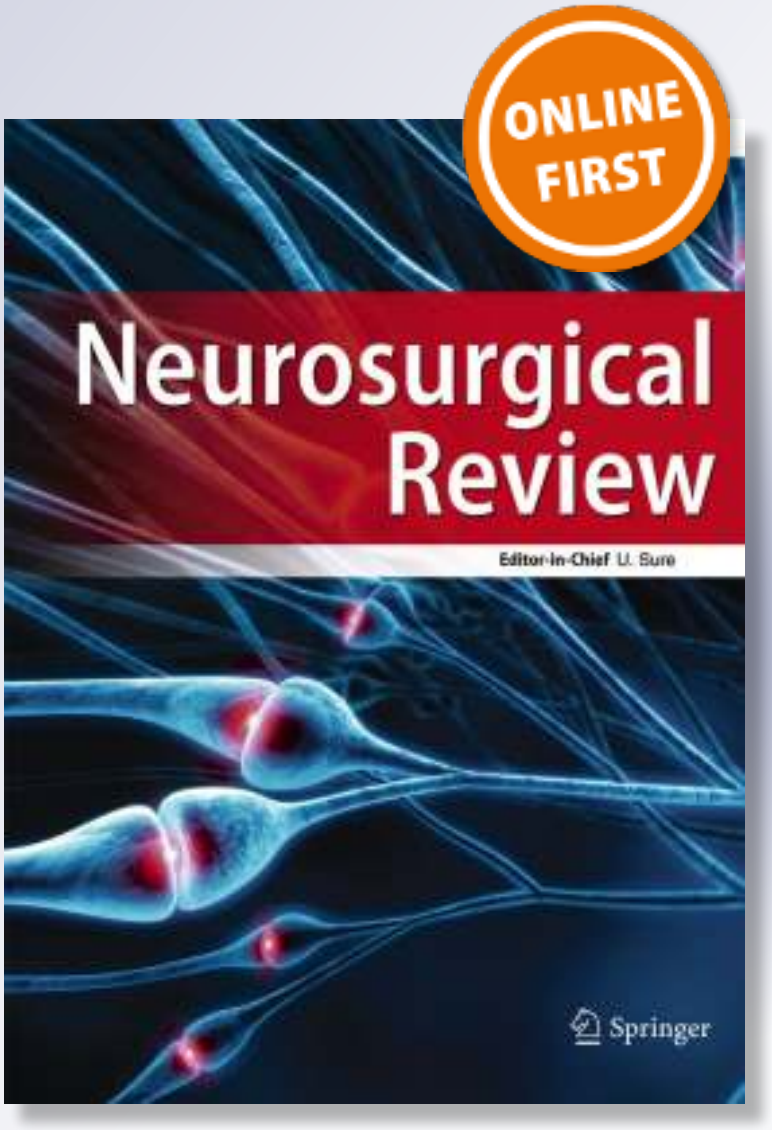
Neuroendoscopic biopsy: analysis of a series of 80 patients

Ángela Ros-Sanjuán, Bienvenido Ros-López, Guillermo Ibáñez-Botella, Miguel Domínguez-Páez, Antonio Carrasco-Brenes, et al.

Neurosurgical Review

ISSN 0344-5607

Neurosurg Rev
DOI 10.1007/s10143-018-1046-x



Springer

Neurosurgical Review
https://doi.org/10.1007/s10143-018-1046-x

ORIGINAL ARTICLE

Neuroendoscopic biopsy: analysis of a series of 80 patients

Ángela Ros-Sanjuán[1] · Bienvenido Ros-López[1] · Guillermo Ibáñez-Botella[1] · Miguel Domínguez-Páez[1] · Antonio Carrasco-Brenes[1] · Miguel Ángel Arráez-Sánchez[1]

Received: 26 June 2018 / Revised: 27 October 2018 / Accepted: 29 October 2018

Abstract

Neuroendoscopy enables diagnostic biopsy of intraventricular and/or paraventricular tumors and the simultaneous treatment of associated hydrocephalus in selected cases. The objective of this paper was to analyze the effectiveness and safety of this procedure. This retrospective study included 80 patients between 2 months and 78 years old diagnosed with intraventricular and/or paraventricular expansive lesion who underwent neuroendoscopic biopsy from 2004 to 2016. Collected variables were gender, age at diagnosis, clinical presentation, tumor location, surgical technique, management of hydrocephalus, pathological findings, procedure-related complications, and follow-up time. Neuroendoscopic biopsy was performed in 80 patients. Mean age at diagnosis was 27 years, and 52.5% were men. According to the Depreitere Classification, 71 were level I (conclusive diagnosis), 1 level III (problematic categorization), and 8 level IV (non-interpretable diagnosis). The most frequent diagnosis was grade I astrocytoma (14%). Diagnostic success per patient was 88.7%. Sixty-nine patients had hydrocephalus at diagnosis, 37 of whom were treated with endoscopic third ventriculostomy (ETV), with septostomy (SPT) in 14, and only SPT in 4. Twenty-eight patients underwent ventricular peritoneal shunt (VPS), with SPT in 20. The ETV success rate was 70.9%. The complication rate per patient was 11%: five patients presented intraventricular hemorrhage, three of whom died; one patient presented cerebrospinal fluid fistula; three presented transient oculomotor impairment. Postoperative follow-up was from 1 month to 12.4 years (mean 45 months). Neuroendoscopy is an effective procedure for the pathological diagnosis of intraventricular and paraventricular tumors, allowing the treatment of associated hydrocephalus. Nevertheless, it is not exempt from serious complications and requires proper training.

Keywords Neuroendoscopic biopsy · Endoscopic third ventriculostomy · Ventriculoperitoneal shunt · Neuroendoscopy

✉ Ángela Ros-Sanjuán
rossanjuanangela@gmail.com

Bienvenido Ros-López
broslopez@yahoo.es

Guillermo Ibáñez-Botella
gibanezb@telefonica.net

Miguel Domínguez-Páez
dr.dominguez@institutoarraez.com

Antonio Carrasco-Brenes
antoniocarrasco87@gmail.com

Miguel Ángel Arráez-Sánchez
marraezs@commalaga.com

[1] Neurosurgery Department, Hospital Regional Universitario, University of Malaga, Av. Carlos Haya, s/n 29010 Málaga, Spain

Introduction

Neuroendoscopy is a minimally invasive procedure that offers advantages over classic approaches in terms of morbidity, cost, surgical time, and return to daily life [7, 22, 31, 33, 34]. Management of certain intraventricular and/or paraventricular tumors does not require aggressive surgical treatment, and thus, neuroendoscopy may be the only surgical procedure needed [5, 21]. According to the literature, the diagnostic success rate of endoscopic biopsy varies between 61% and 100%, while the success rate of endoscopic third ventriculostomy (ETV) in tumor pathology is between 70% and 80% [5, 22]. The objective of this study was to analyze the effectiveness and safety of this procedure in our series of patients.

