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Endoscopic third ventriculostomy versus ventriculoperitoneal shunt in the treatment of obstructive hydrocephalus due to posterior fossa tumors in children

Nasser M. F. El-Ghandour

Abstract

Object This study compares endoscopic third ventriculostomy (ETV) and ventriculoperitoneal shunt (VPS) in the treatment of pediatric patients with marked obstructive hydrocephalus due to midline posterior fossa tumors.

Methods Fifty-three pediatric patients with a midline posterior fossa tumor (32 medulloblastomas and 21 ependymomas) associated with marked hydrocephalus were studied. Patients were divided into two groups: group A (32 patients) operated by ETV with a mean follow-up of 27.4 months and group B (21 patients) operated by VPS with a mean follow-up of 25 months.

Results Both procedures proved to be effective clinically and radiologically. In group A, intraoperative bleeding occurred in two cases (6.2%) and cerebrospinal fluid leakage in one case (3.1%). In group B, shunt infection occurred in two cases (9.4%), one of these two cases died 4.5 months postoperatively from ventriculitis. Subdural collection occurred in two cases (9.4%), epidural hematoma in one case (4.7%), and upward brain herniation in one case (4.7%). Endoscopic third ventriculostomy proved to be superior due to shorter duration of surgery (15 min versus 35 min), lower incidence of morbidity (9.3% versus 38%), no mortality (0% versus 4.7%), and lower incidence of procedure failure (6.2% versus 38%).

Conclusion The shorter duration of surgery, the lower incidence of morbidity, the absence of mortality, the lower incidence of procedure failure, and the significant advantage of not becoming shunt dependent make ETV be recommended as the first choice in the treatment of pediatric patients with marked obstructive hydrocephalus due to midline posterior fossa tumors.

Keywords Endoscopic third ventriculostomy · Obstructive hydrocephalus · Pediatric patients · Posterior fossa tumors · Ventriculoperitoneal shunt

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Introduction

Posterior fossa is a common site for various tumors to occur during childhood. It was estimated that they comprise 54–60% of childhood brain tumors. Medulloblastomas represent approximately 20% of all childhood central nervous system tumors [49]. Ependymomas represent approximately 10% of all reported primary intracranial tumors in children [19]. Neurosurgeons are still divided in their opinions concerning the best way to manage obstructive hydrocephalus due to posterior fossa tumors.

Placement of a shunt was the operative "state of the art" over years [1, 2, 10, 26, 27]. However, the technological advances and changes in the availability of neuroimaging systems have allowed for earlier diagnosis and have led most pediatric neurosurgeons to use a combination of cortico-steroids, direct approach to the tumor, and external ventricular drainage (EVD) [17, 43, 48, 51, 63]. The obstructive nature of the associated hydrocephalus makes internal cerebrospinal fluid (CSF) diversion to be a promising alternative. There are many studies which discuss the role of ETV in the treatment of obstructive hydrocephalus of different etiologies including some cases due to posterior fossa tumors [20, 28, 68], and only few studies specific for posterior fossa tumors in children [8, 55, 58].

Many articles have been published concerning the morbidity and mortality as well as the outcome of both CSF shunts and ETV, but the comparison between both procedures has rarely been addressed in the literature [13, 24, 31, 67]. The purpose of this study is to evaluate the role of ETV as compared to shunting procedure in the management of obstructive hydrocephalus due to posterior fossa tumors in children. This study compares the outcome and morbidity of both procedures in the management of these cases. It is the first study which is specific for midline posterior fossa tumors in pediatric patients with advanced hydrocephalus.

Material and methods

Fifty-three pediatric patients with obstructive hydrocephalus due to posterior fossa tumors were studied during the period between September 2003 and March 2009. The study included only patients with midline posterior fossa tumors (medulloblastomas and ependymomas), whereas cerebellar, brain stem, and cerebellopontine angle tumors were excluded. Cases of medulloblastomas and ependymomas are especially selected due to their vulnerability to cause marked obstructive hydrocephalus and in order to be able to compare homogeneous patients. A full history was taken, and all patients were subjected to a complete neurological examination. Preoperative computed tomography (CT) scan and magnetic resonance (MR) imaging were reviewed with special attention being paid to the degree of ventricular enlargement, the presence of periventricular edema, and location of the tumor. The degree of hydrocephalus (mild, moderate, marked) was defined in all cases based on a preoperative CT scan. The maximum width of the lateral ventricles at the frontal horns was divided by the largest transverse diameter of the skull's internal table, producing a standardized ratio (Evans Ratio or Ventricular Index) [59]. Mild, moderate, and marked ventriculomegaly was designated for ratios of 0.27 to 0.34, 0.35 to 0.40, and >0.40, respectively. A ratio of <0.27 was considered to be normal. All the patients had severe hydrocephalus, whereas patients with mild–moderate hydrocephalus and nonhydrocephalic patients were excluded from the study.

