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ORIGINAL ARTICLE

Microsurgical endoportal MRI/US-navigated approach for the resection of large intraventricular tumours: a 20-consecutive patients case series

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ABSTRACT

Objectives: Deep lesions located in lateral and third ventricles can be accessed thorough interhemispheric transcallosal or transcortical trans-ventricular approaches. Traditional brain retractors are made by 'non-cerebral engineered' spatulas, which do not equally distribute pressure on surrounding structures damaging brain. In this paper, we present a series of 20 intraventricular tumours resected through a MRI/US-navigated microscopic transcortical endoportal approach.

Patients and methods: Between January 2014 and December 2017, 20 patients underwent US-MRI neuronavigated (Esaote®, Genova, Italy) transcortical endoportal (Vycor® Viewsite Brain Access System TC Model, Vycor® Medical Inc., Boca Raton, FL) surgery for intraventricular deep-seated lesions with the intent to reach maximal safe resection.

Results: Gross total removal was achieved in 14 patients (70%). The only prognostic factor that resulted in statistical significance related to surgical radicality from multivariate analysis was white matter infiltration ($p = 0.043$), regardless of other tumour (dimensions, origin and location inside ventricular system, histopathology) and patient (age, gender, clinical presentation) characteristics. The mean duration of surgery was 225.9 min (± 59). Neither critical events, nor major bleedings, nor intraoperative deaths occurred during surgery. One case of postoperative CSF infection (5%) was registered. Six patients (30%) required permanent CSF drainage system (Ommaya reservoir, VP shunt) in the postoperative period. The mean Functional Independence Measure (FIM) score at last follow-up was 105 (range: 65–124).

Conclusions: Transcortical transventricular endoportal surgery seems to be a valuable alternative to transcallosal surgery, although further prospective multicentre studies with larger number of patients, evaluation of pre- and post-operative neuropsychological outcomes and achievement of postoperative DTI and f-MRI are needed to confirm our results.

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Endoportal neurosurgery; minimally invasive neurosurgery; retractorless surgery; endoventricular tumours; endoventricular neurosurgery

Introduction

Brain retraction to reach deep-seated lesions has always represented a challenge in neurosurgery. Brain spatulas do not equally distribute retraction forces on surrounding tissues, causing cortical and white matter damages.[1–6] Dedicated cerebral tubular retractors, known as *portal systems*, have been developed to equally distribute pressure over an elliptical surface and are increasing in popularity in neurosurgical practice.[3,7–13] Minimal white matter injuries along the surgical pathway have been documented on postoperative MRI when using portal retractors.[3]

In this study, we present our institutional experience of 20 consecutive intraventricular tumours resected thorough transcortical transventricular endoportal approach exploring advantages and drawbacks of the VBAS portal system (Viewsite™ Brain Access System TC Model, Vycor Medical™ Inc., Boca Raton, FL).

Materials and methods

Patient and tumour characteristics

Between January 2014 and December 2017, 20 consecutive patients underwent ultrasound (US)-magnetic resonance imaging (MRI) neuronavigated transcortical endoportal surgery for intraventricular lesions with the intent of maximal safe resection. Patient and tumour variables (age, gender, Karnofsky Performance Status (KPS) score, presenting signs and symptoms, tumour histopathology, extent of resection, postoperative surgical complications and neurological sequelae) were prospectively collected. Written informed consent was obtained from each patient. Patients' data management was conducted in accordance with the Declaration of Helsinki as revised in Edinburgh in October 2000.

Portal system technical features

The VBAS portal system (Viewsite™ Brain Access System TC Model, Vycor Medical™ Inc., Boca Raton, FL) was used in all cases. It is composed of an internal element – the *introducer* – thanks to which the system is advanced into the brain splitting the white matter up to the target and then removed, and an external part – the *working channel* – that may be fixed by a lateral tab to a self-retaining system and through which surgical instruments are inserted to reach the operative field. This portal

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Supplemental data for this article can be accessed here.

system is made of optically clear polycarbonate that allows visualisation of cerebral parenchyma. It has an elliptical section and is available in four widths – 12, 17, 21 and 28 mm – and in three lengths – 30, 50 and 70 mm.

Surgical technique

All patients underwent preoperative MRI. Functional MRI (f-MRI) and DTI tractography were integrated when needed to preserve eloquent areas and choose the optimal cortical entry point. All surgeries were performed by one neurosurgeon (P. M.) Under general anaesthesia, the patient head was fixed in a 3-pin Mayfield head-holder. Then, the head position was registered and paired with the magnetic navigation system (Esaote®, Genova, Italy). Skin incision and craniotomy were planned based on tumour location. The ideal cortical access and surgical trajectory were identified thanks to intraoperative US (iOUS) by using micro-convex 3–15 MHz probes (SC 3123 and LA332 appleprobe, Esaote®, Genova, Italy), sparing cortical vessels, eloquent cortical areas and white fibre tracts.

