Minimally invasive surgery with tubular retractor system for deep-seated or intraventricular brain tumors: report of 13 cases and technique description

Cirugía mínimamente invasiva con sistema retractor tubular para tumores cerebrales profundos o intraventriculares: reporte de 13 casos y descripción de la técnica

Alberto Valarezo Chuchuca[1], Leah Morejón Hasing[2], Xavier Wong-Achi[1,3]

[1] Deparment of Neurosurgery, National Oncologic Institute "Dr. Juan Tanca Marengo"-SOLCA, Guayaquil 090505, Ecuador.
[2] Department of Neurosurgery, Luis Vernaza Hospital, Guayaquil 090313, Ecuador.
[3] Universidad Espíritu Santo, Samborondón 092301, Ecuador.

Declarations of interest: none.

Resumen

Antecedentes: El tratamiento quirúrgico de los tumores en aquellas áreas del cerebro consideradas de difícil abordaje se está volviendo accesible gracias a la cirugía mínimamente invasiva. Mediante el uso de un sistema retractor tubular, se proporciona desplazamiento circular y distribución simétrica del cerebro, reduciendo las complicaciones postoperatorias de retracción prolongada, así como el riesgo de edema e infarto. Esto se ha convertido en un método ideal para llegar a áreas como las regiones parenquimatosas profundas, subcorticales e intraventriculares. **Métodos:** De enero de 2015 a noviembre de 2018, se seleccionaron trece casos de pacientes diagnosticados con tumores intraparenquimatosos o intraventriculares. La resección quirúrgica se realizó con la ayuda del microscopio, neuroendoscopio y retractores tubulares. El estudio volumétrico y la profundidad del tumor se obtuvieron con la RM mediante el sistema de neuronavegación. La profundidad se midió desde el punto de entrada en la superficie cortical hasta el área más cercana al tumor. **Resultados:** Se logró resección total macroscópica en ocho pacientes, resección subtotal en tres, resección parcial en un caso y se realizó una biopsia. Un paciente desarrolló hidrocefalia y otro una fístula de líquido cefalorraquídeo (LCR) como complicación posquirúrgica. **Conclusiones:** La cirugía mínimamente invasiva para la escisión de tumores podría permitirnos acceder directamente a lesiones cerebrales profundas y disminuir la lesión del tejido cerebral circundante, así como prevenir adherencias de este en los retractores tubulares. Simultáneamente, la técnica microquirúrgica y endoscópica podría acortar el tiempo quirúrgico. El propósito de esta técnica es reducir la morbilidad asociada a los procedimientos quirúrgicos convencionales y los días de hospitalización en la Unidad de Cuidados Intensivos, mejorando así la calidad de vida.

Palabras clave: Cirugía mínimamente invasiva, retractor tubular, tumores profundos, sistema de neuronavegación.

Abstract

Background: Surgical treatment of tumors in those areas of the brain considered difficult to reach is becoming accessible thanks to minimally invasive surgery. Through the use of a tubular retractor system, a circular displacement and a symmetrical

---

Correspondence:
Xavier Wong-Achi, M.D.
Universidad Espíritu Santo, Samborondón 092301, Ecuador.
xawong@uees.edu.ec
+593 96 099 1300
ORCID iD: https://orcid.org/0000-0001-5186-6339

distribution of the brain are provided, reducing the postoperative complications of prolonged retraction, as well as the risk of edema and infarction. This has become an ideal method to reach areas such as deep parenchymal, subcortical and intraventricular regions. **Methods:** From January 2015 to November 2018, we selected thirteen cases of patients diagnosed with intraparenchymal or intraventricular tumors. Surgical resection was performed with the assistance of a microscope, neuroendoscope, and brain tubular retractors. The volumetric study and the depth of the tumor were obtained on the MRI using the neuronavigation system. Depth was measured from the entry point on the cortical surface to the area closest to the tumor. **Results:** Gross total resection was achieved in eight patients, subtotal resection in three, partial removal in one case and one biopsy was performed. One patient developed hydrocephalus and one a cerebrospinal fluid (CSF) fistula as a post-surgical complication. **Conclusions:** Minimally invasive surgery for tumor excision could allow us to directly access deep brain lesions and decrease injury to the surrounding brain tissue, as well as prevent adhesions from it in tubular retractors. Simultaneously, the microsurgical and endoscopic technique could shorten the surgical time. The purpose of this technique is to reduce the morbidity associated with conventional surgical procedures and the days of hospitalization in the Intensive Care Unit, thus improving quality of life.