Published online: 07 November 2018

Material and methods

Patients and variables collected

A retrospective descriptive study was conducted in a series of 80 patients between the ages of 2 months and 78 years diagnosed with a solid and/or cystic intraventricular and/or paraventricular tumor who underwent neuroendoscopic surgery between 2004 and 2016 for biopsy and treatment of associated hydrocephalus. Patients diagnosed with colloid cyst were excluded. The following variables were collected: gender, age at diagnosis, clinical presentation, tumor location, surgical technique, management of associated hydrocephalus, pathological findings, complications arising from the endoscopic procedure, and follow-up time. Time of development was classified according to the symptoms as acute (< 1 week), subacute (< 1 month), or chronic (> 1 month). Tumor location was divided into four groups according to whether they were located in the lateral ventricle (1), anterior/middle third of the third ventricle or diencephalic region (2), posterior part of the third ventricle/pineal region (3), and a fourth group of extensive tumors (4) encompassing those diffuse infiltrative lesions that affected different adjacent neural structures or occupied more than one ventricular compartment. Patient follow-up was recorded in months of survival from the intervention to last visit, or death. The success of the ETV, associated or not with septostomy (SPT), was defined as the absence of another intervention until the end of follow-up, with a minimum period of 6 months after the procedure.

Endoscopic technique

All procedures were performed under general anesthesia, in the supine position with the head in a neutral, slightly flexed position and fixed to a Mayfield craniostat, except in pediatric patients where the horseshoe headrest was preferred. A rigid endoscope was used with a diameter of 8 mm and one working channel with a 0° viewing angle (Aesculap model by B. Braun DG and GAAB model by Karl Storz GmbH & Co. KG). In most cases, a right precoronal burr hole was performed to enable treatment of the hydrocephalus and to collect specimens. To biopsy lesions of the posterior half of the third ventricle, a trajectory was made with a burr hole 2–4 cm anterior to the coronal suture. Ringer's solution was used for irrigation. First, endoscopic procedures were undertaken to restore cerebrospinal fluid (CSF) circulation, via ETV and/or SPT, and second, endoscopic biopsy or resection of the lesion subsequent to biopsy collection. ETV was performed by mechanical perforation and posterior dilation of the stoma with a number 4 Fogarty balloon in adults and a number 3 and/or 4 in pediatric patients. In 15 patients, a navigation system (BrainLAB, Inc. or Medtronic) was used to optimize the surgical trajectory. For patients without hydrocephalus, navigational guidance and precannulation with a standard ventricular catheter was used. In some cases, continuous irrigation with warm lactated Ringer's solution is necessary to avoid collapse of the ventricles. An irrigation pump with pressure control is used. It is important to bear in mind that continuous irrigation can lead to insufflation of the ventricular compartment and subsequent elevation in ICP. In this regard, the patency of an egress portal must be maintained at all times during the procedure. Once the tumor is approached, an avascular region of the mass is identified and biopsied with cupped forceps. Samples are taken from multiple sites. Sampling is performed with forceps that allow the 360° torque, in the clock needle direction and, on the contrary, to uninsert without damage. Coagulation of the tumor surface is avoided until biopsies have been obtained. Ventriculoperitoneal shunt (VPS) was the first option for treatment of hydrocephalus in patients in whom ETV was not technically possible due to occupation of the anterior portion of the third ventricle. Examples are shown in Fig. 1.

Classification of the accuracy of the pathological findings

The accuracy of the histopathological findings according to WHO 2007 Classification of Tumors of the Central Nervous System was evaluated using the Depreitere Classification [9] on a four-level scale: level I, fully diagnostic; level II, diagnostic with some reservation; level III, pathological categorization problematic; and level IV, not interpretable.

Results

Clinical data

Of the total of 80 patients, 38 were women and 42 were men. Twenty-five were pediatric patients, ranging in age from 2 months to 14 years. The mean age at diagnosis was 27 years. The most frequent clinical presentation was intracranial hypertension (93%). Half of the cases (40 patients) had chronic clinical signs, with associated behavioral disturbance, cervical pain, dizziness, or speech disturbance. Seventeen patients also had associated focal neurological deficits, and six had seizures. A total of 81 endoscopic procedures were performed. One pediatric patient underwent a second endoscopic biopsy, the first of which failed due to bleeding that made it impossible to collect a specimen. The follow-up period was from 1 month to 12.4 years, with a mean follow-up time from intervention to June 2017 of 45 months. During follow-up, of the 80 patients, 23 died and 6 were lost to follow-up due to transfer to other centers and/or home country.