The patients were grouped into two groups: group A included 32 cases operated by ETV and group B included 21 cases operated by VPS. Surgical failure means that the CSF diversion procedure could not be completed successfully. The patients were assessed postoperatively clinically regarding any improvement or worsening of preoperative symptoms and occurrence of new neurological deficits or postoperative complications. Follow-up CT scan was done for all the patients 3–5 days postoperatively (unless needed earlier), and it was examined regarding any improvement of hydrocephalus or periventricular edema or any change in size of subarachnoid space. Magnetic resonance imaging with CSF flow analysis and cine flow images were obtained prior to tumor excision in 12 cases included in group A. The tumor was directly approached 1–2 weeks after the CSF diversion procedure.

Any recurrence of intracranial hypertension symptoms among the follow-up period was considered to be an indication for repeating the CT scan and/or MR imaging. Any recurrence of hydrocephalus was considered to be a postoperative failure and it was an indication to perform a revision procedure. Revision means repeating the same CSF diversion procedure which was performed initially. The follow-up period ranged from 6.5 months to 6 years with a mean of 27.4 months in group A, and from 4.5 months to 5 years with a mean of 25 months in group B. Any documented mortality was recorded to be either hydrocephalus-related or nonhydrocephalus-related.

Data were collected and summarized in both groups regarding the duration of surgery, improvement of symptomatology, improvement of hydrocephalus, incidence of surgical failure, incidence of surgical complications, postoperative deficits, postoperative failure, incidence of shunt-free patients, and incidence of revision of the CSF diversion procedure. Data of both groups were analyzed and compared using the Student's t test, chi-square test, and Kaplan–Meier survival analysis with logrank test.

Demographic data

Among 32 patients included in group A, 18 patients were males and 14 were females. Their age ranged from 2 to 12 years with a mean of 6.5 years. In group B, 12 patients were males and nine patients were females. Their age ranged from 2.5 to 11.5 years with a mean of 7.2 years. The most common symptoms were increased intracranial pressure (ICP) symptoms in the form of headache, vomiting, and/or blurring of vision which were present in all patients included in both groups. Gait ataxia was present in 10 out of 32 patients (31.2%) included in group A, and in 8 out of 21 patients (38%) included in group B. The incidence of sixth nerve palsy, deteriorated conscious level, bulbar symptoms were 28.1%, 12.5%, 6.2%, respectively, in group A, compared to 28.5%, 9.4%, 14.2%, respectively, in group B. The duration of symptoms ranged from 1 to 24 weeks with a mean of 14.4 weeks in group A, and from 1.5 to 36 weeks with a mean of 18.6 weeks in group B (Table 1). The posterior fossa tumor was midline in all the patients included in both groups and it was associated with severe hydrocephalus.

Table 1 Preoperative findings in 53 pediatric patients with obstructive hydrocephalus due to posterior fossa tumors

Preoperative findings	ETV group	VPS group	p value
Number of patients	32	21	–
Age in years (mean ± SD)	6.5 (±2.7)	7.2 (±2.6)	0.3
Sex (males: females)	18:14	12:9	0.8
Duration of symptoms in weeks (mean ± SD)	14.4 (±8.1)	18.6 (±12.9)	0.1
Symptomatology			
Intracranial hypertension	32 (100%)	21 (100%)	–
Gait ataxia	10 (31.2%)	8 (38%)	0.8
Sixth nerve palsy	9 (28.1%)	6 (28.5%)	0.7
Deteriorated consciousness	4 (12.5%)	2 (9.4%)	0.9
Bulbar palsy	2 (6.2%)	3 (14.2%)	0.6

Results

Group A

This group consisted of 32 pediatric patients with obstructive hydrocephalus due to posterior fossa tumors (20 medulloblastomas, 12 ependymomas) who were operated by ETV. The procedure time ranged from 10 to 30 min with a mean of 15 min. Arterial bleeding occurred in two patients (6.2%), it was minor, did not necessitate termination of the procedure, and it stopped with continuous irrigation. The procedure was completed successfully, and an external ventricular drain was left for few days; however, both patients needed a repeated ETV later on.