An external ventricular drain (Codman® Ventricular Drainage Kit, Codman®, Raynham, MA) specifically modified to remove the rigid outer end of the stylet was placed under US guidance to reach the ventricle (Figure 1(a,b)). Cerebrospinal fluid (CSF) was drained to relieve intracranial pressure (ICP), relax the brain and allow the safe introduction of the portal retractor (Video 1). The portal length was chosen calculating the depth from the cortex to the target and the distance between the tubular external edge and the cortical surface necessary to move and fix the retractor to the self-retaining system, as needed. The portal width was selected considering the tumour size, expected tumour bleeding risks and proximity to eloquent cortical areas. The VBAS was kept in a vancomycin solution while not in use to further reduce the post-operative infection risks. Once CSF has been drained, the portal system was modified, enlarging the small hole in the introducer tip of few millimetres to allow the EVD to pass through it (shown in Video 1). The introducer was then advanced throughout the corticectomy which was slightly larger than the tubular width to prevent cortical injuries during its positioning (Figure 1(c)). The retractor's elliptical shape tends to split rather than cut whit matter reducing retraction-derived damages. The VBAS was advanced through the ventricular ependyma. Once in place, the introducer was removed by releasing its latch locking system, the portal system was fixed to a self-retaining retractor (Phanton

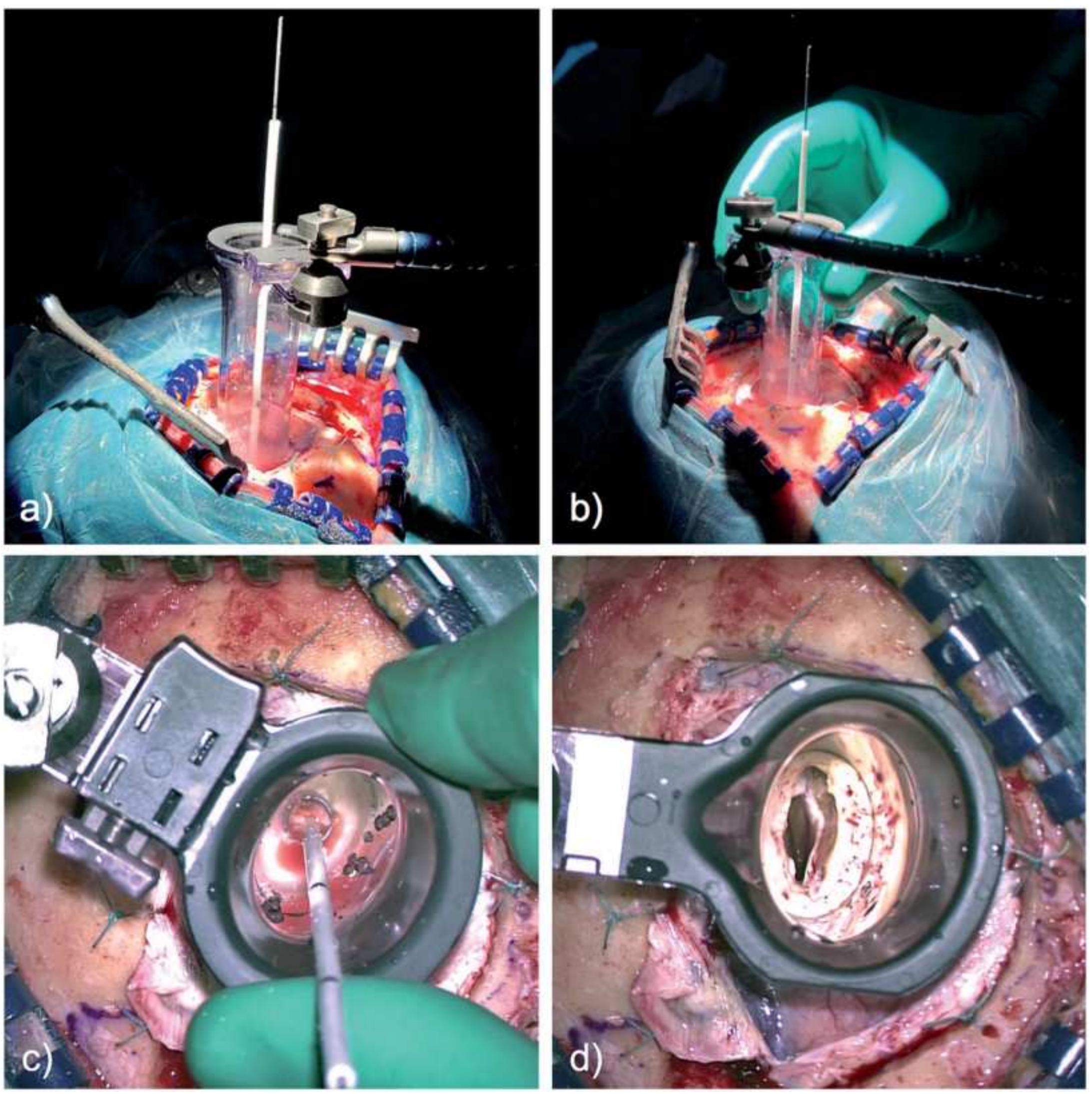

Figure 1. An EVD catheter specifically modified was placed into the ventricle under US guidance, providing the most accurate surgical trajectory (a, b). Once CSF has been drained, VBAS was gently advanced throughout the corticectomy, that was slightly larger than the tubular width to prevent cortical injuries during its positioning (c). The VBAS introducer was removed, the portal system was fixed to a self-retaining retractor and the tumour resection was started under the microscope vision (d).

Fukushima Neurological Holding Systems®, TeDan Surgical Innovations, Sugar Land, TX), and tumour resection was started thorough the portal working channel under microscope vision (Figure 1(d)). The VBAS trajectory can be changed easily, tilting its distal extremity in order to visualise different tumour portions.[14,15] Bayoneted instruments afford a wide range of manoeuvrability, given the tubular shape of the working channel. It is important to operate inside the ventricles to obtain the best surgical view, and to be aligned with the tumour major axis. When the tumour resection was completed and haemostasis was achieved, the VBAS was extracted and the EVD was left in place closed for 3 days.