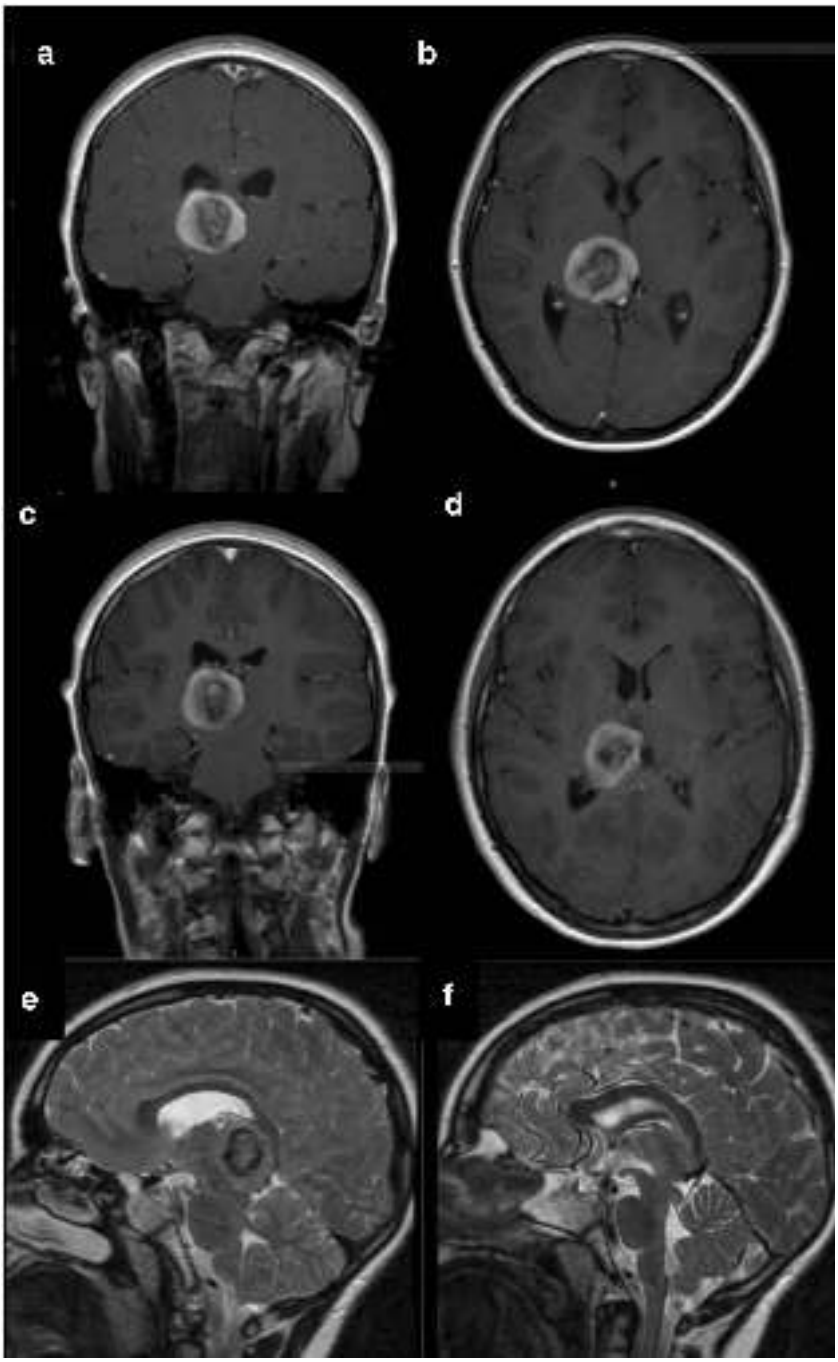
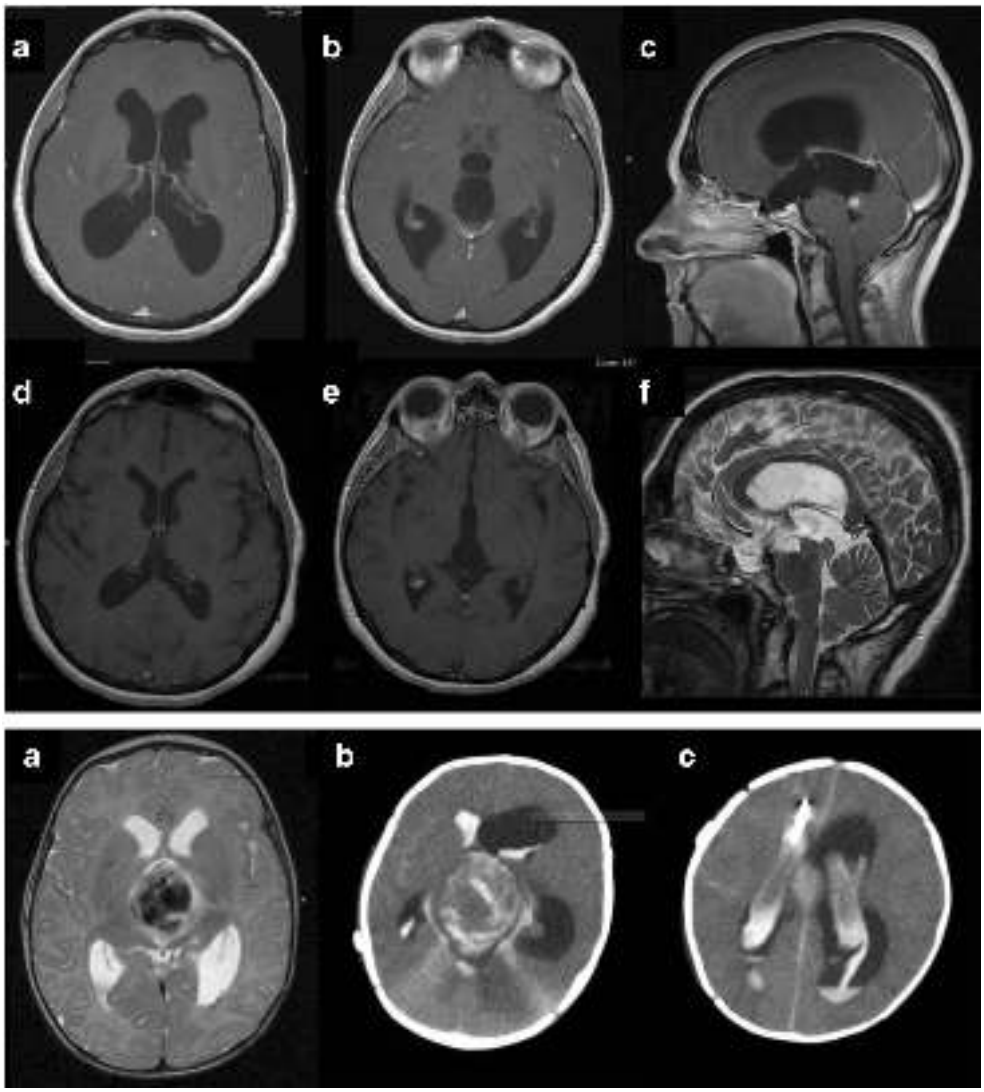


Fig. 1 Case 1. Failed biopsy. A 10-month-old boy had episodic headache without neurological deficits. MRI showed a paraventricular tumor at the right thalamic region (**a**, **b**). This was surgically assisted by neuronavigation through the right lateral ventricle, and neuroendoscopic biopsy was done (three seemingly pathological samples were obtained) after ETV procedure. Postoperative course was uneventful; histopathological diagnosis was "non-conclusive" or level IV. Two years after, the tumor is stable and ETV is patent (**c**–**f**). Case 2. Successful procedure: treatment for hydrocephalus and biopsy, a 51-year-old woman with dizziness and headache. The MRI showed a tumor next to the sylvian aqueduct and hydrocephalus associated (**a**–**c**). ETV and neuroendoscopic biopsy were done without complications. The histopathological diagnosis was "grade I pilocytic astrocytoma." She is asymptomatic after 4 years of follow-up with functional ETV (**d**–**f**). Case 3. Complications, a 2-month-old girl with neurological impairment (hypotonia and lethargy). MRI showed a paraventricular tumor occupying the third ventricle and obstructive hydrocephalus (**a**). She underwent neuroendoscopic biopsy and VPS. Twelve hours later, the patient went into a coma, and CT showed IVH and intratumoral swelling (**b**, **c**). The histopathological diagnosis was "medulloblastoma/PNET"

