Original Article

Neuroendoscopy in Children

La neuroendoscopie chez les enfants

*Figaji, A.A., Fieggen,A.G., Peter, J.C.
Division of Paediatric Neuroscience, School of Child and Adolescent Health
University of Cape Town, Red Cross War Memorial Childrens' Hospital South Africa

Abstract

Background: The emergence of endoscopy as a neurosurgical tool in recent years has changed the surgical management of many intracranial conditions.

Patients and Methods: A prospective series of endoscopic operations in children with neurosurgical conditions at Red Cross Childrens Hospital.

Results: Endoscopy for 237 procedures, including third ventriculostomy, tumour biopsy, fenestration procedures and a variety of other indications are reported.

Conclusion: The indications for endoscopy, limitations of the procedures, operative strategies and results are discussed. Endoscopy is a valuable addition to the options available for managing varios intracranial pathologies.

Keywords: neuroendoscopy, hydrocephalus, intracranial cysts, brain tumours endoscopic third ventriculostomy, children

Résumé

Arrière-plan: L'émergence, au cours de ces dernières années, de l'endoscopie comme un outil neurochirurgical a changé la gestion chirurgicale de beaucoup de maladies intracrâniennes. ***Patients et malades:*** Une série prospective d'opérations endoscopiques sur des enfants atteints de maladies neurochirurgicales à l'Hôpital infantile de la Croix Rouge. ***Résultats:*** Nous rapportons 237 procédures incluant une troisième ventriculostétomie, une biopsie tumorale, des procédures de fenestration et diverses autres indications. ***Conclusion:*** Nous discutons des indications pour l'endoscopie, des limitations des procédures, des stratégies chirurgicales et des résultats. L'endoscopie est une méthode valable qui s'ajoute aux options disponibles pour gérer diverses pathologies intracrâniennes. ***Mots-clés:*** neuroendoscopie, hydrocéphalie, kystes intracrâniens, tumeurs cérébrales, troisième ventriculostétomie endoscopique, enfants.

Introduction

Endoscopy has been a valuable addition to the options available for treating a variety of intracranial pathologies in the last decade. Endoscopic third ventriculostomy (ETV) may obviate the need for cerebrospinal (CSF) shunt placement for hydrocephalus. Non-communicating hydrocephalus can be treated by creating a stoma in the floor of the third ventricle, allowing CSF from the ventricles to bypass a more distal obstruction by directly accessing the subarachnoid space. Endoscopic fenestration procedures may relieve the mass effect of various cysts or isolated ventricular compartments by opening these into the rest of the ventricular system or the subarachnoid cisterns. Endoscopic biopsy is an alternative to stereotactic biopsy or craniotomy for obtaining tissue diagnosis of paraventricular lesions. We report our experience over a 6-year period in the use of neuroendoscopy for these and other procedures in the management of children with neurosurgical conditions.

Patients and Methods

Data from paediatric neuroendoscopy operations performed from September 1999 to September 2005 were extracted from a prospectively maintained database at Red Cross Childrens Hospital. Recorded data included: indication for the operation, patient age, initial radiographic imaging, operative findings, type of endoscopic procedure performed, histology results, complications, clinical outcome and post-operative imaging. Inclusion in the study required detailed clinical and radiological follow-up. The data of patients for whom adequate follow-up information was not available were recorded but were excluded from further analysis.

Technique and equipment

Most endoscopic procedures were performed using Aesculap (Aesulap, Tuttlingen, Germany) and Storz (Karl Storz, Tuttlingen, Germany) rigid neuroendoscopes with 15 and 30 degrees of viewing angulation; a flexible endoscope was used for choroid plexus

Correspondence: Figaji A. A., Institute of Health, Klipfontein Rd, Rondebosch, Cape Town, South Africa. Figaji@ich.uct.ac.za

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coagulation. All procedures were performed freehand, without the use of scope-holding devices, stereotaxis or neuronavigation. The conventional approach for ETV involved a right parasaggital incision, 2-3 centimetres from the midline, with placement of a precoronal burrhole through which the right lateral ventricle was cannulated with the endoscope or a sheath. The scope was then navigated into the third ventricle via the foramen of Monro (Fig 1) and the anatomy of the floor of the third ventricle was identified with particular reference to the position of the mammilary bodies, the basilar artery and the infundibular recess (Fig 2). The stoma was created in the floor of the third ventricle between the basilar artery and the clivus by blunt perforation using a semi-rigid balloon catheter or closed forceps. After confirming the opening into the subarachnoid space and the position of the cisternal vessels, the stoma was further enlarged to an appropriate size using a figure-of-eight balloon catheter (Integra Neurosciences, New Jersey, USA) or Fogarty catheter (size 3). Technical success of the procedure was confirmed by identification of the cisternal anatomy visualised through the stoma.

