]

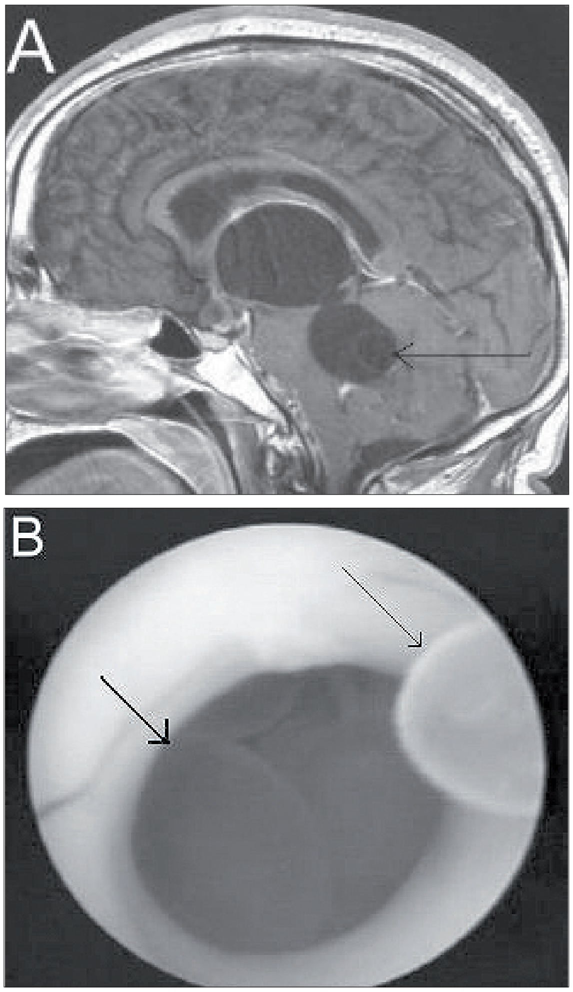

Fig. 3. A: Sagittal MRI of a patient with hydrocephalus caused by intraventricular neurocysticercosis. An enlarged fourth ventricle can be seen with intraventricular cysts (arrowed). B: Endoscopic view inside the third ventricle, directed at the cerebral aqueduct (thick arrow). Neurocysticercal cysts are pictured inside the third ventricle (thin arrow), and can be seen faintly inside the fourth ventricle through the aqueduct. After endoscopic removal of the cysts the hydrocephalus resolved without any further treatment.

Endoscopic fenestration procedures for isolated ventricles and intracranial cysts may also obviate the need for a shunt, or at least simplify compartmentalised hydrocephalus so that only a single shunt is required, avoiding the increased complications of multiple shunt systems. Endoscopic biopsy of paraventricular lesions avoids a large craniotomy for open biopsy with more extensive brain dissection, and stereotactic biopsy in anatomically high-risk regions. The use of angled endoscopes may improve visualisation in open operations for tumour resections and aneurysm clipping where direct vision is obstructed. Finally, there is probably a favourable economic impact created by the avoidance of expensive shunt systems, the prolonged management of shunt sepsis, and craniotomies.

As with all other surgical techniques, the benefit and risks of endoscopy must be evaluated critically, particularly as the learning curve is steep. Schroeder *et al.*[3] found a 1% procedural mortality, 1.6% permanent morbidity and 7.8% transient morbidity in their series, and Teo *et al.*[4] reported a 7% incidence for significant complications and 13% for insignificant complications. In general, complications include CSF leak, CSF infection, epilepsy, intraoperative bleeding, postoperative haematoma, and injuries to the basilar artery complex, hypothalamus, cranial nerves and fornix. Although rare, basilar artery injury is the most feared complication of ETV,[5] with high mortality reported due to the ensuing subarachnoid haemorrhage. This may occur during the creation of the ETV stoma because of the proximity of the artery immediately below the third ventricle floor.

In this series there was a 0.5% operative mortality, 1% permanent morbidity and 10.6% transient morbidity. Swelling of a large tumour is a well-known complication of any form of minimal biopsy, and led to the death of 1 of our patients. The number of cases abandoned reflects the selection of patients undergoing surgery and the aetiology of hydrocephalus. In our setting hydrocephalus is more frequently associated with myelomeningocele and CSF infection than in most other reports[6], both of which are associated with distorted anatomy.