Histological diagnosis by endoscopic biopsy

Tumor tissue was obtained in 80 cases. According to the Depreitere Classification, in 71 biopsies, the diagnoses were conclusive (88.7% diagnostic success per patient). Diagnoses were conclusive in 90% of patients without hydrocephalus (level I). One patient without hydrocephalus showed unidentifiable pathological tissue considered to be level III, described as "cystic fragments constituted by brain tissue with gliosis and ependymal cells, suggesting malformation of the ventricular system." The diagnosis was a casual finding, and the patient was asymptomatic. Expectant management was adopted. In eight cases, the samples were non-interpretable tissue or level IV: open surgery was carried out in two patients with result of atypical teratoid rhabdoid tumor and adenocarcinoma metastasis. Conservative management was done for two pediatric patients whose biopsies were level IV: an asymptomatic patient with a stable paraventricular tumor at the right thalamic region and functional ETV (Fig. 1, case 1) and a child with clinical history of myelomeningocele, multiloculated hydrocephalus, and intraventricular mass suggestive of abscess, which was stable in periodic controls and

Fig. 1 (continued)



towards the unlikely diagnosis of neoplasia. The follow-up was lost after 6 months in a 57-year-old man with level IV biopsy from a posterior diencephalic lesion who during the procedure suffered intraventricular hemorrhage (IVH) and external ventricular drain (EVD) was required. Septal vein was coagulated. He presented self-limited seizures during postoperative time and recovered without sequels. Other two patients, whose biopsies were unclear, died because of rapid tumor progression, and palliative care was adopted. A 78-year-old patient died in relation to IVH and EVD after biopsy of pineal mass. The eight cases whose samples were level IV (11.6%) had hydrocephalus. The highest diagnostic efficacy per patient was obtained with lesions located in the anterior half of the third ventricle (100%—23 samples), followed by extensive lesions (86.6%—13 of 15 samples), those in the lateral ventricle (84.6%—11 of 13), and in the posterior half of the third ventricle (82.7%—24 of 29). There was one case of a synchronous tumor in the sellar and pineal regions, with biopsy of the sellar region revealing germinoma. The most frequent pathological diagnosis was grade I pilocytic astrocytoma (14%), followed by craniopharyngioma (9.8%). All cases of pilomyxoid astrocytomas were pediatric. The diffuse astrocytomas included one case of subependymal giant cell astrocytoma associated with tuberous sclerosis. The pathological findings were characterized by their broad heterogeneity. In our series, of 11 patients without hydrocephalus, histological results were level I in 10 and level III in 1 patient. The most frequent diagnosis in this group was "low-grade ependymoma," as shown in Table 1.

Treatment for hydrocephalus

Of the 80 patients, 69 had associated hydrocephalus at diagnosis (86.2%) (Table 2). ETV was initially performed for the

Table 1 Level I biopsy diagnoses [9]

Histological finding	Hydrocephalus	
	Yes	No
Grade I pilocytic astrocytoma	9	1
Craniopharyngioma	6	1
Grade III astrocytoma	6	–
Low-grade ependymoma	1	4
Pilomyxoid astrocytoma	4	1
Grade II astrocytoma	4	–
Glioblastoma	4	–
Germ cell tumor	3	1
Non-Hodgkin's lymphoma	1	1
Choroid plexus papilloma	2	–
Medulloblastoma/PNET	2	–
Central neurocytoma	2	–
Epidermoid cyst	2	–
Pineoblastoma	1	–
ACTH-secreting pituitary adenoma	1	–
Anaplastic ependymoma	1	–
Neuroglial cyst	1	–
Low-grade neuroglial tumor	1	–
Chordoid glioma	1	–
Oligodendroglioma	1	–
Dysgerminoma	1	–
EST	1	–
Cavernoma	–	1
PTPR	1	–
Pleomorphic pineocytoma	1	–
M lung	1	–
M prostate	1	–
M cervix	1	–
M UPT	1	–
No. of patients (71)	61	10

PNET primitive neuroectodermal tumor, *EST* endodermal sinus tumor, *PTPR* papillary tumor of the pineal region, *M* metastasis, *UPT* unidentified papillary tumor (thyroid or breast)

treatment of hydrocephalus in 37 patients: 28 adults and 9 pediatric patients (associated SPT in 14 adults) (Fig. 1, case 2). A VPS was placed in 28 patients (associated SPT in 20). Four patients with univentricular hydrocephalus underwent SPT and biopsy only. Of the patients initially treated with ETV (37), eight patients eventually required VPS placement and one underwent repeat ETV due to late stoma closure (at 113 months). Of these eight patients, five had early failure requiring a VPS in the first 6 months after the endoscopic procedure, while in the other three cases, ventriculostomy failure was delayed. Four patients died from tumor progression in the first 6 months following ETV, and two cases were lost to follow-up. Of the remaining 31 patients, 22 were VPS free at completion of follow-up, with an ETV success rate of 70.9%. Of the 69 patients with hydrocephalus, 11 patients died in the first 6 months after treatment due to tumor progression and 5 were lost to follow-up. Of the remaining 53 patients, in 24 cases (45.2%), the hydrocephalus was resolved without valve implantation: 22 treated with ETV (with associated SPT in 9) and 2 with SPT alone. SPT associated with other procedures (ETV or VPS) or alone was performed in 50.9% of the patients with hydrocephalus (27 cases out of 53). Of the 11 patients without associated hydrocephalus, 3 underwent endoscopic tumor resection and 8 underwent biopsy alone.