Alternative endoscopic approaches were often required for biopsy and fenestration procedures. The specific approach was determined by the ventricular configuration and location of the lesion involved. The most common of these included: the low frontal approach to the posterior third ventricle via the Foramen of Monro, the lateral coronal approach to the septum pellucidum, and the occipital approach to the trigonal region of the lateral ventricle.

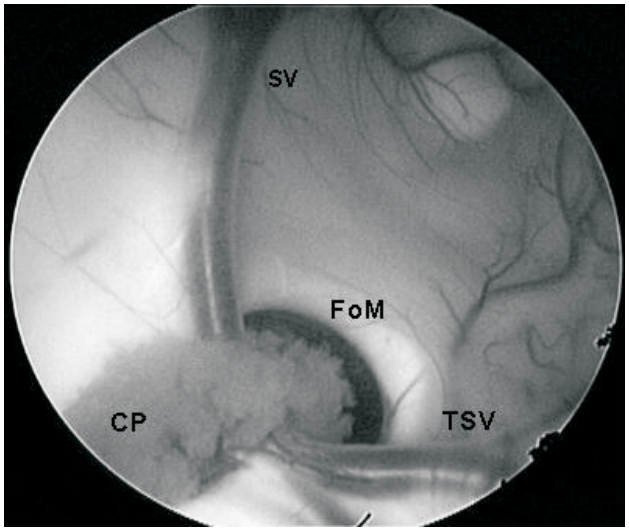


Fig 1: Typical endoscopic view in the right lateral ventricle showing the foramen of Monro (FoM), the choroid plexus (CP), septal vein (SV) and thalamostriate vein (TSV). The third ventricle is entered through the foramen of Monro.

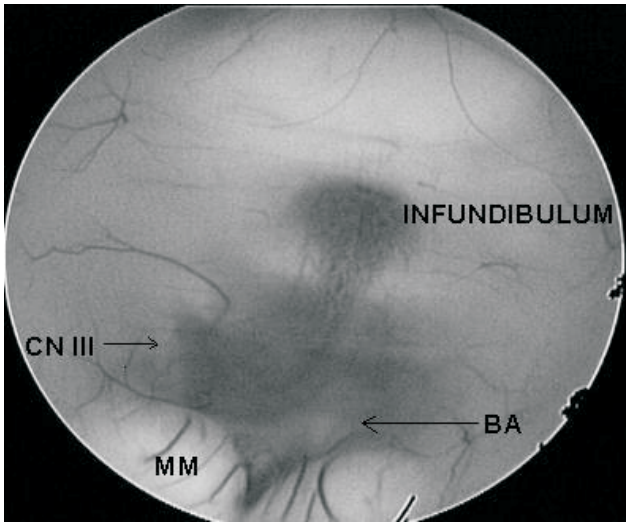


Fig 2. Endoscopic view of the floor of the third ventricle showing the typical anatomy, including the position of the mamillary bodies (MM) posteriorly, the infundibulum, and the basilar artery (BA) just beneath the floor and anterior to the mamillary bodies. The left oculomotor nerve (CN III) can be seen faintly beneath the floor, laterally placed, as it exits the midbrain en route to the cavernous sinus.

Results

During this period, 302 consecutive neuroendoscopic operations were performed in adults and children. Of these, 213 (71%) operations were in children, involving 237 separate procedures. Nineteen patients (9%) had more than one procedure performed in a single sitting, usually ETV plus biopsy or fenestration procedures. The median age for children in the series was 3 years, ranging from 2 weeks to 14 years old. The spectrum of procedures performed can be seen in Table I.

Endoscopic biopsy

All lesions that were biopsied were paraventricular in location. Endoscopic biopsy yielded a positive result in all patients in whom the area of abnormality was clearly apparent; an inconclusive result was obtained in the 2 cases in which the lesion was not well visualized, both of which were in the thalamic region. Histological diagnosis included: primitive neuroectodermal tumour, germinoma, pineoblastoma, glioma (thalamic, optic, brainstem) and tuberculous granuloma.