Tuberculous meningitis is a common cause of hydrocephalus in our environment and it presents a particular technical challenge to the endoscopist.[7] If it is thought that the procedure cannot be accomplished safely we do not proceed further, which probably accounts for the relatively low incidence of haemorrhagic complications and the absence of hypothalamic injury in the series.

The use of air encephalography is uncommon in modern practice. It has been used in this series as part of a protocol to distinguish between communicating and non-communicating forms of hydrocephalus. We have found it helpful in selected cases where the distinction could not be made with conventional imaging techniques, thereby improving the selection of patients. It is important, however, that this is performed as part of a strict protocol; we have previously described such a protocol for modified lumbar air encephalography in this context.[8]

The success rate of ETV in the treatment of hydrocephalus is influenced by a number of factors. The most significant is the aetiology of the hydrocephalus; therefore the reliability of the diagnosis of non-communicating hydrocephalus is of crucial importance. ETV was successful for 88% of patients in group 1 – this is in agreement with the results of other series showing that ETV success is highest where there is a clear lesional obstruction visible on preoperative imaging.[9,10]

However in most cases of hydrocephalus, there is uncertainty regarding the exact level of the CSF obstruction, especially in postmeningitic and posthaemorrhagic hydrocephalus, which results in a lower success rates.[11] In this series, ETV was successful in 58% of cases where the level of obstruction was not firmly established. Reported success rates of ETV for aqueduct stenosis vary from 50% to 80%,[12,13] probably because aqueduct stenosis may be the primary cause or a secondary feature of hydrocephalus. A history of prior shunt insertion and a longer time interval between the onset of hydrocephalus and ETV may be favourable factors, perhaps reflecting the time that it takes for the patency of the subarachnoid space and the CSF absorptive capacity to be restored after a meningitic or haemorrhagic insult. Good results have been reported for the treatment of shunt dysfunction.[14]

According to the findings of the most series,[1,11] age is another factor influencing the likelihood of success, with a less favourable outcome reported in children under the age of 2 years, and particularly those under 6 months. The most likely explanation is the age-related immaturity of the CSF-absorptive capacity and the decreased pressure gradient across the arachnoid granulations secondary to open sutures.[1] Despite the poorer results reported for younger patients, some authors still support a policy of attempting ETV as an initial procedure in the hope of achieving shunt dependence.[1]

If ETV fails, this is usually evident within 1 - 2 months of surgery,[11,15] occurring either because of stomal closure or abnormal CSF absorption (stoma patent). Late failure after ETV is thought to be relatively uncommon and is usually due to stomal closure; in this case ETV can generally be safely repeated.[16] Death as a result of untreated hydrocephalus is described in patients who have not had adequate follow-up. Despite the relatively low percentage of late failures, these patients must still be considered to be at risk of stomal closure and therefore should be followed up in the same manner as shunted patients. The report by Cinalli *et al.*[12] is of particular interest because it includes patients who underwent stereotactic third ventriculostomy, an older procedure, with some patients followed up for 17 years. The overall functional ventriculostomy rate was 72% at 6 years, with no significant differences between the endoscopic and stereotactic groups. No failures were reported in either group after 5 years.

Endoscopy is an attractive minimally invasive option for obtaining tissue for histological diagnosis, also allowing concurrent treatment of the hydrocephalus or isolated ventricles commonly occurring with paraventricular lesions, which avoids a separate operation for this. However, assessment of the histological results should take into account how well the abnormal area was visualised endoscopically, the imaging characteristics of the lesion and the clinical information available.

Conclusion

The experience from the neurosurgical unit at the University of Cape Town confirms that endoscopy is a valuable surgical tool in neurosurgery. Fundamental to the success of the procedures are adequate training for the surgeon and the appropriate selection of patients. Although the learning curve is steep, the complications are relatively few. Endoscopy has become the procedure of choice for a number of neurosurgical conditions at our institution. It is another example of how a minimally invasive tool can yield maximal effectiveness. Within the central nervous system, this is a welcome addition.

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