The intracranial hypertension symptoms improved postoperatively in 31 out of 32 cases (96.9%), ataxia improved in four out of ten cases (40%), sixth nerve palsy improved in six out of nine cases (66.7%). All the four cases presented with deteriorated conscious level became fully conscious (100%) immediately postoperatively. Postoperative CT scan showed mild improvement of hydrocephalus in 28 out of 32 cases (87.5%). The presence of CSF flow void across the ventriculostomy with an apparent systolic/diastolic flow in postoperative MRI confirmed its patency.

Cerebrospinal fluid leakage occurred in one patient (3.1%), and it stopped spontaneously on the 4th postoperative day. Gross total tumor excision was performed in 26 cases (81.3%), whereas in the remaining six cases (18.7%), the tumor was excised subtotally (Table 2). During surgery for excision of the posterior fossa tumor, the dura was lax enough in all the cases and there was no need for intraoperative CSF tapping. Retraction of the cerebellum was surprisingly easy and harmless, which gave us a good exposure and facilitated tumor dissection in most of the cases. Recurrence of hydrocephalus occurred in two patients at 6.5 and 14 months postoperatively, respectively (both patients had intraoperative bleeding), and a re-ventriculostomy was performed. No permanent procedure related morbidity

or mortality was seen in this group of patients. Among the mean duration of follow-up of this group (27.4 months), all the 32 patients (100%) were shunt free.

Group B

This group consisted of 21 pediatric patients with obstructive hydrocephalus due to posterior fossa tumors (12 medulloblastomas, 9 ependymomas) who were operated by VPS. The procedure time ranged from 20 to 60 min with a mean of 35 min. The intracranial hypertension symptoms improved postoperatively in all cases (100%), ataxia improved in two out of eight cases (25%), and sixth nerve palsy improved in three out of six cases (50%). Both patients presented with deteriorated conscious level became fully conscious (100%) immediately postoperatively. Postoperative CT scan showed marked improvement of hydrocephalus in all cases (100%).

Shunt infection occurred in two patients (9.4%, Table 3), 1.5 and 5.5 months postoperatively, respectively. Subdural collection occurred in two cases (9.4%), it was bilateral and was evacuated surgically in one case because it had a significant mass effect and led to clinical symptoms. It was unilateral and resolved conservatively in the other case. Epidural hematoma occurred in one case (4.7%) and it was surgically evacuated. Deterioration of consciousness and Parinaud's syndrome occurred in one case (4.7%), it was attributed to upward herniation and tumor excision was performed in this case on an urgent basis, and the patient recovered completely. The tumor was totally excised in 14 cases (66.7%), whereas in the remaining seven cases (33.3%), the excision was subtotal. Two patients (9.4%) developed pseudomeningocele after tumor excision, and it resolved spontaneously after shunt revision.

Among the mean follow-up duration of this group (25 months), postoperative failure was encountered in eight cases. Shunt revision was performed 15 times in these eight patients. The cause of first failure was proximal occlusion in three cases, distal occlusion in two cases, infection in

Table 2 Surgical findings in 53 pediatric patients with obstructive hydrocephalus due to posterior fossa tumors

Surgical findings	ETV group (32 cases)	VPS group (21 cases)	P value
Duration of surgery in minutes (mean ± SD)	15.0 (±5.8)	35.4 (±13.8)	0.000
Tumor type			
Medulloblastoma	20 (62.5%)	12 (57.1%)	0.9
Ependymoma	12 (37.5%)	9 (42.9%)	0.9
Extent of resection			
Total	26 (81.3%)	14 (66.7%)	0.3
Subtotal	6 (18.7%)	7 (33.3%)	0.3

two cases, and disconnection in one case. The number of revisions per patient among these eight cases with postoperative failure was 1.8, and the mean duration which lapsed between the VPS procedure and the first revision procedure was 5.6 months (Table 4). All the 21 patients (100%) included in this group became shunt dependent. There is only a single case of mortality (4.7%), and it was hydrocephalus-related. This is one of the two patients with shunt infection, who developed ventriculitis and died 4.5 months postoperatively.