Complications of the procedure

The overall complication rate was 11%. Hydrocephalus was present in all these patients. Five patients had severe IVH, four of whom required EVD placement. In one patient, the septal vein was damaged and coagulated during the procedure, requiring EVD. In this case, the samples were non-interpretable tissue (level IV). In another, IVH occurred during the attempt to collect a tumor sample, requiring discontinuation of the intervention and a repeat endoscopic biopsy procedure that revealed choroid plexus papilloma. Three of the patients with IVH died, two in the first 24 h after surgery: a pediatric patient with severe neurological impairment whose histology was medulloblastoma/PNET developed intracranial swelling and intratumoral hemorrhage after neuroendoscopic biopsy and VPS. No EVD was placed (Fig. 1, case 3), and a 78-year-old patient with spontaneously massive IVH and EVD placement whose result was ACTH-secreting pituitary adenoma. Another 78-year-old patient died 1 month after the procedure because of complication due to HIV and EVD without a clear diagnostic (level IV). Three patients demonstrated oculomotor disturbances: one with self-limited diplopia and Parinaud's syndrome, one with a transient midbrain condition with left third cranial nerve palsy and right hemiparesis, and in another case with third cranial nerve palsy with complete resolution. The three patients had clinical history of ETV. One patient debuted with CSF fistula at 2 weeks due to ETV closure associated with tumor progression (pinealoblastoma), and meningeal infection. No complications were found in patients without hydrocephalus.

Discussion

Success neuroendoscopic biopsy

The diagnostic success of neuroendoscopic biopsy described in the literature varies between 61 and 100% (Table 3). Ahn et al. [1] describe higher diagnostic efficacy in lesions located in the lateral ventricle and pineal regions (100% and 87.5%)

Table 2 Treatment for hydrocephalus

Total 69	ETV 37 (14 + SPT)	Only STP 4	VPS 28 (20 + SPT)
Follow-up	Failed ETV: - 8 VPS[a] - 1 Re-ETV - 2 Lost - 4 Exitus < 6 m	- 1 Lost - 1 Exitus	- 2 Lost - 5 Exitus
Final follow-up Mean 45 m Total 53	Success ETV 22 (9 + SPT) (70.9%)	2	29[a]

m months

[a] Patients with clinical history of previous failed ETV included

and lower diagnostic efficacy in thalamic and tectal lesions (57% and 25%, respectively). Due to the great histological heterogeneity, especially in the pineal region, the neuroendoscopic approach takes on crucial importance, considering that certain expansive processes such as germ cell tumors, lymphomas, or metastases are not generally considered for microsurgical treatment. In the present study, to classify histological success, we used the Depreitere scale, approved for pediatric series [9]. No universally standardized criteria exist to unify the histopathological results obtained by endoscopic biopsy, characterized by a diverse oncological group. The greatest diagnostic efficacy was obtained with lesions in the anterior half of the third ventricle with a diagnostic rate of 100%, followed by extensive lesions (86.6%), those in the lateral ventricle (84.6%), and in the posterior half of the third ventricle (82.7%). The absence of hydrocephalus in our series did not make it difficult to obtain a biopsy. To our knowledge, the absence of hydrocephalus does not contraindicate neuroendoscopic biopsy in selected cases, being navigation essential to avoid complications.

Treatment for hydrocephalus

Additionally, ETV and/or SPT enable treatment of associated hydrocephalus, present in 80–90% of cases [2, 7, 9, 12, 20, 22, 25, 29, 31–34]. These techniques are considered the treatment of choice in selected patients [5, 6, 15, 20–24, 26, 28, 32], especially in those with lesions of the posterior third ventricle [2, 23, 29]. In patients younger than 1 year of age, the ETV success rate is lower [15, 17, 18, 26, 30], and therefore, the indication for surgery should be individualized. The success of ETV in tumor lesions is estimated to be around 70–82.6% [5, 6, 9, 11, 25, 31–33]. Macarthur et al. [13] describe 95% and 83% success rates in the short and long term, respectively, and Mohanty et al. [22], in the long term, at 86%. Depreitere et al. [9] establish a 64% ETV success rate in their series. Some authors report the possibility that biopsy may play a role in ETV failure due to an obstructive mechanism requiring VPS placement [29, 33]. However, others such as Depreitere [9] found no data to indicate that endoscopic biopsy affected the success of ETV. Tumor location has also been described as a factor related to the success of ventriculostomy, favoring lesions in the pineal region and midbrain [29]. The ETV technique offers a number of advantages over VPS [29], including the elimination of the risk of peritoneal dissemination, valve complications (malfunction, infection, valve over-drainage, among others), and the non-inclusion of valve infection in the differential diagnosis of patients with fever and/or abdominal pain.

Complications

Neuroendoscopic biopsy is not entirely without risk. Mortality of 0–3.7% and morbidity of 6–18% have been reported according to each series [5, 6, 12, 13, 16, 19–22, 24, 32–34]. The most feared complication is intraventricular bleeding due to the inherent difficulty in its control. The risk of hemorrhage (with clinical repercussions) is 2.33–3.6% [1, 6, 9, 12, 13, 19, 25, 31–34]. In the study by Mohanty et al. [22], the incidence of bleeding from biopsy was 3.5%. Depreitere et al. [9] describe a 19% complication rate, 10% of which were due to hemorrhage. These bleeding complications may be related to the histological findings [24]. Minor bleeding can be controlled through irrigation with warm lactate Ringer's solution, while major bleeding requires bipolar coagulation if the bleeding point is established. Compressing gently with Fogarty balloon can be useful. Once hemostasis is achieved, the developed clot is aspirated as much as possible. If hemostasis is not effective and bleeding obstructs vision, the procedure will be abandoned and an EVD will be placed. Preoperative imaging studies as well as navigation systems can be very useful for surgical planning, characterizing the lesion and minimizing morbidity and mortality, especially in patients without hydrocephalus [3, 24]. In the study by Ersahin et al. [11], the increase in complications was related to undertaking a second endoscopic procedure. Although morbidity and mortality rates