Endoscopic biopsy was usually accompanied by

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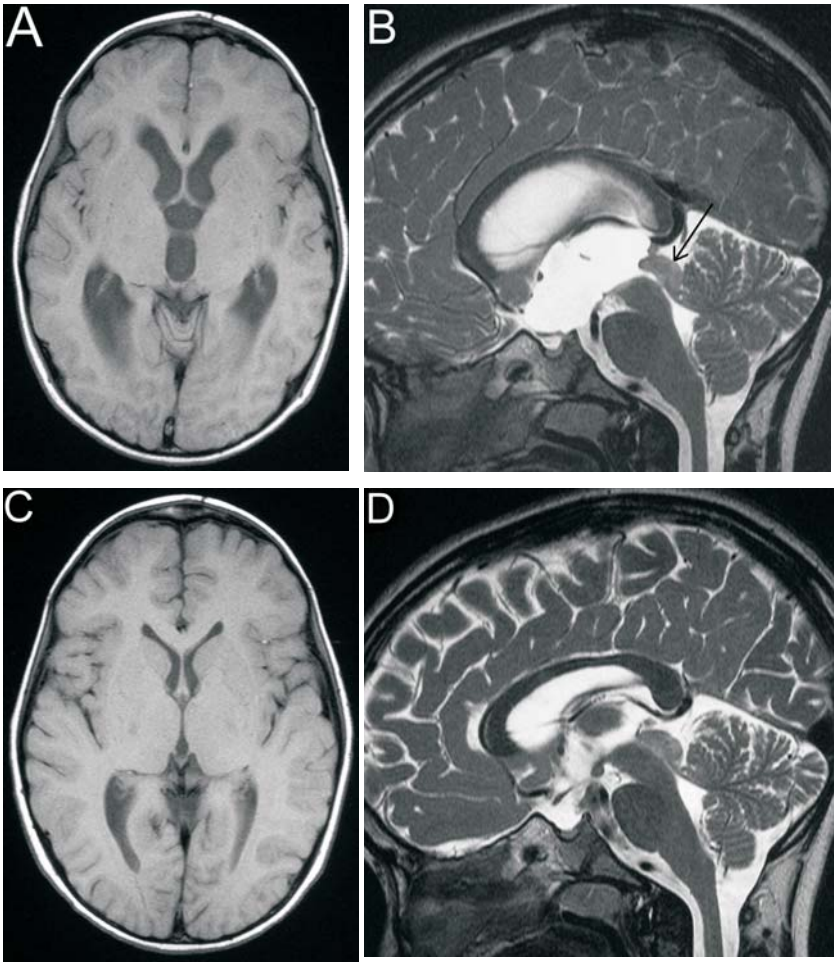


Fig 3 A+B: An 8-year old boy with a tectal glioma causing hydrocephalus by obstruction of the cerebral aqueduct. A, Axial T1-weighted MRI demonstrating hydrocephalus; B, Sagittal T2-weighted MRI demonstrating the mass in the tectum (arrowed) and the third ventricular anatomy. Note how the floor of the third ventricle is bowed inferiorly and displaced downwards. The obstruction of the aqueduct by the tectal mass is shown clearly, and there is no CSF flow void in the aqueduct. C+D: Same patient 3 months after ETV. C, Axial T1-weighted MRI showing complete resolution of the hydrocephalus; D, Sagittal T2-weighted image showing the straightened position of the floor of the third ventricle after relief of pressure, and the flow void in the prepontine cistern caused by the CSF flow across the stoma in the floor (separate from the flow void of the basilar artery).

ETV or a fenestration procedure due to the association of hydrocephalus and ventricular isolation with intracranial mass lesions. In these cases the fenestration or ETV was generally performed prior to the biopsy, so that any bleeding from the biopsy site did not interfere with the treatment for hydrocephalus.

ETV for hydrocephalus

Median follow-up for successful ETV cases was 2 years and 7 months (range 3 months to 6 years). In 8 patients clinical and radiological follow-up was inadequate and these data were excluded from further analysis. The results of ETV in 3 age categories can be seen in Table II. Failure of ETV was defined by the persistence of symptoms, high external ventricular drainage posto-peratively, and/or lack of radiological improvement or progressive ventri-culomegaly. All of these cases had subsequent ventriculoperitoneal shunt insertion. Of patients who had adequate follow-up, ETV was succes-sful in 61 of 101 procedures (60%), requiring redo in 9 cases due to an inadequate first procedure or stomal closure. The success rate was 40% under the age of 2, and 69% over the age of 2. The pathology causing hydrocephalus is shown in Table III, divided into 2 age groups.

Subgroup analysis revealed the highest rate of ETV success (94%) occurred in patients with a clearly visualised obstruction of the distal ventricular system, in whom there was no evidence of previous haemorrhage or sepsis (29 of 31 cases). An example of this can be seen in Fig 3.