Discussion

Cerebrospinal fluid shunts

The development of hydrocephalus in children with posterior fossa tumors is one of the main factors influencing the outcome. Children are very sensitive to ICP elevation, thus management of hydrocephalus has an utmost priority before any considerations are given to the surgical approach of the posterior fossa tumor itself. It is claimed that a precraniotomy shunt provides improvement in the patient's physiological condition, a "slack posterior fossa," and a smooth postoperative course [2, 50]. In one series [2], the operative mortality rate was decreased with preoperative

shunting. However, following tumor excision, the obstructive component of the hydrocephalus is relieved in most patients, and the flow of CSF will be restored, thus the shunt will be no more necessary, but the patient now becomes shunt dependent. As long-term survival becomes more frequent in children with posterior fossa tumors, issues pertaining to the quality of life, such as postoperative shunt dependency become increasingly important and must be taken into consideration. Moreover, placement of shunt is a blind procedure and shunt systems are prone to several complications.

External ventricular drainage

Improvements in the availability and type of neuroimaging systems have resulted in establishing a markedly earlier diagnosis. This, coupled with the extensive list of potential complications associated with ventricular shunting in this patient population, resulted in another strategy recommending the use of corticosteroid therapy, early surgery, and EVD [17, 43, 48, 51, 63]. Nevertheless, EVD is associated with a significant risk of infection [59] and hemorrhage [58]. Moreover, such treatment might not be appropriate in young children with advanced hydrocephalus because these patients usually need a permanent diversion procedure. It was estimated that children who have advanced hydroceph-

Table 3 Morbidity and mortality in 53 pediatric patients with obstructive hydrocephalus due to posterior fossa tumors

Morbidity and mortality	ETV group (32 cases)	VPS group (21 cases)	p value
Morbidity (Total)	3 (9.3%)	8 (38%)	0.03
Bleeding	2 (6.2%)	0	–
CSF leak	1 (3.1%)	0	–
Infection	0	2 (9.4%)	–
Subdural collection	0	2 (9.4%)	–
Epidural hematoma	0	1 (4.7%)	–
Upward herniation	0	1 (4.7%)	–
Pseudomeningocele	0	2 (9.4%)	–
Mortality (Total)	0	1 (4.7%)	0.8
Hydrocephalus-related	0	1 (4.7%)	0.8
Nonhydrocephalus-related	0	0	–

Table 4 Results of outcome in 53 pediatric patients with obstructive hydrocephalus due to posterior fossa tumors

Results of outcome	ETV group (32 cases)	VPS group (21 cases)	*p* value
Improvement of symptoms			
I.C. hypertension	31/32 (96.9%)	21/21 (100%)	0.2
Gait ataxia	4/10 (40%)	2/8 (25%)	0.8
Sixth nerve palsy	6/9 (66.7%)	3/6 (50%)	0.9
Conscious level	4/4 (100%)	2/2 (100%)	–
Bulbar symptoms	0/2 (0%)	0/3 (0%)	–
Improvement of hydrocephalus (in postoperative C.T. scan)	28/32 (87.5%)	21/21 (100%)	0.2
Duration of follow-up in months (mean ± SD)	27.4 (±20.5)	25 (±19.7)	0.6
Postoperative failure	2 (6.2%)	8 (38%)	0.003
Time to first failure in months (mean ± SD)	10.3 (±5.3)	5.6 (±4.6)	0.2
Shunt-free patients	32 (100%)	0	–
Shunt-dependant patients	0	21 (100%)	–
Number of revisions in postoperative failure patients (mean ± SD)	1	1.8 (±0.8)	0.2

alus and children who are younger than 3 years of age had persistent hydrocephalus which required a postoperative shunt in about 80% of cases [16]. Approximately, one third of patients overall will eventually require placement of a shunt [41]. Many factors have been reported to be associated with required shunt placement including a young age (<10 years), midline tumors, more severe ventricular enlargement at diagnosis, incomplete tumor resection, CSF-related infection, prolonged use of EVD, cadaveric dural grafts, and persistent pseudomeningocele [3, 9, 12, 14, 41, 48, 57].

Endoscopic third ventriculostomy

Jones et al. [33] appear to be the first who attempted ETV prior to resection of a case of posterior fossa tumor (medulloblastoma) [34]. The procedure was successful in controlling the intracranial hypertension, but the patient experienced increased ataxia. We did not observe this phenomenon in any of our patients. The rational basis of ETV is provided by the obstructive nature of hydrocephalus due to the presence of blockage of CSF pathway at level of the fourth ventricle outlets or at the aqueduct of Sylvius. Endoscopic third ventriculostomy creates a communication between the ventricular system and the subarachnoid spaces at the level of floor of the third ventricle (Fig. 1a).