Surgical results, postoperative complications and neurological outcomes

Immediate postoperative CT-scan and 48-h MRI were provided in each case. After surgery, all patients were routinely transferred in the Neurointensive Care Unit. Preoperative administration of anti-epileptic drugs was performed only in patients who presented with seizures. Neurological outcomes were assessed at the time of last follow-up evaluating both neurological sequelae and the Functional Independence Measure (FIM) score, an 18-item score system based on physical, psychological and social function evaluation used to assess the patient's level of disability. Each item is scored from 7 to 1, with 7 indicating complete independence and 1 total need of assistance, and the overall score runs from a minimum of 18 to a maximum of 126. Globally, the FIM score represents a useful indicator of the severity of patient disability, especially considering daily life activities.[16,17]

Statistical analysis

Quantitative variables were expressed as means ± standard deviation or medians, and categorical variables were expressed as numbers (percentages). Normality of distribution was assessed using histograms. Multiple logistic regression analysis was used to determine which variables independently predicted the extent of tumour resection. Results of multivariable modelling were expressed as p for significance, odds ratio (OR), and 95% confidence interval (CI) after adjustment for covariates. A two-tailed probability (p) value $\leq$ 0.05 was considered to indicate statistical significance. Statistical analysis was performed with SPSS software (IBM® Corporation, Released 2011, SPSS® Statistics for Macintosh, Version 20.0, Armonk, NY).

Results

Patient and tumour characteristics

The main patient and tumour characteristics are summarised in Tables 1 and 2. Patients' age ranged from 15 to 71 years (47.9 ± 18.0) and the male-to-female ratio was 1:1. The presenting signs and symptoms can be grouped in two categories (Table 1): the non-specific – headache (85%), vertigo (45%), nausea and vomiting (30%) – and the tumour-related clinical cluster – cognitive decline (40%), visual deficits (35%) and hemiparesis (5%). Seizures represented the tumour manifestation only in two cases (10%). The mean tumour volume was 30.4 cc (median: 18.5 cc). Tumours were sited in the midline in 9 cases (45%) and in the lateral ventricles in the remaining 11 (55%). The lesions arose from the foramen of Monro or third ventricle (35%), thalamus (25%), septum pellucidum (15%), tela choroidea (10%), trigone (10%) and caudate nucleus (5%). The histopathological diagnosis was obtained in all cases, as detailed in Table 2.

Table 1. Patients characteristics and clinical presentation.