Table 3 Summary of the literature review on neuroendoscopic biopsy

Author and year	Successful biopsies	Successful ETV	Complications
Pople et al. (2001)[a] [28]	32/34 (94%)	17/18 (94.4%)	5% (1 IVH) No M
Macarthur et al. (2002) [20]	17/28 (61%)	–	3.6% No M
Yurtseven et al. (2003) [34]	18/18 (100%)	–	No M
Badie et al. (2004) [4]	46/47 (98%)	–	–
Yamini et al. (2004)[a] [33]	4/6 (66.7%)	2/6 (33%)	15% No M
Ray et al. (2005)[b] [29]	–	32/43 (74%)	–
Luther et al. (2005) [19]	5/6 (83%)	–	No M
Souweidane et al. (2005) [31]	23/24 (95.8%)	22/22 (100%)	No
Chernov et al. (2006)[a] [6]	23/23 (100%)	22/23 (95%)	4% No M
O'Brien et al. (2006) [25]	25/33 (76%)	28/41 (68%)	No
Depreitere et al. (2007)[b] [9]	19/25 (69%)	9/14 (64%)	19.4% No M
Tirakotai et al. (2007) [32]	46/46 (100%)	20/20 (100%)	(1 IVH) No M
Fiorindi et al. (2008) [12]	19/23 (82.6%)	–	No
Cappabianca et al. (2008) [5]	37/41 (90%)	15/19 (79%)	4% (1 IVH) No M
Al-Tamimi et al. (2008)[a,b] [2]	8/12 (75%)	–	–
Ahn et al. (2010)[b] [1]	23/33 (69.7)	14/17 (82.4%)	6.1% (2 IVH) No M
Mohanty et al. (2011) [22]	72/85 (83%)	45/52 (86%)	31% (3 IVH)
Morgenstern et al. (2011)[a] [23]	13/15 (86.7%)	15/15 (100%)	
Oppido et al. (2011) [27]	54/60 (90%)	–	(2 IVH) No M
Hayashi et al. (2011) [16]	574/641 (89.7%)	263/316 (83.2%)	11.3%
Domínguez et al. (2011) [10]	25/28 (89%)	–	29%
Naftel et al. (2011) [24]	18/20 (90%)	–	–
Constantini et al. (2013) [8]	265/293 (90.4%)	–	(16 IVH)
Azab et al. (2014) [3]	1735/1927 (90.04%)	–	–
Miwa et al. (2015) [21]	443/485 (91.3%)	204/215 (94.4%)	26%
Miwa et al. (2015)[b] [21]	195/206 (94.7%)	91/101 (90.1%)	24.4%
Giannetti et al. (2015) [14]	43/48 (89.6%)	–	10% (3 IVH)

M mortality, *IVH* intraventricular hemorrhage

[a] Pineal lesions

[b] Pediatric series

are low and endoscopic techniques are considered safe with high diagnostic efficacy, the risk of hemorrhage and potentially fatal complications are present and require proper patient selection, preoperative studies, use of navigation in designated cases, and surgical expertise [5, 7, 11, 17]. Concerning complications, in our series, two cases presenting IVH had a diagnosis of glioblastoma and choroid plexus papilloma [24]. Other complications described are CSF fistula and infection, focal neurological deficits, with third cranial nerve palsy being the most frequent, or side effects secondary to central nervous system lesions such as syndrome of inappropriate antidiuretic hormone secretion or coma due to vasogenic edema [10, 17].

Endoscopic technique and published series results

This work updates our previously published series [10]. To our knowledge, endoscopy can have some advantages over the stereotaxic procedure or guided with navigation: sampling under direct vision, which implies better control of the hemorrhage and the site where the samples are taken, and resolve the hydrocephalus in the same act. We used a single trajectory to achieve our surgical goals. A precoronal burr hole 10 cm from the nasion allows the ETV to be performed without injuring the column of the fornix [10] and samples to be taken of lesions in the posterior portion of the third ventricle/pineal region. Some authors propose two trajectories in selected cases [23]. Rigid endoscopes are usually used for lateral and anterior third ventricular tumors, whereas flexible endoscopes are often used for posterior third ventricular tumor. We do not use flexible endoscope routinely in our center. Flexible endoscopes make the approach for simultaneous ETV and biopsy through a single burr hole theoretically more feasible; however, suboptimal visualization, disorientation, and smaller working channels limit their utility when compared with rigid