Operative findings

An argument was existing regarding the feasibility of performing ETV in obstructive hydrocephalus due to posterior fossa tumors, which was believed to be technically more difficult than in cases of congenital aqueduct stenosis. This is because the tumor bulk may displace the brain stem forward and obliterate the interpeduncular cistern, thus making ETV impossible. Our findings support what was previously reported [58], that posterior fossa tumors tend to elevate the brain stem as they push it forward. Thus, the floor of the third ventricle is displaced largely above the posterior clinoid, making enough room for the fenestration. Endoscopic third ventriculostomy was technically easy and successful in all the cases (100%) included in the present study, and this makes us conclude that the presence of anatomical distortion of the floor of the third ventricle due to posterior fossa tumors does not make the ETV procedure technically more difficult than in other cases. However, a recent study reported abandonment of ETV due to severely distorted anatomy in 1 out of 37 pediatric patients (2.7%) with posterior fossa tumors [8]. The mean duration of surgery in the ETV group was 15 min compared to 35 min in the VPS group (*p*<0.01).

Operative outcome

In the current study, both procedures (ETV and VPS) proved to be effective clinically and radiologically. Improvement of intracranial hypertension symptoms occurred in 96.9% of ETV group and in 100% of the VPS group. Postoperative CT scan showed improvement of hydrocephalus in 87.5% of ETV group (Fig. 1b and c) and in 100% of VPS group, however, the decrease in ventricular size was marvelous in the VPS group. Another two studies [28, 68] have reported a significant experience in 17 and 21 cases, respectively, both with a 76% success rate of ETV in controlling hydrocephalus. More recent studies reported better results, in a study including 67 pediatric patients with
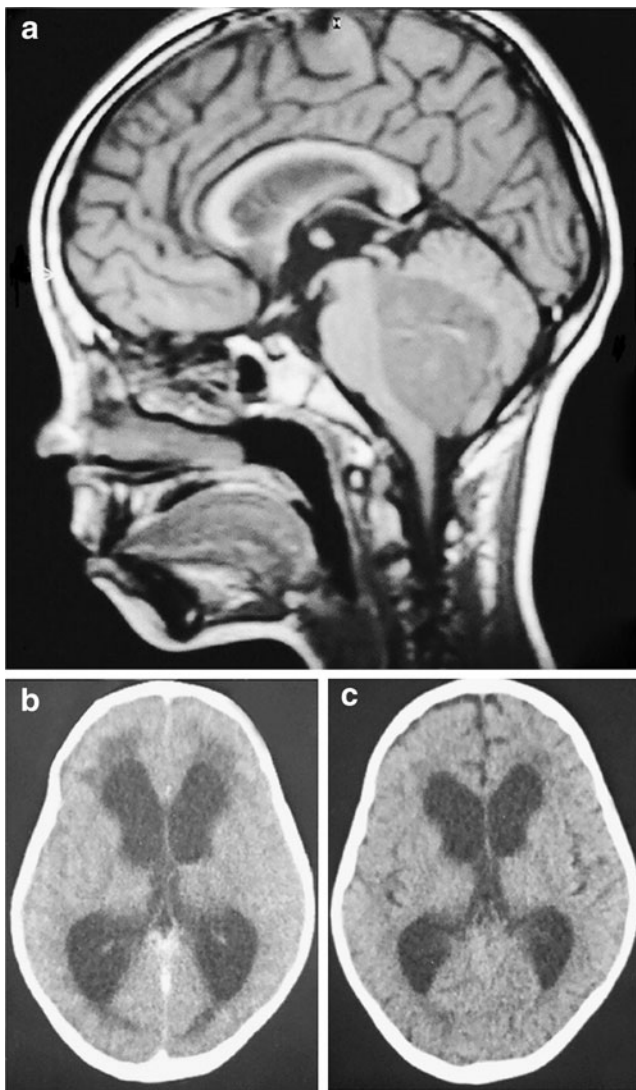
Fig. 1 a Magnetic resonance imaging T1-weighted *sagittal view* of a case of posterior fossa tumor (medulloblastoma), demonstrating communication between third ventricle and prepontine cistern after ETV. b Preoperative axial CT scan image showing severe obstructive hydrocephalus due to posterior fossa tumor. The presence of massive periventricular edema signifies acutely occurring hydrocephalus. c Postoperative axial CT scan image obtained 3 days after ETV showing mild reduction in ventricular size, resolution of periventricular edema, and opening of subarachnoid space

obstructive hydrocephalus due to posterior fossa tumors operated by ETV, immediate postoperative symptomatic resolution occurred in 98.5% of patients [58]. In another series of 20 pediatric patients with posterior fossa tumors, ETV successfully resolved the intracranial hypertension before tumor removal in 95% of patients [55].