Age (years; mean ± SD)	47.9 ± 18.0
Gender (male/female)	10 (50) / 10 (50)
KPS before surgery (%)	
70	2 (10)
80	3 (15)
90	5 (25)
100	10 (50)
Presenting signs and symptoms (%)	
Headache	17 (85)
Vertigo	9 (45)
Nausea/vomiting	6 (30)
Cognitive decline[a]	8 (40)
Memory deficits	*3 (15)*
Confusion	*4 (20)*
Behavioural alterations	*2 (10)*
Visual deficits[b]	7 (35)
Scotomas	*2 (10)*
Visual acuity reduction	*5 (25)*
Visual field defects	*3 (15)*
Hemiparesis	1 (5)
Seizures	2 (10)

KPS: Karnofsky Performance Status.
[a]Two patients present more than one cognitive alteration.
[b]Three patients present more than one visual deficit.

Table 2. Tumour characteristics.

Tumour dimensions (cc; mean ± SD)	30.4 ± 45.6
Tumour location inside ventricular system (%)	
Midline	9 (45)
Left	7 (35)
Right	4 (20)
Tumour origin (%)	
Foramen of Monro/third ventricle	7 (35)
Tela choroidea	2 (10)
Septum pellucidum	3 (15)
Thalamus	5 (25)
Caudate nucleus	1 (5)
Trigone	2 (10)
Pathological diagnosis (%)	
Neuroepithelial neoplasms	12 (60)
Pilocytic astrocytoma	*1 (5)*
Astrocytoma	*2 (10)*
Glioblastoma	*3 (15)*
Oligodendroglioma	*1 (5)*
Central neurocytoma	*3 (15)*
Subependymoma	*2 (10)*
Benign cystic lesions	6 (30)
Arachnoid cyst	*2 (10)*
Colloid cyst	*4 (20)*
Meningiomas	1 (5)
Metastases	1 (5)
Pathological grade (%)	
Not applicable	7 (35)
1	5 (25)
2	4 (20)
3	1 (5)
4	3 (15)

Surgical results, postoperative complications and neurological outcomes

The results of surgery are given in Table 3. Gross total removal was achieved in 14 patients (70%). Three out of six cases with subtotal resection underwent adjuvant radiation therapy: Gamma Knife stereotactic radiosurgery (GKSRS) and conventional radiotherapy in one and two cases, respectively. According to themultivariate analysis, the only prognostic factor related to surgical radicality resulted the white matter infiltration (OR: 1.081, 95% CI: 1.073–1.090, $p = 0.043$), regardless of other tumour (dimension, origin, location within the ventricular system, histopathology) and patient characteristics (age, gender, clinical presentation). The mean surgical duration was 225.9 min (± 59) compared to 278.3 min achieved by the senior author using traditional surgical approaches to resect intraventricular lesions. Neither critical events, nor major bleedings, nor deaths occurred during surgery. In 15 patients (75%), EVD was left in place for 72 h after surgery, and in 6 of them (30%) a permanent CSF drainage system (Ommaya reservoir or ventriculo-peritoneal shunt) was implanted over the first postoperative month. No postoperative haemorrhages were recorded. One patient had a CSF infection (5%) with consequent ventriculitis, sepsis and multi organ failure that caused his death 1 month after surgery. Three other patients (15%) died within 6 months because of progressive disease (PD). All patients underwent clinical and radiological follow-up at our hospital. The average follow-up duration was 13.0 months (median: 8.0; range: 6–30), with a KPS ≥ 80 registered in 80% of patients. Analysing neurological outcomes at last follow-up, no new-onset seizures were reported, while behavioural alterations and memory deficits were recorded in one and two cases, respectively. Finally, the mean FIM score was 105 (range: 65–124).

Table 3. Surgical results, postoperative complications and permanent neurological sequelae.

Duration of surgery (minutes; mean ± SD)	225.9 ± 59.9
Extent of surgical resection (%)	
Gross total resection	14 (70)
Subtotal resection	6 (30)
Intraoperative EVD placement (%)	15 (75)
CSF drainage system placement (%)	6 (30)
Ommaya reservoir	3 (15)
VP shunt	3 (15)
Postoperative surgical complications (%)	
Haemorrhage	0
CSF infection	1 (5)
Permanent neurological sequelae (%)	
Cognitive decline	3 (15)
Memory deficits	*2 (10)*
Confusion	*0*
Behavioural alterations	*1 (5)*
Hemiparesis	0
Visual deficits	0
Seizures	0
FIM score (mean ± SD)	105 ± 16.1
KPS at last follow up[a] (%)	
<70[b]	3 (16)
80	4 (21)
90	7 (37)
100	5 (26)

CSF: cerebro-spinal fluid; EVD: external ventricular drainage; KPS: Karnofsky Performance Status; VP: ventriculo-peritoneal.

[a]KPS was registered at last follow-up for 19 patients, because one patient died 1 month after surgery.

[b]All patients with KPS <70 died within 6 months after surgery for disease progression.