Key words: Minimally invasive surgery, neuroendoscopy, tubular retractor, deep tumors, neuronavigation system.

Abbreviations

VBAS: ViewSite Brain Access System.
MRI: Magnetic resonance imaging.
CSF: cerebrospinal fluid fistula.

Introduction

Multidisciplinary treatment of primary brain tumors includes surgical resection, chemotherapy, and radiation therapy[1]. The vast majority of intracerebral tumors require maximum excision to improve neurological status[2,3]. Deep intraparenchymal and intraventricular tumors require deep tissue transgression and retraction, often for long periods of time, causing direct trauma to brain tissue[4,5], putting pressure on the brain causing injuries such as edema, contusions and hemorrhages, documented in the literature[6,7,8,9,10,11,12,13]. Recent technological advances, such as neuronavigation and anatomical knowledge of the nervous tracts through tractography, have stimulated the use of minimally invasive surgery for these types of tumors that were once considered inaccessible and inoperable[14,15]. The most commonly instruments used in brain retraction during procedures are ribbon or blade retractors, however neurosurgeons have a need for devices that provide better surgical outcomes, benefitting both the surgeon and the patient. Decreased brain retraction can be achieved through symmetric distribution using tubular retractor system, that permits entry to the targeted site while distributing brain tissue evenly in a 360° dispersion pattern[5,16,17,18,19]. ViewSite Brain Access System (VBAS) is a clear cylindrical disposable set of devices of different sizes which provides a surgical corridor to access sites within the brain and cerebellum with minimal disruption of the surrounding tissues. It is inserted into the brain tissue guided by neuronavigation system. Once the objective is reached, the blunt introducer responsible for the dissection of the nervous tracts is removed, allowing a space to work. We describe the surgical technique and present our experience in thirteen cases using this method.

Methods

An observational descriptive study was conducted from january 2015 to november 2018 in a series of thirteen patients diagnosed with deep brain and intraventricular tumors, treated in the Neurosurgery department of the National Oncologic Institute "Dr. Juan Tanca Marengo" - SOLCA. Clinical, surgical and radiological data, including location of the lesion, histopathological classification and degree of surgical resection were obtained from patients records. Surgical resection was assisted with a Carl Zeiss surgical microscope and/ or Karl Storz rigid endoscope with a 6-degree optic x 2 mm in diameter x 12 cm in length. The tubular retractor system 17L (17 mm width x 11 mm height x 70 mm length) and 21L (21mm wide x 15mm height x 50mm length) VBAS (Vycor Medical, Inc., Boca Raton, Florida, USA) was used (Figure 1). The surgical trajectory was planned under the guidance of the BRAINLAB Curve neuronavigation system. Determination of tumor depth and volume was performed with Multiva 1.5 T magnetic resonance imaging (MRI). Measurements were made on contrast-enhanced T1-weighted MRI in high-grade gliomas and metastases, including a case of radionecrosis; and on T2-weighted-Fluid Attenuated Inversion Recovery

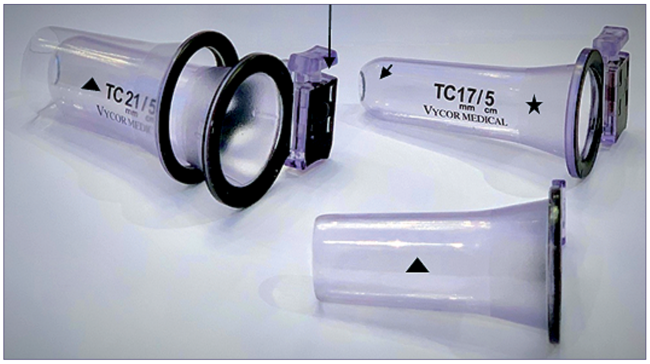

Figure 1. ViewSite Brain Access System (VBAS) consisting of the introducer (black star) and the atraumatic distal end (short black arrow). It also has the locking system (long black arrow) in addition to the surgical port (black triangle).

(FLAIR) for low-grade gliomas. The depth of the tubular retractor path was measured from the entry point on the cortical surface to the area closest to the tumor surface.

