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ORIGINAL ARTICLE

Purely neuroendoscopic resection of intraventricular tumors with an endoscopic ultrasonic aspirator

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Abstract

Surgery for intraventricular tumors remains a controversial and evolving field, with endoscopic resection becoming more popular. We present a series of nine consecutive cases of purely endoscopic resection of intraventricular tumors with the aid of an ultrasonic aspirator specific for neuroendoscopy. Nine patients (five men, four women) aged 18–74 years (mean 43.7) underwent surgery. The most common symptom was headache. In all cases, magnetic resonance imaging showed single supratentorial intraventricular lesions (five lateral ventricle, four third ventricle). The average maximum diameter was 20.5 mm (range 11–42). Associated hydrocephalus was found in eight cases at diagnosis. Five patients underwent complete macroscopic resection. Three underwent subtotal resection and one underwent partial resection (two thirds of the tumor). The mean endoscopic procedure time was 70 min (37–209). The eight patients with associated hydrocephalus also underwent endoscopic septostomy to improve cerebral spinal fluid circulation, with one patient additionally requiring endoscopic third ventriculostomy and another requiring Monro foraminoplasty. One patient required ventriculoperitoneal shunting. The mean post-operative follow-up was 15.1 months (range 2–33). At the time of analysis, no patient showed recurrence or regrowth of the operated lesion. The histological diagnoses and degree of resection were three subependymomas with complete resection, three colloid cysts with two complete and one subtotal resection, one pilocytic astrocytoma with partial resection (approximately two thirds of the lesion), one epidermoid tumor with subtotal resection, and one central neurocytoma with subtotal resection. The endoscopic ultrasonic surgical aspirator can be a safe and effective tool for the removal of intraventricular tumors, even in firmer solid lesions.

Keywords Neuroendoscopy · Intraventricular tumor · Ultrasonic aspirator · Oncology

Introduction

Surgery for intraventricular tumors remains a controversial and evolving field. The last 10 years have witnessed increasing publications of cases and case series of endoscopic resection of intraventricular tumors [2, 5, 11, 14] and no longer just for colloid cysts [3, 6, 8] or other cystic lesions [4, 7]. The latest technical advances, such as the NICO myriad system [1] and the SONOCA ultrasonic aspirator [5, 11], have enabled problems such as those arising from the lengthy surgical time required for the resection of solid tumors to be resolved. The gold standard in these lesions remains microsurgical resection. However, in carefully selected cases, the endoscopic route can provide great advantages. One example is the minimally invasive transcortical approach, which involves a smaller incision, reduced blood loss, rapid recovery, and reduced parenchymal injury, to which must be added the superb visualization of the lesion and its anatomical relationships. In the present report, we describe our experience with a series of nine

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consecutive cases of purely endoscopic resection of intraventricular tumors using the SONOCA ultrasonic aspirator.

Material and methods

We present a descriptive case series of adult patients with resected intraventricular tumors using a single-portal endoscopic approach at our center between March 2015 and January 2018.

Patient selection

Adult patients who presented symptoms related to the presence of a supratentorial intraventricular tumor (lateral ventricular system or third ventricle) with radiological signs of benignity (poorly vascularized lesions) diagnosed by nuclear magnetic resonance studies were included in the study.

Endoscopic technique

All procedures were performed under general anesthesia, with the head in a neutral, flexed position and held in place with a Mayfield head clamp. We used a Gaab rigid endoscope (Karl Storz GmbH) with one working channel and 0° viewing angle, and the compatible ultrasonic aspirator (Sonoca, Söring GmbH). During the procedure, a Storz® irrigation pump with Ringer solution was used for periodic irrigation. The neuroendoscopic procedure combined excision of the lesion with maneuvers to treat hydrocephalus when present (septostomy for univentricular or biventricular hydrocephalus, foraminoplasty for stenosis of the foramen of Monro, and endoscopic third ventriculostomy for triventricular hydrocephalus).

Data collection

The following variables were collected retrospectively: age at the time of surgery, gender, clinical symptoms, anatomical location of the lesion, maximum diameter of the lesion, presence and characteristics of the associated hydrocephalus, endoscopic maneuvers performed, endoscopic resection time, degree of resection, intraoperative or postoperative complications, histological diagnosis, and follow-up time.

Results

The demographic and clinical variables of the nine patients in the series are shown in Table 1. Magnetic resonance imaging in all cases showed single intraventricular supratentorial lesions. The most frequent location was in the frontal horn of the lateral ventricle (five patients, in two of whom there was also a close anatomical relationship with the ipsilateral foramen of Monro) (Fig. 1). The remaining four patients had lesions located in the third ventricle (one of these affecting the posterior third ventricle) (Fig. 2). The average maximum diameter of these lesions was 20.5 mm (range 11–42).

Eight of the nine patients had associated hydrocephalus at the time of diagnosis. This was asymmetrical biventricular (three patients), symmetrical biventricular (three patients), and unilateral (two patients). The course was chronic with the exception of one patient (Fig. 3) who debuted with acute hydrocephalus and coma, requiring emergency external ventricular drain placement.