Discussion

Despite limited literature, authors with experience in using portal retractors agree about the benefits of these tools for intraventricular tumour and haemorrhage exoscopic and microscopic approaches.[3,18–20] Endoscopic resection is an option but case series remain limited.[21]

We decided to undertake the US-MRI neuronavigated transcortical endoportal (VBAS) strategy since 2014 due to the limitations of transcallosal approaches for the treatment of large intraventricular lesions especially if far from the midline with concomitance HCP.[22–25] At that time, the VBAS was the first commercially available CE registered tubular retractor on the market in Italy. Among the different portal retractors commercially available to now, the VBAS presents some features that made it appealing. Its elliptical section offers a scant extra space for the bayoneted instruments increasing surgical manoeuvrability. The conical shape affords for a decreased white matter retraction force at depth with no significant limitation in the exposure. The polycarbonate manufacturing makes it optically clear without reflections and glares that can be occasionally observed with metallic retractors especially under powerful operative microscope light. Its transparency helps as well to check the underlying cerebral parenchyma while gradually splitting white matter during its positioning. Finally, it is disposable and ready to use in different sizes and widths (Figure 2). However, different tubular retractors have been launched on the market over the last years. They are made of different materials, such as plastic or metal, and different sizes and widths, but incomplete data have been reported in literature to draw conclusions about the advantages of one over the others (Figure 3).

In our clinical series, transcortical transventricular endoportal surgery for deep-seated intraventricular tumours led to a rate of surgical gross total removal (70%) in line with those reported in literature, associated significant low rates of postoperative complications and neurological sequelae and good postoperative patients' performance status.[25,26]

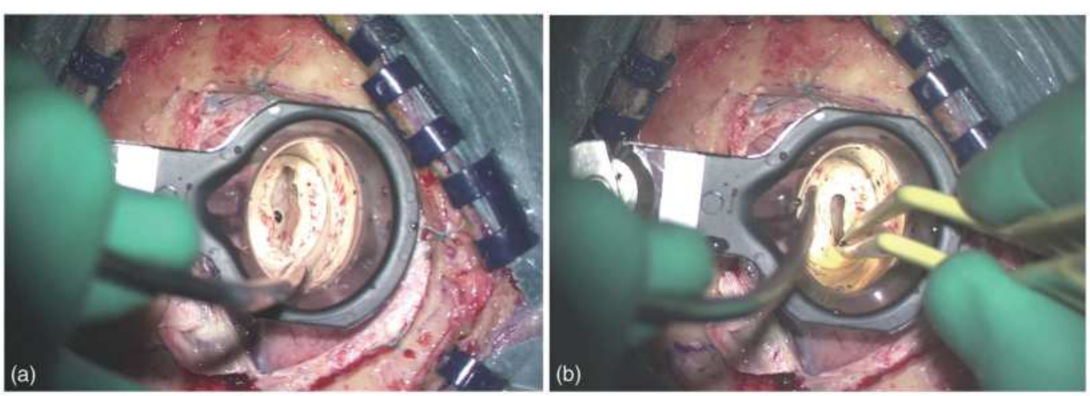

Figure 2. The tubular shape and the polycarbonate manufacturing, that makes it optically clear with thin walls, allow the underlying cerebral parenchyma visualization without limiting surgical working space and instrument manoeuvrability (a, b).