Technique description

All patients underwent MRI with and without contrast and tractography, according to the neuronavigation protocol. Under general anesthesia, Mayfield skull clamp was used to position the head depending on the location of the tumor. Surface registration and infrared-based navigation was performed with the z-touch BrainLAB neuronavigation system to help in planning the approach and transcortical route, avoiding the nerve tracts preferably locating the gyrus closest to the injury.

A mini craniotomy (≤ 3 cm in diameter) was planned, and the durotomy was preferably performed in a cruciate or X-shaped fashion (Figure 2). We identified the gyrus previously established during planning (Figure 3), initiating the microdissection to its depth, and subsequently performing the corticotomy no larger than 15 to 20 mm to facilitate initial dissection of the retractor. The tubular retractor was gently introduced, which minimize brain tissue disruption with low retraction pressure due to the distribution of retraction force in all directions of the area. It can be repositioned in a rota-

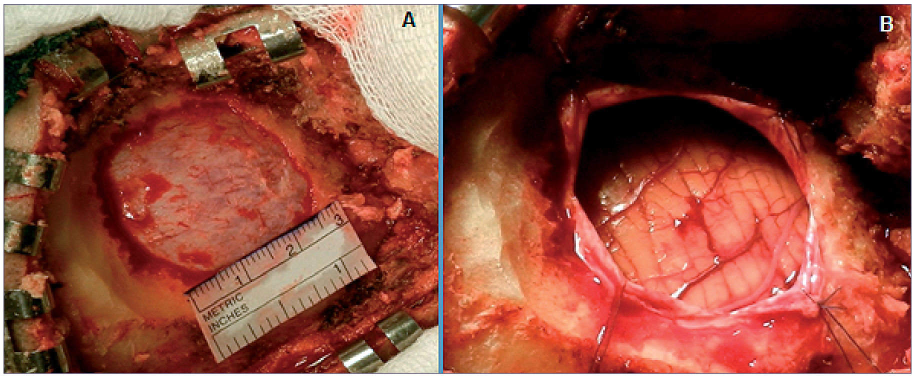

Figure 2. (A) Intraoperative image of the mini-craniotomy performed and (B) dural opening in x-shaped fashion.