Fenestrations

Endoscopic fenestration procedures included tumour cyst fenestration, septal fenestration (septostomy) for isolated lateral ventricles, intraventricular membrane fenestration for multiseptated ventricles, and arachnoid cyst fenestration. Fenestrations were performed in 30 patients, requiring reopening after stomal closure or inadequate opening in 8. Ultimately, fenestration was successful in 24 of 28 cases; data from 2 cases were insufficient for adequate analysis.

Other procedures

In 31 cases, procedures other than biopsy, fenestration or ETV were performed. These included: endoscopy-assisted craniotomy for tumour resection, endoscopy-

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Table 1: List of procedures performed

Neuroendoscopic Procedures		Number
ETV	- Initial	100
	- Redo ETV	17
Biopsy	- Initial	15
	- Redo Biopsy	2
Fenestrations	- Septal	10
	- Tumour Cyst	2
	- Intraventricular	7
	- Arachnoid cyst	8
	- Other (schizencephaly, Dandy-Walker malformation, cavum septum pellucidum cyst)	3
	- Redo fenestrations	8
Abandoned		25
Others	- Endoscopic shunt or Ommaya placement	
	- Shunt retrieval	
	- Endoscopic inspection	31
	- Endoscopy-assisted tumour removal	
	- Choroid plexus coagulation	
Total		**237**

Table 2: ETV Success per age group

Age	Total	ETV Success	ETV Failures	% Success
Less than 6 months	12	4	8	33
6-12 months	10	6	4	60
13-24 months	10	3	7	30
Older than 2 yrs	70	48	21	69

assisted placement of ventricular shunt and Ommaya reservoir, removal of intraventricular catheters, opening of the foramen of Monro, choroid plexus coagulation and intraventricular inspection of pathology. In twenty-five cases, the planned procedure was not completed because the anatomy was considered not sufficiently recognisable to proceed safely.

Complications

Cerebrospinal fluid (CSF) leakage from the wound was the most common complication, occurring in 20 cases (9%); this was usually associated with ETV or fenestration failure. The CSF leak was followed by the subsequent development of CSF infection in 4 of these cases. There were no cases of CSF infection directly related to the endoscopic procedure. Venous bleeding from the tumour biopsy sites was relatively common, but of no ultimate significance as the bleeding cleared with intraoperative irrigation in all cases. In 2 cases, prolonged irrigation (approximately 30 minutes) was required before clearing of the CSF was achieved and haemostasis could be confirmed. No arterial injuries occurred and there were no cases hypothalamic injury. There were no perioperative deaths.

Discussion

Neuroendoscopy was originally employed in the early part of the 20th century as a method for treating hydrocephalus, using crude instrumentation. It fell into disuse because of technical limitations at the time, the high mortality of the operations and the introduction of CSF shunts for hydrocephalus. The re-emergence of neuroendoscopy in the modern era due to improved technology and preoperative neuroimaging for surgical planning, combined with the more realistic appraisal of the long-term complications of CSF shunts, has provided a welcome alternative to the conventional management of many complex neurosurgical disorders.

Endoscopic biopsy

In this series, 15 intracranial lesions were biopsied, with 2 inconclusive results obtained, both of which occurred with lesions not well visualised endoscopically. Endoscopic biopsy was found to be a good alternative to stereotactic biopsy, avoiding the risk of deep vascular injury, particularly in the pineal region.

Table 3: Aetiology of hydrocephalus in 2 age-groups.

Age Group	Unknown	Haemorrhage	Infection	MMC*	Tumour	Others	Total
Less than 2 years old	11(30.5%)	3(8%)	10(28%)	8(22%)	2(5.5%)	2(5.5%)	36(100%)
More than 2 years old	17(23%)	4(5%)	14(19%)	10(14%)	27(37%)	1(1.4%)	73(100%)

*MMC - Myelomeningocele

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The risk of sampling error must be kept in mind for all forms of limited biopsy however; therefore the final diagnosis must take into account not only the histological findings but also the radiological appearance of the lesion and the demographic profile of the patient. Endoscopic biopsy usually produces relatively small pathology specimens; therefore the surgeon should attempt to obtain multiple specimens from different sites and from as deep within the lesion as possible. The limited size of the specimen should be taken into account particularly for gliomas, in which grading of the lesion may not be accurate with such small specimens. The risk of significant bleeding from the biopsy site should always be considered; this can be reduced by preoperative planning on MRI and good selection of site intraoperatively. The surgeon should also be prepared for prolonged irrigation with warmed Ringers Lactate should this be necessary.