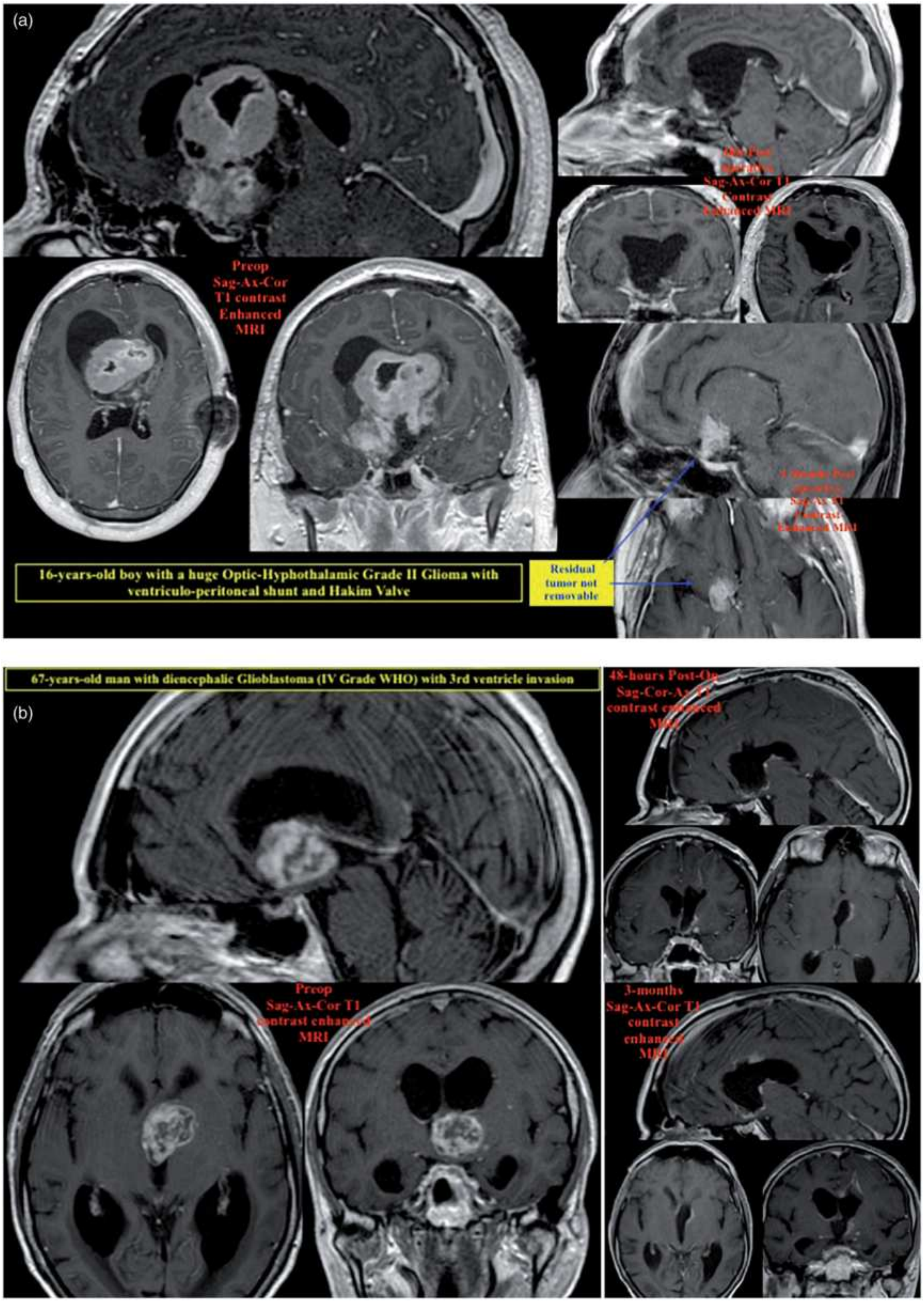

Figure 3. (a) Pre-operative, post-operative and 3-months follow up sagittal, axial and coronal contrast enhanced MRI of a 16-years-old boy operated for an optic-hypothalamic grade II astrocytoma; sub-total resection. (b) Pre-operative, post-operative and 3-months follow up sagittal, axial and coronal contrast enhanced MRI of a 67-year-old man operated for a diencephalic glioblastoma (WHO Grade IV); gross total resection. (c) Pre-operative, post-operative and 3-months follow up sagittal, axial and coronal contrast enhanced MRI of a 46-year-woman operated for a third ventricle colloid cyst; gross total resection. (d) Pre-operative, post-operative and 3-months follow up sagittal, axial and coronal contrast enhanced and FLAIR MRI of a 24-year-man operated for a diffuse diencephalic astrocytoma; gross total resection. (e) Pre-operative, post-operative and 3-months follow up sagittal, axial and coronal contrast enhanced MRI of a 21-year-man operated for an atypical central neurocytoma; gross total resection.