The ventricular system was cannulated based on anatomical landmarks through a frontal burr hole in seven of the nine patients. In the two remaining patients (one without associated hydrocephalus and one with a large lesion and important anatomical distortion), the procedure was performed with the aid of neuronavigation. (Fig. 4a, b). Six of the nine patients underwent surgery through a precoronal burr hole 12 cm from the nasion and 3 cm from the midline. The three remaining patients required access 10 cm from the nasion (two of them with third ventricular lesions and one with a large lateral ventricular lesion).

In all cases, biopsy was possible using forceps and tumor resection by ultrasonic aspiration through the working channel of the endoscope. A Sonoca 300 ultrasonic aspirator system (Söring GmbH) was used. This system has a frequency range of 20–80 kHz and its vacuum suction is 0–0.9 bar. In five patients, the resection was macroscopically complete (Fig. 5) (Video 1; Intraoperative screenshot: Fig. 6a, b, c, d, e, f, g, h, i). In three patients a subtotal resection was performed due to technical difficulty and other factors including capsular adhesion to eloquent structures requiring intracapsular debulking, large lesion size (Fig. 7) (Video 2; Intraoperative screenshot: Fig. 8a, b, c, d, e, f, g, h, i), and decreased intraoperative visibility resulting from bleeding. Finally, there was one case in which partial resection of approximately two thirds of the tumor was performed, due to the close anatomical relationship of the lesion with the choroid plexus. However, this was sufficient for decompression of the foramen of Monro, contributing to the restoration of cerebrospinal fluid (CSF) circulation dynamics at this level.

With regard to endoscopic maneuvers to improve CSF circulation dynamics (in addition to tumor excision), the eight patients with associated hydrocephalus underwent septostomy (of these, in addition to septostomy, one underwent endoscopic third ventriculostomy and one underwent Monro foraminoplasty). In all cases, these maneuvers were performed prior to the initiation of tumor resection. The mean endoscopic time (from access to the ventricle to removal of the endoscope) was 70 min (range 37–209).

The biopsy material obtained was sufficient to establish a reliable diagnosis in all the patients. The most frequent histological diagnoses were subependymoma (three patients) and

Table 1 Demographic and clinical variables of the nine patients in the series

Case number	Gender	Age	Clinical signs	Number of surgical procedures	Histological diagnosis	Lesion location	Maximum diameter (mm)	Location of burr hole
1	M	55	Episodes of loss of consciousness and gait disturbance	1	Subependymoma (WHO Grade I)	Body of RLV	21	Right Kocher's point (precoronal)
2	F	18	Headache and vomiting	1	Pilocytic astrocytoma (WHO grade I)	Septum RLV adjacent to foramen of Monro	11	Right Kocher's point (precoronal)
3	F	31	Coma. Headache in previous days	2	Colloid cyst	III ventricle	16	Left frontal 10–3
4	M	68	Dizziness and gait disturbance	1	Epidermoid tumor	Posterior III ventricle	27	Right Kocher's point (precoronal)
5	M	52	Gait disturbance, dizziness and headache	1	Subependymoma (WHO Grade I)	Body of RLV	13	Right Kocher's point (precoronal)
6	M	41	Headache, nausea and vomiting	1	Colloid cyst	III ventricle	15	Right frontal 10–3
7	M	74	Intermittent headache and gait disturbance	1	Subependymoma (WHO Grade I)	Right frontal horn adjacent to foramen of Monro	25	Right Kocher's point (precoronal)
8	F	27	Headache and disorientation	2	Colloid cyst	III ventricle	15	Left Kocher's point (precoronal)
9	F	28	Headache, blurred vision and loss of strength in RUL	3	Central neurocytoma (WHO Grade I)	Body of LLV	42	Left frontal 10–3

Case number	Hydrocephalus	Hydrocephalus treatment	Degree of resection	Endoscopic time (min)	Intraoperative complications	Postoperative complications	Follow-up (months)	Radiological residual disease
1	No		Total	37			33	Absence of recurrence
2	Yes. Biventricular Right>Left	Septostomy + excision	Partial (2/3)	70			27	Radiological stability
3	Yes. Acute biventricular Left>Right	EVD + septostomy + excision	Total	50		Meningitis with negative culture	23	Absence of recurrence
4	Yes. Mild biventricular	Septostomy + ETV + excision	Subtotal	77			19	Radiological stability
5	Yes. Unilateral	Septostomy + foraminoplasty + excision	Total	38			15	Absence of recurrence
6	Yes. Biventricular	Septostomy + excision	Total	45			9	Absence of recurrence
7	Yes. Unilateral	Septostomy + excision	Total	44		Fever spike associated with respiratory symptoms	6	Absence of recurrence
8	Yes. Biventricular	Septostomy + excision	Subtotal	60	Bleeding. Post-surgical EVD	EVD obstruction and CSF fistula	2	Radiological stability
9	Yes Biventricular Left>Right	Septostomy + excision	Subtotal	209	Bleeding. Post-surgical EVD	CSF fistula and meningitis with negative culture. Hydrocephalus	2	Radiological stability

RUL right upper limb, *WHO* World Health Organization, *RLV* right lateral ventricle, *LLV* left lateral ventricle, *ETV* endoscopic third ventriculostomy, *EVD* external ventricular drainage