I believe that obstructive hydrocephalus secondary to posterior fossa tumors in children with good absorption of CSF from the subarachnoid space is a good selection for ETV. This is completely different from the long standing hydrocephalus associated with thickened third ventricular

floor, possible significant anatomical anomalies [46, 53], and nonoptimal CSF absorption from the subarachnoid space in cases of congenital hydrocephalus, which undoubtedly will adversely affect the outcome and increase the incidence of morbidity. Although ETV achieves complete clinical recovery without reducing ventricular size in cases of aqueduct stenosis [42, 64], it achieves both clinical recovery and a definite improvement of hydrocephalus in pediatric patients with posterior fossa tumors.

Morbidity and mortality

The placement of a shunting device entails significant long-term risk of infection and malfunction. The development of shunt infection in a pediatric patient represents a particularly morbid condition with up to 20% infection related mortality [71]. A 22% infection rate per patient and 6% infection rate per procedure has been reported over a 10-year period study [4]. Migration and dissemination of tumor cells via shunt catheter to the peritoneal cavity is possible in both medulloblastomas and ependymomas, an incidence of up to 19% of extracranial metastasis was reported after shunting [27]. Overdrainage with possible occurrence of subdural, extradural, or intracerebral hematomas [29], upward transtentorial herniation [17], and intratumoral hemorrhage [70] may occur following shunting in advanced hydrocephalus. A 10% rate of upward herniation has been reported in cases of posterior fossa tumors subjected to preliminary shunting [17].

The overall complication rate of ETV in the literature is about 5–10% [65]. It includes uncontrollable bleeding, memory disturbance from injury to the fornix [23, 33], focal neurological deficits, third nerve palsy [33], and hypothalamic dysfunction [40]. Cerebrospinal fluid leakage was the commonest complication in one study [56].

In the current study, intraoperative bleeding was an important predictor for a bad outcome among the ETV group patients. Its incidence among this group was 6.2% compared to 0% in the VPS group. Both patients who were subjected to arterial bleeding needed a re-ventriculostomy operation later due to postoperative closure of the initial ventriculostomy. We agree with what was reported previously that increased experience in endoscopy leads to a reduction of surgery-related complications [32].

Postoperative complications in the VPS group proved to be more fatal than in the ETV group. Postoperative complications in the ETV group included CSF leak in one patient (3.1%), it was transient and was resolved conservatively. On the other hand, postoperative shunt infection occurred in two cases (9.4%) and it ended in mortality due to ventriculitis in one case (4.7%), and the other case was subjected to three shunt revision procedures. Subdural collection occurred in two cases (9.4%) after VPS (one of

these two cases was bilateral and needed surgical evacuation), one case (4.7%) developed epidural hematoma which was evacuated surgically, and one case (4.7%) suffered a presumed "upward herniation" but recovered completely after urgently excising the posterior fossa tumor.

The increased incidence of subdural collection, epidural hematoma, and upward herniation in group B may be related to the marked decrease in ventricular size encountered after VPS, which makes us conclude that ETV is the more physiological procedure. After tumor excision, pseudomeningocele occurred in two cases (9.4%) and it was resolved after performing a shunt revision procedure. The overall incidence of complications was 9.3% in group A compared to 38% in group B ($p<0.05$).

In a study including 20 pediatric patients with obstructive hydrocephalus due to posterior fossa tumors operated by ETV, there was one intraoperative complication due to severe intraventricular bleeding (5%), which resulted in a permanent morbidity. After tumor excision, peudomeningocele occurred in three cases (15%), and CSF leak occurred in one case (5%) [55].

Other studies did not report any mortality or permanent morbidity related to the ETV procedure in the treatment of obstructive hydrocephalus due to posterior fossa tumors in children [8, 58]. Among a series of 67 patients [58], only one patient suffered "brain herniation" and made a complete recovery after immediate tumor removal. Complications included CSF leak (3%), subdural collection (2%), pseudomeningocele (2%), and epidural hematoma (1%). Another study including 37 patients [8] reported CSF infection and meningitis in two cases (5.4%, both resolved with antibiotics), and bleeding in one case (2.7%, spontaneously resolved with no sequelae).