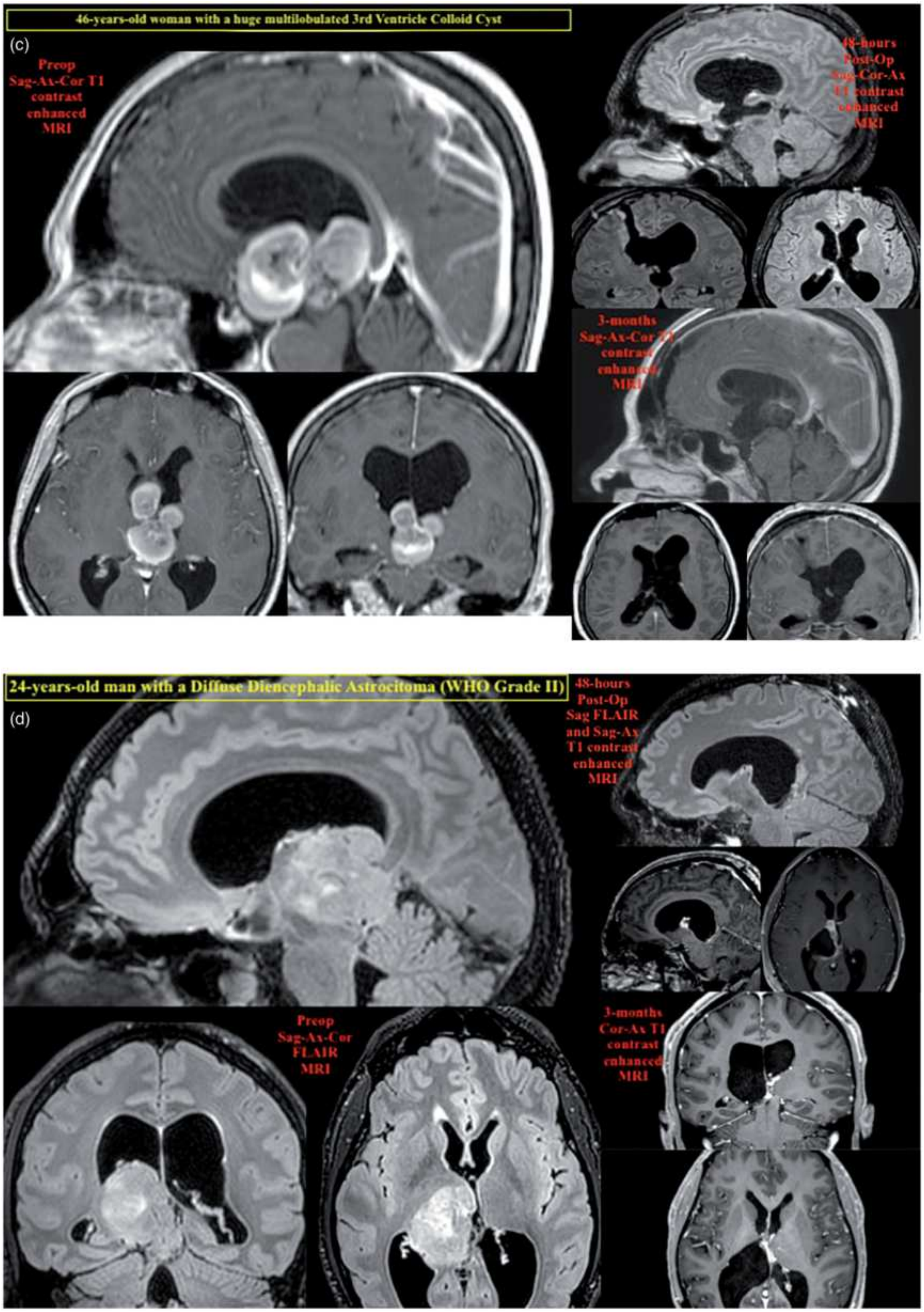

Figure 3. Continued.