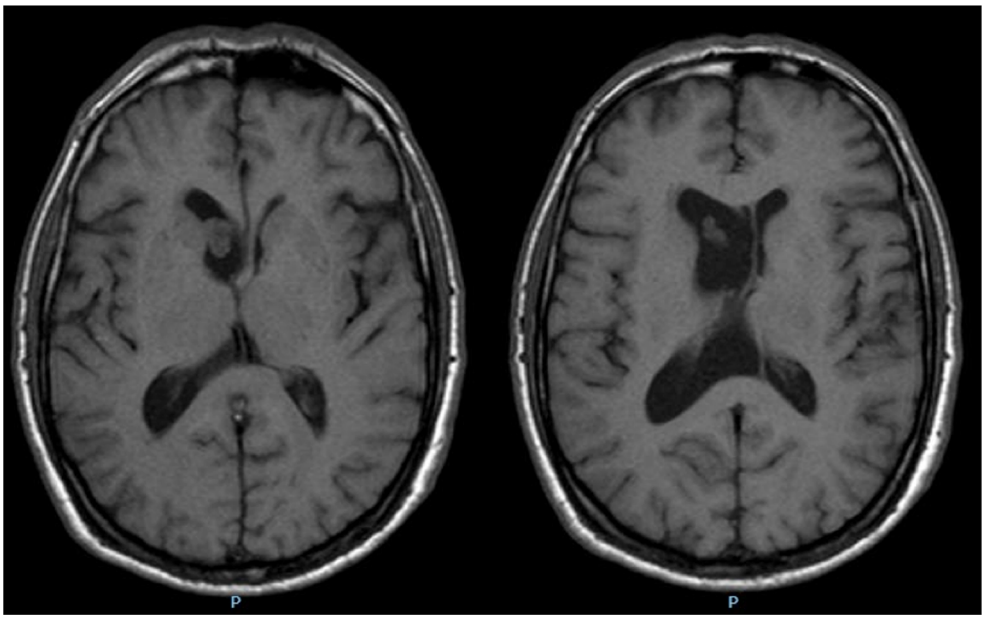

Fig. 1 Lesion of the right lateral ventricle. Subependymoma. Unilateral hydrocephalus

colloid cyst (three patients), followed by pilocytic astrocytoma (one patient), epidermoid tumor (one patient), and central neurocytoma (one patient). In all the cases of subependymoma and in two of the three cases of colloid cysts, complete resection was achieved. In the cases of epidermoid tumor, central neurocytoma, and in one case of colloid cysts, subtotal