In a study comparing both procedures in the treatment of pediatric obstructive hydrocephalus where the ETV group included 24 patients, and VPS group included 31 patients, subdural hematoma occurred in three cases operated by ETV and in one case operated by VPS. There were three unrelated deaths, one in the ETV group and two in the VPS group; in all cases they were at the end point of tumor progression [13].

Failure of the procedure

There is large amount of variability in the literature concerning the failure rate of both procedures in the management of pediatric obstructive hydrocephalus. For ETV, the failure rate ranges from 8% to 69% [6, 7, 11, 18, 21, 24, 25, 31, 33, 35, 37, 38, 44, 47, 52, 60, 61, 67, 72, 74] or from 8% to 47% when the series including infants are excluded [6, 7, 18, 21, 25, 31, 35, 38, 60]. When the follow-up is greater than 2 years, the lowest failure rate is 15% [74]. For VPS, the failure rate ranges between 27%

and 70% [5, 24, 36, 54, 66, 67, 69, 73]. When analyzing studies with follow-up greater than 2 years, the failure rate ranges between 56% and 70% [24, 54, 66, 67, 69]. The failure rate is on the higher side when infants are considered (63%) [54].

In a series of 20 pediatric patients with obstructive hydrocephalus due to posterior fossa tumors, ETV had been successful in controlling hydrocephalus in 16 patients (80%). Of the four failures (20%), one patient (aged 2 months) had intraoperative bleeding. The other three cases had relief of intracranial hypertension symptoms preoperatively and developed hydrocephalus after posterior fossa surgery (7 days, 16 days, and 2 months, respectively). Failure of ETV in these four patients was treated by VPS insertion. Among a mean follow-up period of 21 months (range 5–39 months), 13 patients (65%) were shunt free [55].

In a study including 67 pediatric patients with posterior fossa tumors operated by ETV, the procedure was technically successful in 65 patients (97%). In two patients (3%), ETV had to be aborted due to poor visibility: one because of a mild intraventricular hemorrhage and the other because of markedly xanthochromic CSF. This later patient underwent an immediate posterior fossa tumor resection and a repeated ETV 10 days later. Four patients (6%) ultimately required the insertion of a VPS for the treatment of progressive hydrocephalus. The incidence of shunt-free patients was 94% among a mean follow-up period of 26 months [58].

Among 37 pediatric patients with posterior fossa tumors, preresectional ETV was successful in controlling hydrocephalus in 32 cases (86.5%). In five cases (13.5%), ETV failed with redevelopment of hydrocephalus postoperatively at some point over the course of follow-up (up to 7.5 years) [8]. It has been concluded that ETV has a curative effect on intracranial hypertension and a prophylactic effect by preventing the development of hydrocephalus after tumor removal. In cases where CSF has caused spread of tumor at presentation and chemotherapy has to be undertaken prior to tumor excision, ETV is considered to be a better choice than VPS because any need for reoperation related to shunt failure during the phase of bone marrow transplantation represents a life-threatening situation [58].

Timing of ventriculostomy

The role of ETV in the management of persistent hydrocephalus following excision of posterior fossa tumors has already been confirmed with a success rate reported to be 90% in one study [62], and 81% in another study [45]. However, some neurosurgeons debated whether routine preoperative ETV is actually necessary claiming that the low rate of persistent hydrocephalus does not justify

adopting a routine preoperative ETV [21, 45]. Others recommend its preresectional use in patients with medulloblastomas and ependymomas claiming that tumor resection alone has a low cure rate of hydrocephalus [15]. An incidence between 10% and 62% of persistent or progressive hydrocephalus after primary tumor resection without CSF diversion has been reported in the literature [21, 30, 39, 45]. Re-establishing the patency of CSF flow at the time of tumor resection is not always enough to ensure that postoperative CSF diversion will not be needed [12].

In my opinion, ETV should be performed prior to tumor excision in those patients at particularly high risk of developing postoperative hydrocephalus, such as pediatric patients who have midline posterior fossa tumors associated with marked hydrocephalus. It is also a good choice for patients presenting with acute hydrocephalus to many centers in which emergency surgery for posterior fossa tumors could not be easily performed. In such case, relieving symptoms and signs of acute hydrocephalus allows definitive tumor resection to occur on an elective basis at a time when all experienced personnel are available.