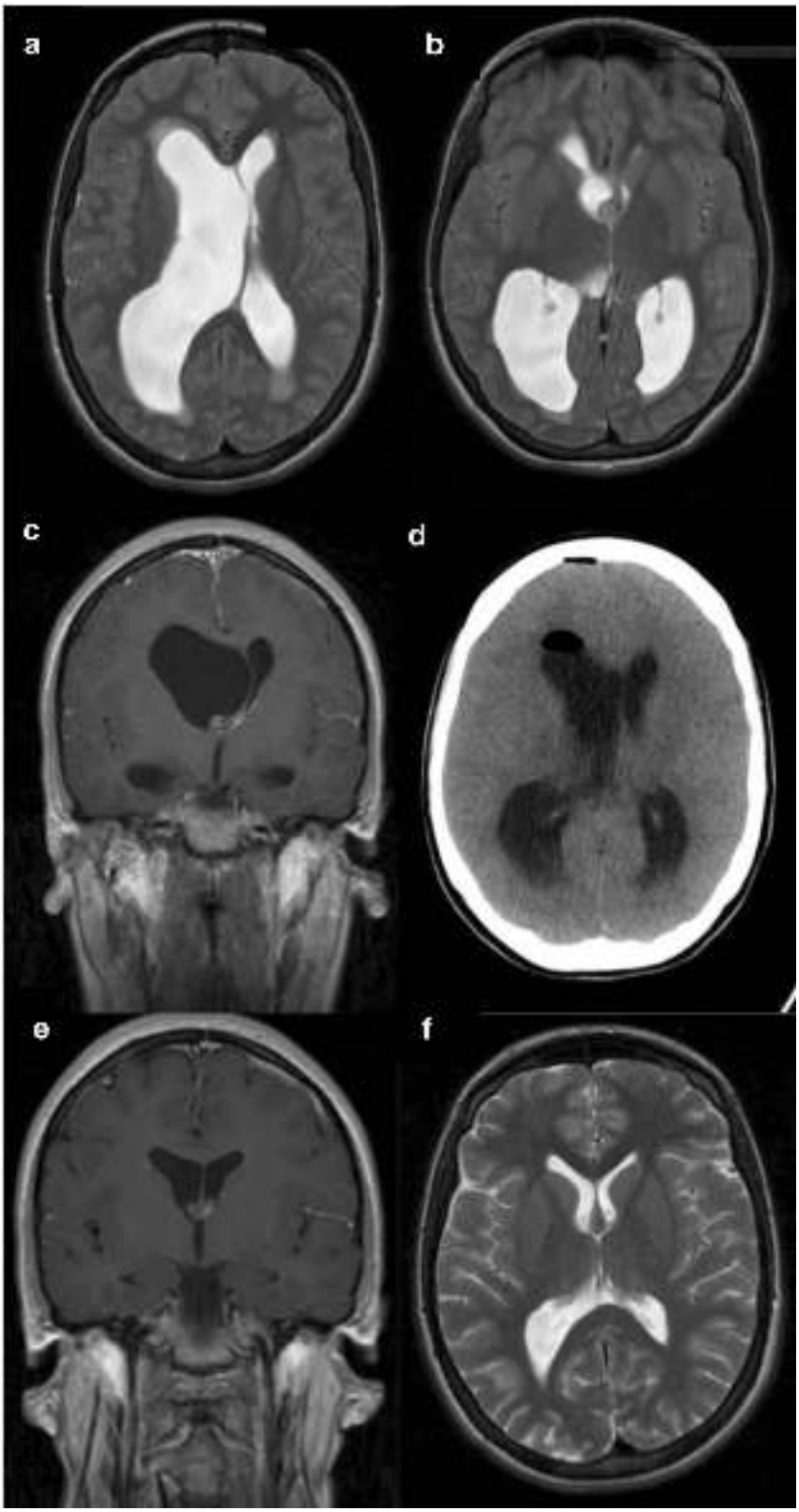


Fig. 2 An 18-year-old woman with headache. MRI showed an intraventricular tumor at the right foramen of Monro (heterogeneous contrast uptake) which causes asymmetrical obstructive hydrocephalus (**a**–**c**). Three samples were obtained by neuroendoscopic biopsy through right lateral ventricle (**d**), and septostomy was done using electrical cutting and Fogarty balloon. The result was "low-grade ependymoma," and the hydrocephalus was resolved (**e**, **f**)

endoscopes [23]. Ninety-three percent of the patients in our series showed signs of intracranial hypertension. Priority was given to restoring CSF circulation (ETV and/or SPT) [9, 10, 22, 23] to prevent any bleeding during biopsy from impeding treatment of the hydrocephalus, contrary to the recommendations of other authors such as Cappabianca et al. [5], who favor performing the biopsy first in order to avoid the accumulation of blood in the basal cisterns. Endoscopic SPT was

an especially useful maneuver in the management of hydrocephalus in our series; performed in 47.8% of our patients, it contributed to improving the success rate in the management of hydrocephalus, especially in lesions of the anterior third of the third ventricle with obstruction of CSF circulation or extensive lesions, facilitating the placement of a single VPS or avoiding the placement of valves in cases of unilateral hydrocephalus (Fig. 2). In addition, endoscopic techniques allow the placement of intraventricular catheters connected to a reservoir when local intrathecal chemotherapy is required.

Neuroendoscopy is an effective procedure in intraventricular and paraventricular tumors for diagnosis through biopsy and resolution of associated hydrocephalus. Nevertheless, it is not exempt from serious complications, and therefore, proper training is essential.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

Ethical approval: statements of human rights All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Informed consent Informed consent was obtained from all individual participants included in the study.

Statements on the welfare of animals This article does not contain any studies with animals performed by any of the authors.

References

1. Ahn ES, Goumnerova L (2010) Endoscopic biopsy of brain tumors in children: diagnostic success and utility in guiding treatment strategies. J Neurosurg Pediatr 5(3):255–262. https://doi.org/10.3171/2009.10.PEDS09172
2. Al-Tamimi YZ, Bhargava D, Surash S, Ramirez RE, Novegno F, Crimmins DW, Tyagi AK, Chumas PD (2008) Endoscopic biopsy during third ventriculostomy in paediatric pineal region tumours. Childs Nerv Syst 24(11):1323–1326. https://doi.org/10.1007/s00381-008-0632-6
3. Azab WA, Nasim K, Chelghoum A, Parwez A, Salaheddin W (2014) Endoscopic biopsy of brain tumors: does the technique matter? Surg Neurol Int 5:159. https://doi.org/10.4103/2152-7806.144597
4. Badie B, Brooks N, Souweidane MM (2004) Endoscopic and minimally invasive microsurgical approaches for treating brain tumor patients. J Neuro-Oncol 69(1–3):209–219
5. Cappabianca P, Cinalli G, Gangemi M, Brunori A, Cavallo LM, de Divitiis E, Decq P, Delitala A, di Rocco F, Frazee J, Godano U, Grotenhuis A, Longatti P, Mascari C, Nishihara T, Oi S, Rekate H, Schroeder HWS, Souweidane MM, Spennato P, Tamburrini G, Teo C, Warf B, Zymberg ST (2008) Application of neuroendoscopy to intraventricular lesions. Neurosurgery 62(suppl 2):575–598. https://doi.org/10.1227/01.neu.0000316262.74843.dd
6. Chernov MF, Kamikawa S, Yamane F, Ishihara S, Kubo O, Hori T (2006) Neurofiberscopic biosy of tumor of the pineal región and posterior third ventricule: indications, technique, complications, and results. Neurosurgery 59(2):267–277. https://doi.org/10.1227/01.NEU.0000223504.29243.0B.
7. Cinalli G, Spennato P, Ruggiero C, Aliberti F, Trischitta V, Buonocore MC, Cianciulli E, Maggi G (2007) Complications following endoscopic intracranial procedures in children. Childs Nerv Syst 23(6):633–644. https://doi.org/10.1007/s00381-007-0333-6
8. Constantini S, Mohanty A, Zymberg S, Cavalheiro S, Mallucci C, Hellwig D, Ersahin Y, Mori H, Mascari C, Val JAC, Wagner W, Kulkarni AV, Sgouros S, Oi S (2013) Safety and diagnostic accuracy of neuroendoscopic biopsies: an international multicenter study. J Neurosurg Pediatr 11(6):704–709. https://doi.org/10.3171/2013.3.PEDS12416
9. Depreitere B, Dasi N, Rutka J, Dirks P, Drake J (2007) Endoscopic biopsy for intraventricular tumors in children. J Neurosurg 106(5 Suppl):340–346. https://doi.org/10.3171/ped.2007.106.5.340
10. Domínguez-Páez M, Puch-Ramírez M, Rodríguez-Barceló S, Medina-Imbroda JM, Romero-Moreno L, Ibáñez-Botella G, Ros-López B, Arráez-Sánchez MA (2011) Neuroendoscopic biopsy. Experience in 31 patients and literature review. Neurocirugía (Astur) 22(5):419–428
11. Ersahin Y, Arslan D (2008) Complications of endoscopic third ventriculostomy. Childs Nerv Syst 24(8):943–948. https://doi.org/10.1007/s00381-008-0589-5
12. Fiorindi A, Longatti P (2008) A restricted neuroendoscopic approach for pathological diagnosis of intraventricular and paraventricular tumours. Acta Neurochir 150(12):1235–1239. https://doi.org/10.1007/s00701-008-0155-7
13. Gaab MR, Schroeder HW (1999) Neuroendoscopic approach to intraventricular lesions. Neurosurg Focus 6(4):e5
14. Giannetti A, Holayama A, Oliveira T, Abi-Sáber H, Souweidane MM (2015) Neuroendoscopic biopsy of brain lesions: accuracy and complications. J Neurosurg 122:34–39. https://doi.org/10.3171/2014.9.JNS132648
15. González L, Ros B, Ibáñez G, Domínguez M, Pérez S, Rius F, Arráez MA (2012) Endoscopic third ventriculostomy success score (ETVSS) predicting success in a series of 50 pediatric patients. Are the outcomes of our patients predictable? Childs Nerv Syst 28(8):1157–1162. https://doi.org/10.1007/s00381-012-1836-3
16. Hayashi N, Murai H, Ishihara S, Kitamura T, Miki T, Miwa T, Miyajima M, Nishiyama K, Ohira T, Ono S, Suzuki T, Takano S, Date I, Saeki N, Endo S (2011) Nationwide investigation of the current status of therapeutic neuroendoscopy for ventricular and paraventricular tumors in Japan. J Neurosurg 115(6):1147–1157. https://doi.org/10.3171/2011.7.JNS101976
17. Iglesias S, Ros B, Ibáñez G, Domínguez M, Medina JM, Arráez MÁ (2013) Factors related to endoscopic third ventriculostomy prognosis in the paediatric population. Neurocirugía (Astur) 24(2):51–56. https://doi.org/10.1016/j.neucir.2012.09.003
18. Av K, Drake JM, Malluci CL, Sgouros S, Roth J, Constantini S (2009) Endoscopic third ventriculostomy in the treatment of childhood hydrocephalus. J Pediatr 155(2):254–9.e1. https://doi.org/10.1016/j.jpeds.2009.02.048
19. Luther N, Edgar MA, Dunkel IJ, Souweidane MM (2006) Correlation of endoscopic biopsy with tumor marker status in primary intracranial germ cell tumors. J Neuro-Oncol 79(1):45–50. https://doi.org/10.1007/s11060-005-9110-0
20. Macarthur DC, Buxton N, Punt J, Vloeberghs M, Robertson IJ (2002) The role of neuroendoscopy in the management of brain tumours. Br J Neurosurg 16(5):465–470
21. Miwa T, Hayashi N, Endo S, Ohira T (2015) Neuroendoscopic biopsy and the treatment of tumor-associated hydrocephalus of the ventricular and paraventricular region in pediatric patients: a