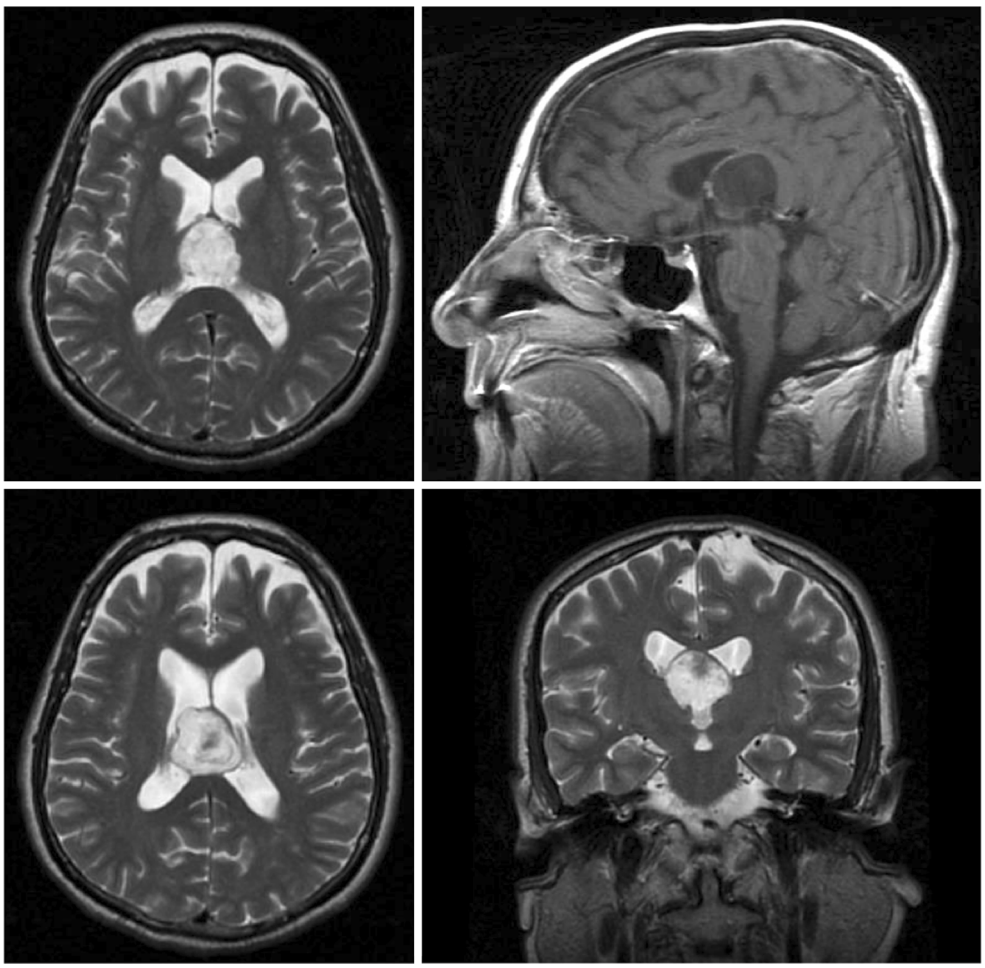

Fig. 2 Lesion of the posterior part of the third ventricle. Epidermoid tumor

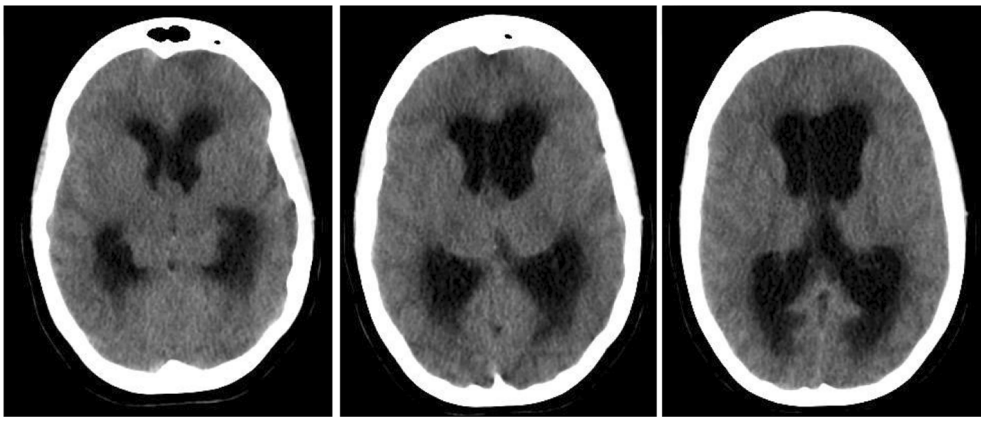

Fig. 3 Acute hydrocephalus as debut of third ventricular colloid cyst

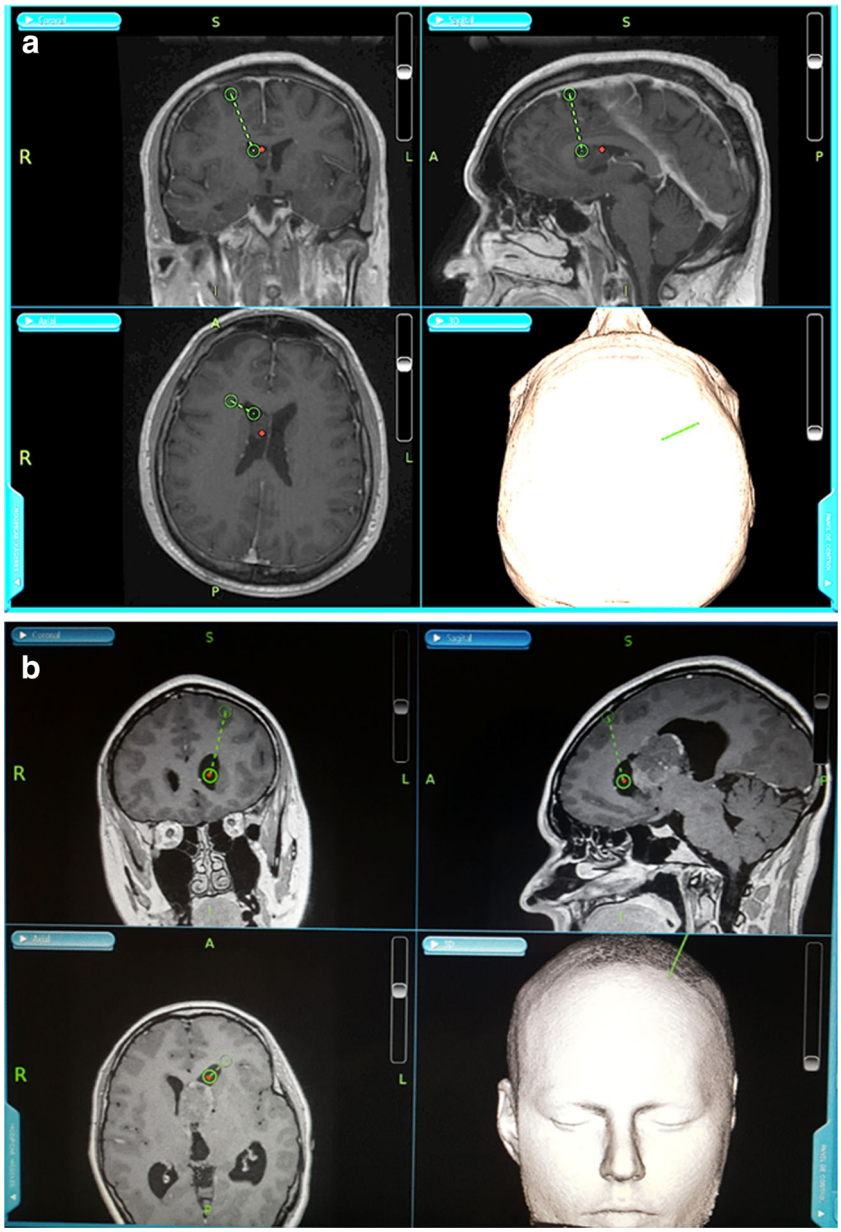

Fig. 4 a Access to right lateral ventricle in patient with intraventricular tumor (subependymoma) without hydrocephalus. b Navigator-guided access to the frontal horn of the left lateral ventricle, anterior to the tumor. Central neurocytoma