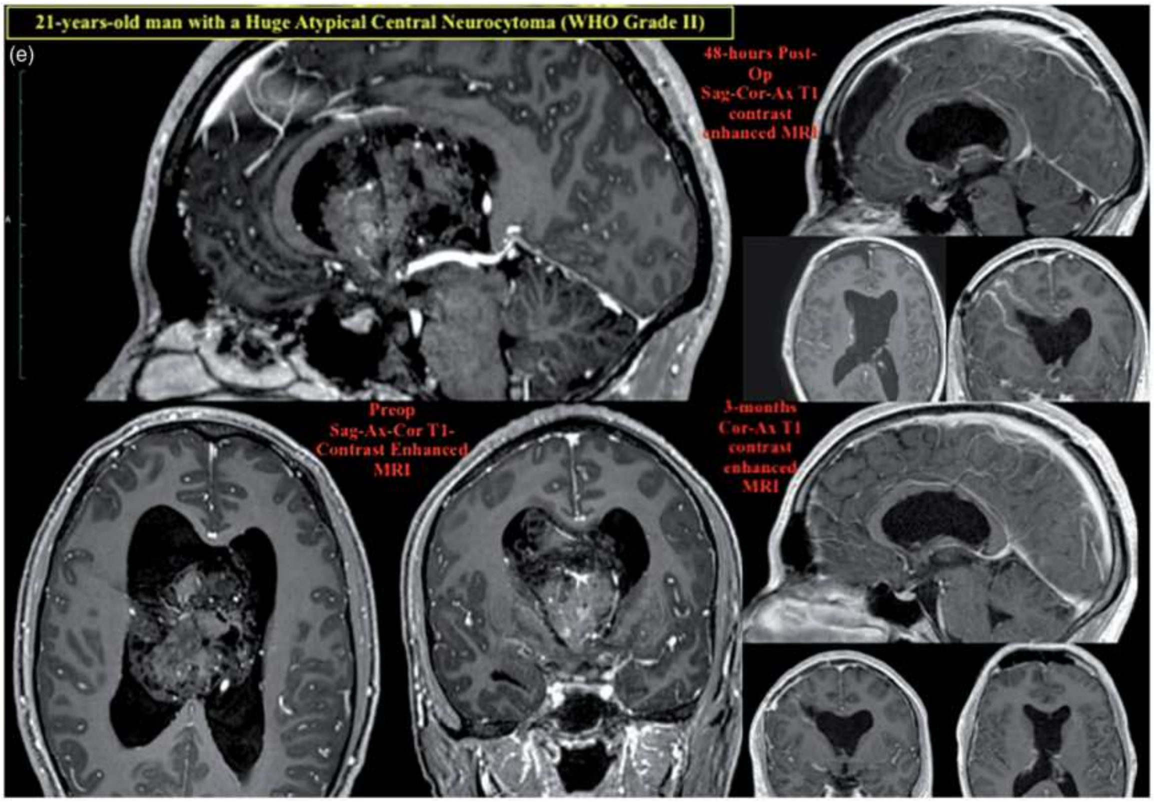

Figure 3. Continued.

According to the multivariate analysis, the only predictive factor for surgical radicality resulted to be the white matter infiltration pattern. Histopathological findings were not confirmed as predictive factors for extent of tumour resection, despite the limited size of the population. In fact, deep-seated glial tumours, particularly basal ganglia glioblastomas, hardly could be totally resected given their infiltrative pattern, differently from other tumours more suitable for gross total removal.

The surgical duration with this technique was reduced in comparison with that previously recorded in the personal senior author's series (225.9 versus 278.3 min). This result could be explained by several factors: the US-MRI navigation, that optimises the ventricular access and the tumour approach, the good surgical exposure and two-handed intraoperative manoeuvrability through the VBAS.[14]

Tubular retractors are subject to the *conizing effect* that increases proportionally with their length, reducing the visibility in deep fields, having as a consequence a possible lengthening of tumour resection time. In spite of this, the VBAS with a maximum length of 7 cm expresses a low magnitude of this disadvantage.[15]

About surgical complications, no case of postoperative haemorrhage was recorded on postoperative CT scan, no ischemic areas were detected around the operative cavity on the early postoperative MRI, and one case of CSF infection was registered. All these results compare well with previous studies.[22,23,25–29] The rate of secondary hydrocephalous that needed permanent shunt placement (30%) appears in line with that reported for transcallosal procedures.[22–25,29] This outcome suggests the low impact of surgical procedure per se, compared to release of tumour debris and blood clots in CSF that affects the pathogenesis of postoperative hydrocephalous. Finally, looking at the neurological sequelae, we identified postoperative cognitive deficits in 15% of cases, but no case of visual impairment nor seizures were observed. There was no evidence of new postoperative neurological deficits related to the disruption of deep fibre tracts. These results are overall better than those reported for traditional transcortical and transcallosal approaches,[25] and in line with other series of transcortical endoportal surgery.[3,7,8,11–13] The FIM score was a reliable tool we used to evaluate the disability outcome.[16,17] Our results (mean FIM score: 105) documented postoperative good levels of independence in daily life activities.

VBAS international availability, moderate cost, easy and ready to use characteristics independently from other equipment make tubular retractors a valid surgical option in the case of intraventricular tumours.

Conclusions

The aim of our study was principally to describe the procedural steps of a new surgical technique, highlighting its advantages and drawbacks. The most significant benefits of US-MRI neuronavigated transcortical transventricular VBAS approach include:

1. performing small corticectomy around the EVD, reducing cortical injury and risk of postoperative neurological sequelae;
2. maintaining a fixed trajectory sliding downwards the tumour, thus preventing the risk to lose the target;
3. preserving the white matter anatomy, taking advantages from its elasticity and potentiality to heal over.
4. visualising the extreme tumour portions, tilting the portal system and eventually using an endoportal endoscope assistance.[14,15]

Ethical approval

All procedures performed in this study 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 each patient at the moment of operation and for every follow up. For participants under the age of 18 years, informed consent have been obtained from a parent and/or his/her legal guardian.

Disclosure statement

All authors certify that they have no affiliations with or involvement in any organisation or entity with any financial interest (such as honoraria; educational grants; participation in speakers' bureaus; membership, employment, consultancies, stock ownership, or other equity interest; and expert testimony or patent-licensing arrangements), or non-financial interest (such as personal or professional relationships, affiliations, knowledge or beliefs) in the subject matter or materials discussed in this manuscript.

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