ETV

The short- and long-term complications of CSF shunting for hydrocephalus have been extensively described; these include haemorrhage, shunt sepsis, overdrainage syndromes, and mechanical dysfunction of the shunt system. The majority of shunted patients will experience a shunt complication given a long enough follow-up period[1,2,3]. As treatment for hydrocephalus, the success rate of ETV is related to the underlying cause of the hydrodynamic disturbance - the best results are seen for patients in whom the obstruction to the ventricular system is clearly visualised, usually as a mass lesion obstructing the aqueduct or posterior third ventricle[4-8]. Although in many cases successful, ETV is not as effective for hydrocephalus caused by subarachnoid haemorrhage or meningitis[4,9-11]. Subgroup analysis in this series supports that contention. It is also argued that ETV success depends on age, with poorer results reported for children under the age of 2 years[12], although this is a matter of some debate[13]. In this series the failure rate of ETV in children under the age of 2 is higher, but the different aetiologies of hydro-cephalus in the age groups must also be considered. Hydrocephalus in this group was more likely to be due to infection, haemorrhage, myelomeningocele or unknown causes, while older children experienced more tumour-related hydrocephalus.

Endoscopic fenestration

Endoscopic fenestration procedures are often effective in relieving the mass effect of intracranial cysts or isolated ventricular compartments, thereby eliminating the need for shunt insertion or craniotomy[14-16]. Even when a shunt is ultimately needed due to obliteration of the normal subarachnoid pathways, endoscopic fenestration may avoid dependence on more than one shunt catheter by opening the isolated compartments into one that is being effectively drained or directing the shunt catheter across multiple membranes with holes along the catheter allowing adequate drainage of all compartments. The key to successful fenestration of symptomatic arachnoid cysts is the creation of a large stoma leading into the basal cisterns. Some arachnoid cysts require cysto-ventriculostomy (opening from the ventricles into the cyst) as well as cysto-cisternostomy (opening the cyst into the basal cisterns). Depending on the anatomy and specific pathology, endoscopic or microsurgical fenestration may be preferred. In this series, 17 of 18 cases requiring fenestration were successfully treated with endoscopy, although 5 cases required re-opening of the stoma. In our experience, secondary closure can be reduced if a large stoma is created by excision of a window in the relevant membrane. In multiseptated ventricles due to infection or haemorrhage, prolonged patency of the stoma is more likely once the acute inflammatory process has resolved.

The other procedures in this series included directed placement (and retrieval) of ventricular catheters and endoscopyassisted craniotomy. Endoscopic assistance may be of help for difficult shunt catheter placement, such as in hydrocephalus with significant intraventricular extension of the tumour, and reservoir catheters can be placed into tumour cysts under direct vision. Endoscopic retrieval of catheters may be required if the proximal catheter of a shunt disconnects and migrates into the ventricle. Craniotomies for deep-seated lesions may be aided by endoscopy for anatomical orientation at depth and inspection of the tumour bed for residual fragments.

The complications of neuroendoscopic surgery have been well described[17,18]. Although largely related to the learning curve, complications may occur even in experienced hands. Procedure-related mortality and major morbidity in other series is most commonly associated with intraoperative arterial injury or hypothalamic injury during ETV[17-19]. Other potential complications include meningitis, endocrinopathies

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and cranial nerve injuries. Venous bleeding is common, especially from biopsy sites, but patience and copious irrigation are usually sufficient for haemostasis, without the need for coagulation. The most common complication in this series was CSF leakage from the wound, which was usually associated with ETV or fenestration failure. The risk of CSF leaks is higher in children, but this may be reduced by avoiding linear scalp incisions over the burrhole, performing small craniotomies in which the bone is replaced, and primary closure of the dura.

In summary, neuroendoscopy provides important alternatives for operative procedures in the management of patients with intracranial space-occupying lesions. There is a strong argument that it is the management of choice in certain circumstances, if available. However, results need to be analysed over a longer period of time. In this series, 60% of children have been spared the long-term risks of CSF shunts with ETV a figure which is considerably higher for patients with visualised obstruction to the ventricular system. Minimally invasive endoscopic biopsy is a useful alternative to the established methods for obtaining histological diagnosis, and fenestration procedures may render multiple shunt insertion a rare necessity. In all circumstances however, although endoscopy may be a useful tool, the best procedure for the specific problem should always be chosen; therefore some situations may still require initial shunting, stereotaxis or craniotomy.

The authors have no competing interests in this publication.

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