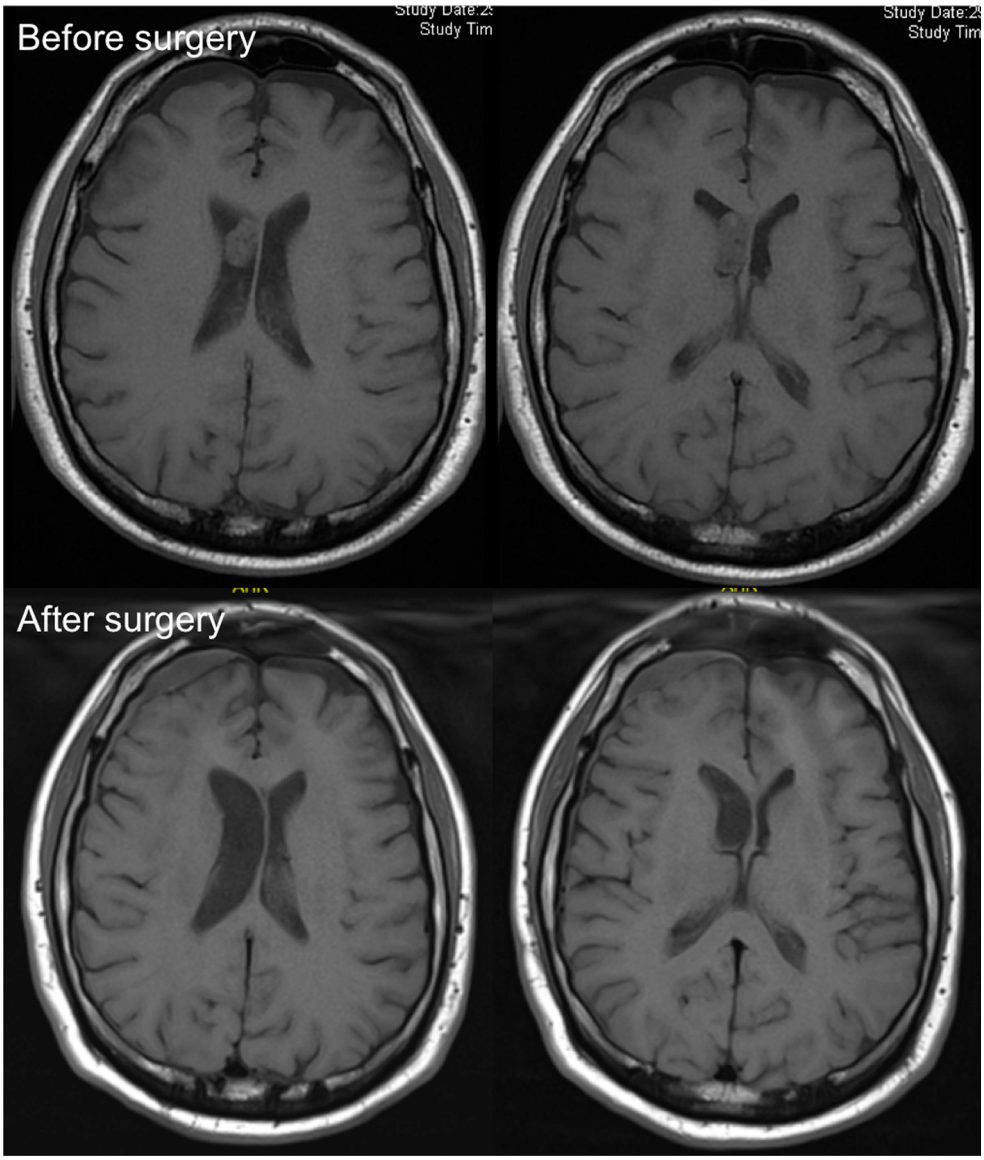

Fig. 5 Pre- and post-surgical management of right lateral ventricular injury. Subependymoma

resection was performed. Finally, in the case of the pilocytic astrocytoma, partial resection was performed (approximately two thirds of the lesion).

Intraoperative complications included two patients with significant bleeding (that is, the visibility of the surgeon was impaired during the procedure). Specifically, this occurred at the point of entry into the lateral ventricle and during ultrasonic tumor fragmentation maneuvers, respectively. In these two cases, external ventricular drain placement was required to control intraventricular hemorrhage and any associated hydrocephalus.