Comparing both procedures

The comparison between ETV and cerebrospinal fluid shunts has rarely been addressed in the literature. In a Swiss series of pediatric patients with obstructive hydrocephalus of different etiologies, where 24 cases (four of them had posterior fossa tumors) were managed by ETV with a mean follow-up of 45 months and 31 cases (five of them had posterior fossa tumors) were managed by VPS with a mean follow-up of 57 months, 33% of patients operated by ETV needed a revision, compared to 52% of the VPS group. The number of revisions per patient was higher for VPS group. The failure rates at 2, 5, and 10 years were 26%, 26%, and 30%, respectively, for the ETV group, compared to 34%, 42%, and 51%, respectively, for the VPS group. The mean time until first revision was 18 months for ETV, and it was 24 months for VPS [13]. Failure of ETV in such cases might be due to some technical difficulties such as small space in front of the basilar artery or arachnoid membranes lower down the clivus. The pathophysiology of the associated hydrocephalus is not completely understood, and some resorption malfunction might be also added to the obstructive etiology [22].

Among 32 patients operated by ETV included in the current study, recurrence of hydrocephalus occurred in two patients at 6.5 and 14 months postoperatively, respectively (both patients had intraoperative bleeding), and a repeated ETV was performed. Among 21 patients operated by VPS, shunt revision was performed 15 times in 8 patients. The incidence of recurrence of hydrocephalus was 6.2% among
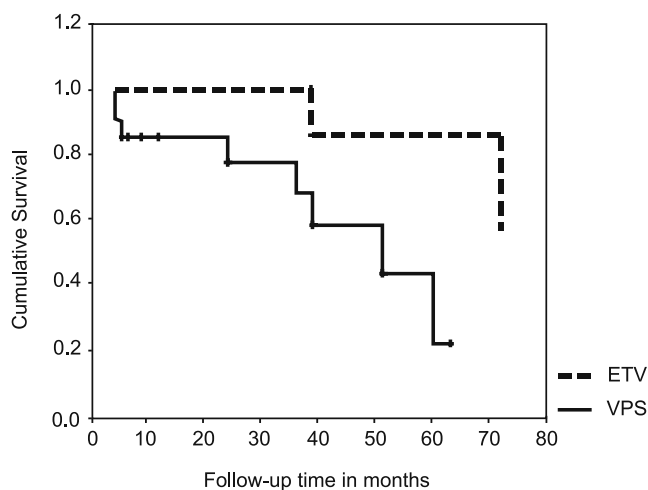

Fig. 2 Kaplan–Meier survival curve plotted for ETV (group A) and VPS (group B) showing a more progressive decrease of the cumulative survival in the VPS group. There is a higher mean survival time for ETV as compared to VPS (the logrank test is highly significant, $p < 0.01$)

ETV patients compared to 38% among VPS patients ($p < 0.01$). All the 32 patients (100%) included in group A were shunt free, among the mean follow-up duration of this group (27.4 months). All the patients (100%) included in group B were shunt dependent among the mean follow-up duration of this group (25 months). The number of revisions per patient (among the eight cases with postoperative failure included in group B) was 1.8, and the mean duration which lapsed between the VPS procedure and the first revision procedure was 5.6 months. Kaplan–Meier survival curve for both groups shows a more progressive decrease of the cumulative survival in the VPS group. The mean survival time in the ETV group is higher than the VPS group (the logrank test is highly significant, $p < 0.01$; Fig. 2).

Our results emphasize that ETV is superior to shunt systems in terms of safety, simplicity, and resultant outcome. It renders the patient independent from a failure-prone shunt system, offers a good opportunity to become shunt free, and makes safe total resection of the tumor feasible. By performing ETV, we gained the benefits of shunt systems in relieving increased ICP but without its acute or long-term postoperative complications. It is a simple, minimally invasive, and physiological method for bypassing obstruction in CSF circulation due to posterior fossa tumors in children.

Conclusion

The shorter duration of surgery, the lower incidence of morbidity, the absence of mortality, the lower incidence of

procedure failure of endoscopic third ventriculostomy as compared to ventriculoperitoneal shunt, and the significant advantage of not becoming shunt dependent make endoscopic third ventriculostomy to be recommended as the first choice in the treatment of pediatric patients with marked obstructive hydrocephalus due to midline posterior fossa tumors. It is a preliminary, simple, safe, effective, physiological, minimally invasive procedure for the relief of elevated intracranial pressure before direct tumor removal.

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