nationwide study in Japan. Neurosurg Rev 38(4):693–704. https://doi.org/10.1007/s10143-015-0629-z

22. Mohanty A, Santosh V, Devi BI, Satish S, Biswas A (2011) Efficacy of simultaneous single-trajectory endoscopic tumor biopsy and endoscopic cerebrospinal fluid diversion procedures in intra- and paraventricular tumors. Neurosurg Focus 30(4):E4. https://doi.org/10.3171/2011.1.FOCUS10295
23. Morgenstern PF, Osbun N, Schwartz TH, Greenfield JP, Tsiouris AJ, Souweidane MM (2011) Pineal region tumors: an optimal approach for simultaneous endoscopic third ventriculostomy and biopsy. Neurosurg Focus 30(4):E3. https://doi.org/10.3171/2011.2.FOCUS10301
24. Naftel RP, Shannon CN, Reed GT, Martin R, Blount JP, Tubbs RS, Wellons JC 3rd (2011) Small-ventricle neuroendoscopy for pediatric brain tumor management. J Neurosurg Pediatr 7(1):104–110. https://doi.org/10.3171/2010.10.PEDS10338
25. O'Brien DF, Hayhurst C, Pizer B, Mallucci CL (2006) Outcomes in patients undergoing single-trajectory endoscopic third ventriculostomy and endoscopic biopsy for midline tumors presenting with obstructive hydrocephalus. J Neurosurg 105(3 Suppl): 219–226. https://doi.org/10.3171/ped.2006.105.3.219
26. Oertel JMK, Baldauf J, Schroeder HWS, Gaab MR (2009) Endoscopic options in children: experience with 134 procedures. J Neurosurg Pediatrics 3(2):81–89. https://doi.org/10.3171/2008.11.PEDS0887
27. Oppido PA, Fiorindi A, Benvenuti L, Cattani F, Cipri S, Gangemi M, Godano U, Longatti P, Mascari C, Morace E, Tosatto L (2011) Neuroendoscopic biopsy of ventricular tumors: a multicentric experience. Neurosurg Focus 30(4):E2. https://doi.org/10.3171/2011.1.FOCUS10326
28. Pople IK, Athanasiou TC, Sandeman DR, Coakham HB (2001) The role of endoscopic biopsy and third ventriculostomy in the management of pineal region tumours. Br J Neurosurg 15(4):305–311
29. Ray P, Jallo GI, Kim RYH, Kim B-S, Wilson S, Kothbauer K, Abbott R (2005) Endoscopic third ventriculostomy for tumor-related hydrocephalus in a pediatric population. Neurosurg Focus 19(6):E8
30. Ros B, Romero L, Ibañez G, Iglesias S, Rius F, Pérez S, Arráez MA (2012) Success criteria in pediatric neuroendoscopic procedures. Proposal for classification and results after 67 operations. Childs Nerv Syst 28(5):691–697. https://doi.org/10.1007/s00381-012-1689-9
31. Souweidane MM, Sandberg DI, Bilsky MH, Gutin PH (2000) Endoscopic biopsy for tumors of the third ventricle. Pediatr Neurosurg 33(3):132–137. https://doi.org/10.1159/000028994
32. Tirakotai W, Hellwig D, Bertalanffy H, Riegel T (2007) The role of neuroendoscopy in the management of solid or solid-cystic intra- and periventricular tumours. Childs Nerv Syst 23(6):653–658. https://doi.org/10.1007/s00381-007-0328-3
33. Yamini B, Refai D, Rubin CM, Frim DM (2004) Initial endoscopic management of pineal region tumors and associated hydrocephalus: clinical series and literature review. J Neurosurg 100(5 Suppl Pediatrics):437–441. https://doi.org/10.3171/ped.2004.100.5.0437
34. Yurtseven T, Erşahin Y, Demirtaş E, Mutluer S (2003) Neuroendoscopic biopsy for intraventricular tumors. Minim Invasive Neurosurg 46(5):293–299. https://doi.org/10.1055/s-2003-44450