Notable postoperative complications included clinical signs of meningitis with altered CSF parameters in two patients. Both had negative cultures. It was decided, however, to use broad-spectrum intravenous antibiotic therapy for at least 3 weeks. One of the two patients simultaneously developed secondary hydrocephalus requiring the placement of an external ventricular drain and subsequently a ventriculoperitoneal shunt. The mean post-procedure follow-up time was 15.1 months (range 2–33). At the time of the analysis, no patient showed recurrence or regrowth of the surgically treated lesion.

Discussion

Purely single-portal endoscopic resection of intraventricular tumors is complex and requires a specific technique with its associated learning curve. A meta-analysis conducted by Barber et al. [2] examined 40 articles involving more than 650 cases of endoscopic resection of intraventricular tumors. The results were promising, with complete or nearly complete resection attained in 75% of the cases. In most of the cases, surgery was performed with standard endoscopic instrumentation including forceps, monopolar or bipolar coagulation,

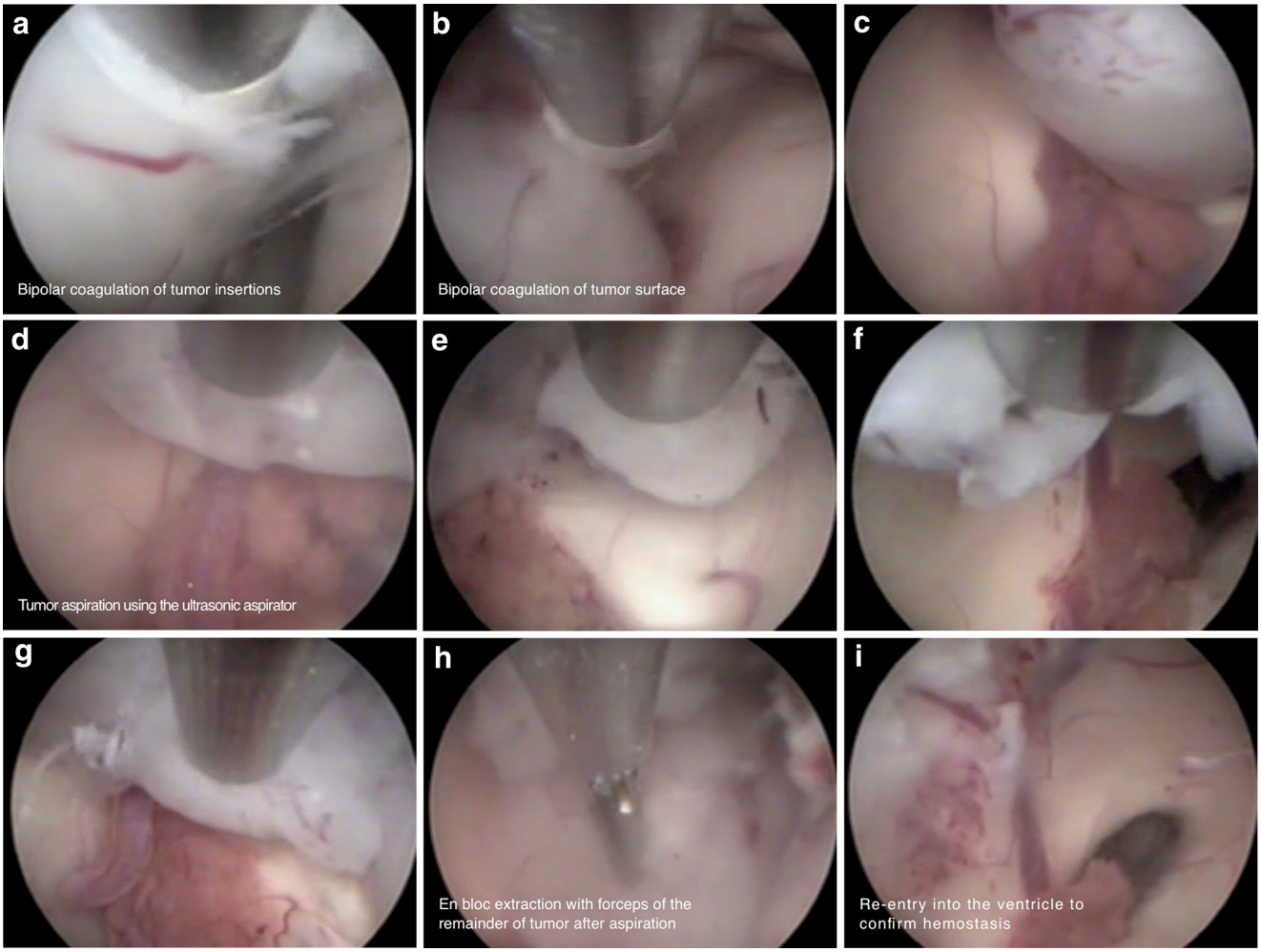

Fig. 6 a, b, c, d, e, f, g, h, i Intraoperative screenshot of complete resection of subependymoma in right lateral ventricle

and suction catheters, while several cases were treated using an assistive tool intended to quickly dissect and remove the tumor. These devices are described as helpful by the neurosurgeons who use them [9, 10, 14].

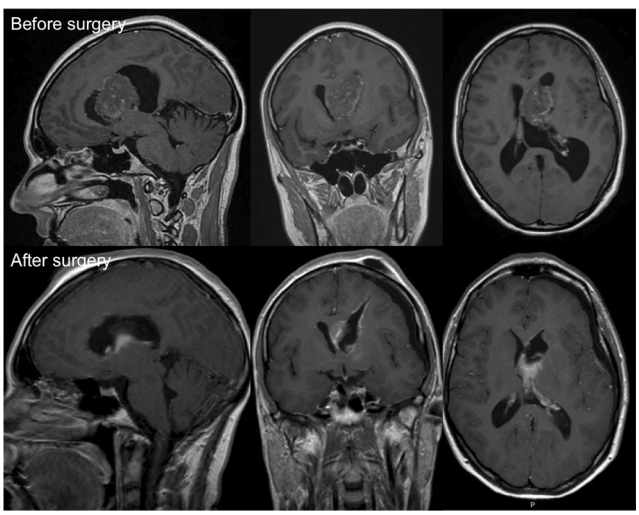

Fig. 7 Pre- and post-surgical management of left lateral ventricular injury. Central neurocytoma

Historical overview

Afterwards, Oertel et al. [11] reported the first application in neuroendoscopy of an ultrasonic aspirator, testing it in cadaveric pig brains. The authors achieved reliable, accurate, and effective aspiration of the paraventricular brain parenchyma under water at the wall of the lateral ventricle. These authors [11] also tested an ultrasonic aspirator in five clinical endoscopic applications: two cases of pituitary macroadenoma (through an endonasal transsphenoidal approach), two cases of ventricular hemorrhage, and one case of cystic craniopharyngioma. All of these were soft lesions that were aspirated without difficulty. In particular, these authors emphasized that the surgical field was not blurred. They concluded that this ultrasonic device could be useful in expanding the spectrum of endoscopic procedures, but remained skeptical as to how this device might perform in firm meningiomas or calcified fibrous tumors.

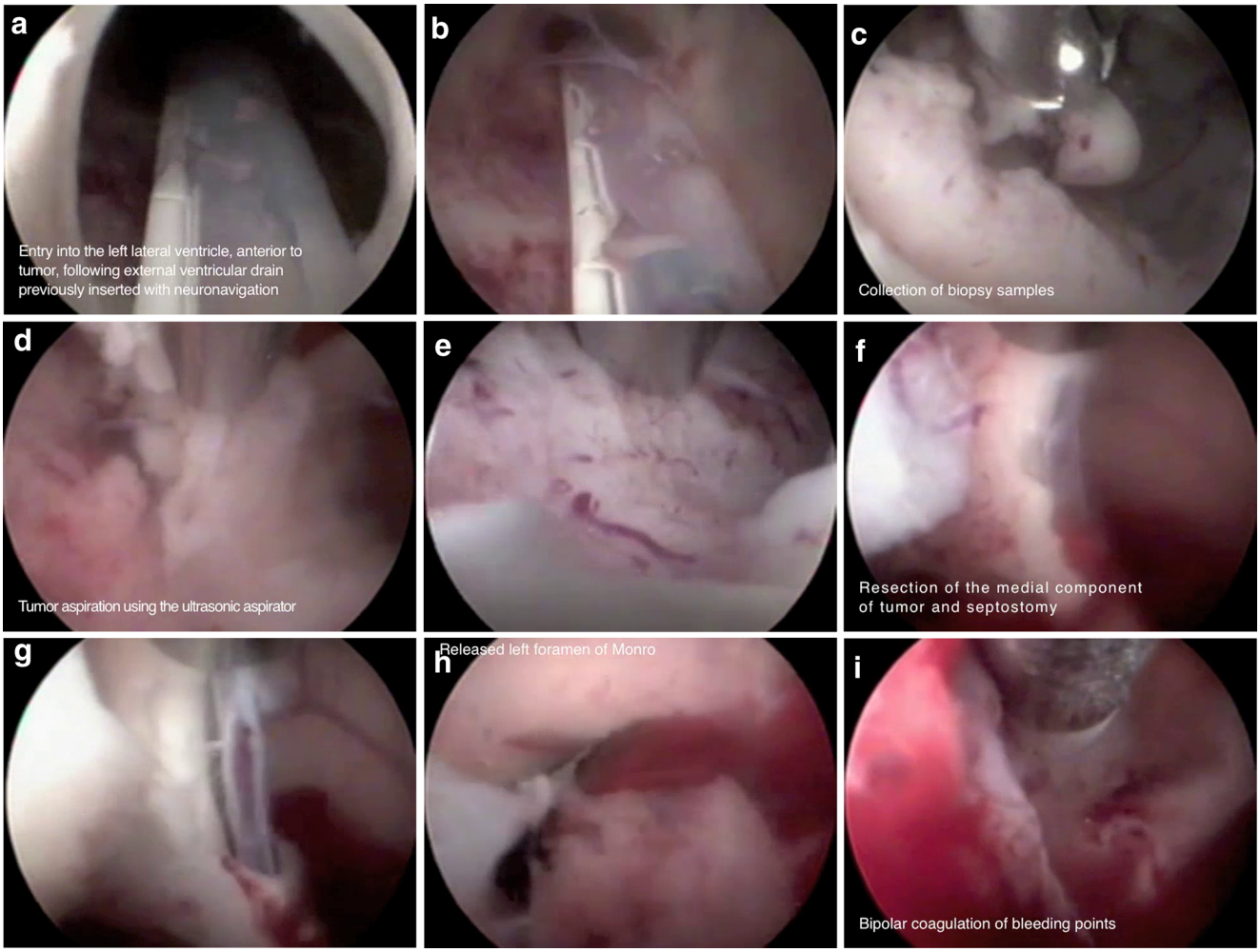

Fig. 8 a, b, c, d, e, f, g, h, i Intraoperative screenshot of subtotal resection of central neurocytoma in left lateral ventricle

The first case of solid tumor resection using an ultrasonic aspirator was described by Selvanathan et al. [14]. The small tumor was located within the aqueduct (low-grade glioneuronal tumor). During the procedure, they noted a temporary loss of visualization due to air bubbles caused by the ultrasonic aspirator during tumor cavitation. The authors described that while vision was obscured the aqueduct sustained a contusion, which may have precipitated a temporary fourth cranial nerve palsy.

Cinalli et al. [5] reported their experience in purely single-portal endoscopic tumor resection in 12 pediatric patients. Six cases were purely intraventricular tumors, two cases were intraventricular and paraventricular tumors, and four cases were suprasellar tumors with invasion of the third ventricle. They achieved a complete or nearly complete resection in more than 50% of cases, without major complications. They did not encounter the problems their predecessors experienced with loss of vision during tumor cavitation caused by the ultrasonic aspirator and the formation of bubbles. Cinalli and colleagues [5] contribute interesting practical details to the technique, such as the need to work with continuous irrigation to prevent collapse of the ventricle while the ultrasonic aspirator is in operation, which also flushes air bubbles resulting from tumor cavitation. Additionally, they report the use of a flexible coagulator introduced through the accessory working channel of the endoscope, thus eliminating the need to remove the ultrasonic aspirator to introduce the coagulator, which could cause an immediate CSF leak and loss of visibility. The authors also note strict control over aspiration with an assistant who immediately clamps the suction tube of the ultrasonic aspirator when an eloquent structure is being aspirated and there is a risk of injury. Cinalli and colleagues [5] also emphasize the learning curve, since as with all new instruments, it is important for the surgeon to be familiar with the settings of the endoscopic ultrasonic aspirator before using it.

Our experience

In our experience, these practical tips have proven to be very useful and effective. We note that the suction capacity of the

ultrasonic aspirator is quite remarkable. In nearly all cases in this series, the device was used at between 60 and 80% of its ultrasonic capacity. It should also be pointed out that in the cases of softer tumors, such as third ventricular colloid cysts, we had to reduce the suction capacity to close to 20%.

For third ventricular tumors, we used the transforaminal approach for colloid cyst resection, employing the technique previously described and published by our group [8]. In case number 4 (Fig. 2), the endoscopic third ventriculostomy was performed in the floor of the third ventricle with access through the foramen of Monro before resection. Subsequently, the tumor resection was undertaken from the right lateral ventricle with access through the choroidal fissure, thus avoiding to damage the foramen of Monro and Fornix [12, 13].

According to Cinalli et al. [5], the main indication for this technique is small tumors in which radical resection can be easily achieved or larger tumors in which radical resection may not be necessary, such as optic pathway glioma and some types of intraventricular craniopharyngiomas that infiltrate the hypothalamus, in which subtotal resection followed by radiation therapy is the treatment of choice.

Our last case, a large central neurocytoma in the left lateral ventricle (Fig. 7) (Video 2; intraoperative screenshot: Fig. 8a, b, c, d, e, f, g, h, i) represents a turning point with respect to what is mentioned above. While it is true that the endoscopic surgery time was longer than in a standard approach with smaller lesions, we believe that a minimally invasive approach through a burr hole can significantly minimize the morbidity and mortality associated with these surgeries when performed in a conventional open manner. By using a flexible coagulator or a laser coagulator and introducing it through one of the accessory working channels of the endoscope, as suggested by the Cinalli group [5], we could have reduced the surgery time by coagulating more easily without removing the ultrasonic aspirator each time.

Endoscopic versus open surgery

The endoscopic approach to intraventricular lesions usually involves shorter surgical time, less blood loss and faster recovery than the open approach, because of the considerable reduction in surgical aggressiveness. The endoscopic approach facilitates access to deep structures with excellent visualization of the anatomy and avoids the morbidity associated with classic transcallosal or transfrontal approaches. It also makes possible the simultaneous treatment of associated alterations in CSF circulation. Similar results to those achieved with microsurgical excision have been attained in selected cases, such as small and poorly vascularized intraventricular masses, as a consequence of the development of instruments such as the endoscopic ultrasonic aspirator. However, open surgery continues to be the gold standard, especially in large and highly vascularized lesions in which endoscopy still has a limited role.

Conclusions

The endoscopic ultrasonic surgical aspirator can be a safe and effective tool for the removal of intraventricular tumors, even with firmer solid lesions. Proper patient selection and neurosurgeons with specific training are essential. At the present time, the main limitation continues to be a larger size or vascularization of the lesion. In the future, greater experience and technological improvements may improve the applicability of this tool.

Compliance with ethical standards

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

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

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