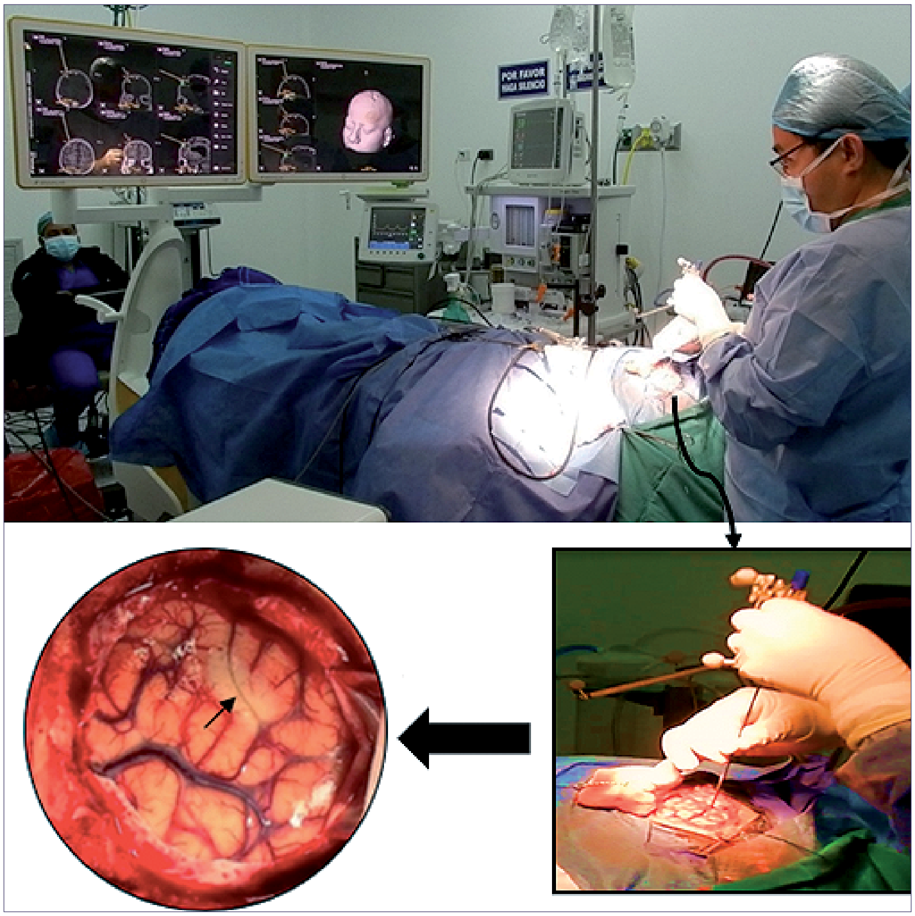

Figure 3. Operating room setup with intraoperative navigation image showing trajectory to the lesion and of the desired sulcus (black arrow) to be targeted for accessing the lesion.

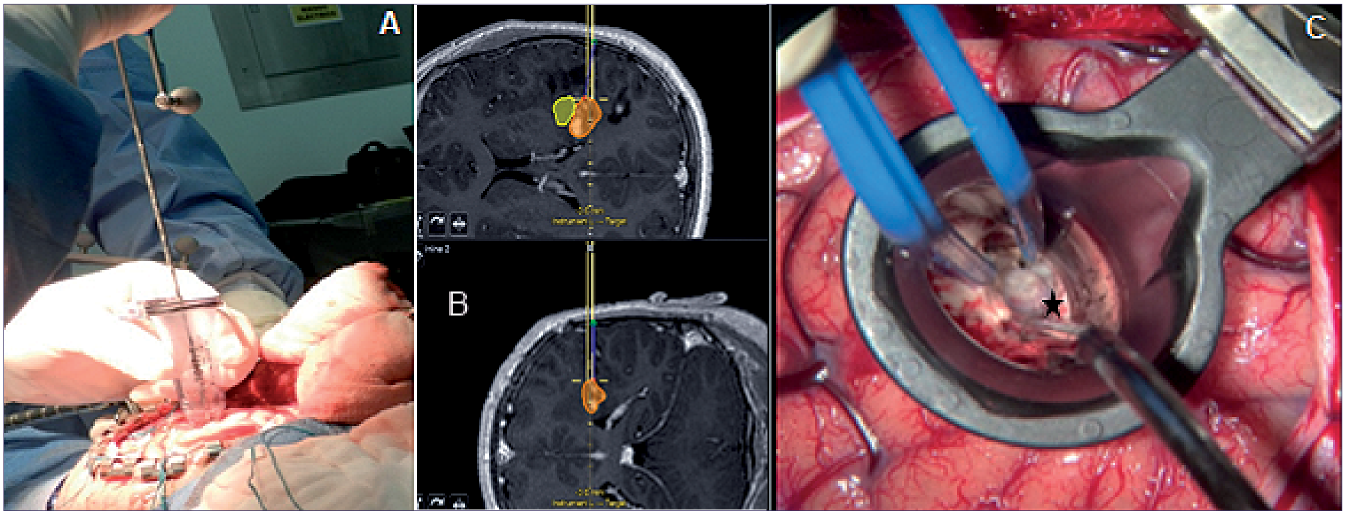

Figure 4. Image of a deep-parenchymal tumor patient who underwent resection with a tubular retractor under microscopic visualization. (A-B) Intraoperative navigation images showing targeting of lesion and perpendicular positioning of the retractor; (C) 17-mm retractor placed through the sulcus to expose the lesion. Gentle retractions encourage tumor tissue to emerge into view (black star), observing the simultaneous use of bipolar forceps and suction through the tubular retractor during tumor removal.

tional 360-degree movements, providing a direct angle of view toward the lesion. It is recommended that the device be inserted perpendicular to the cortical surface (Figure 4A-B). Once the introducer reaches the tumor surface, it is removed and the port slides forward simultaneously, until it reaches the target (Figure 4C). The choice of device diameter and length is chosen based on the diameter of the tumor and the distance of the path from the cerebral cortex. In some cases, it was necessary to change the device during the procedure. Tumor resection was performed under microsurgical and/or neuroendoscopic technique.

Results

During the period of time from 2015 to 2018, thirteen patients (7 males and 6 females), with an overall mean age of 39 years (range 12-75), were diagnosed with brain lesions located in deep or intraventricular areas and selected for excision using the tubular retractor system (VBAS) (Table 1). Tumor location was classified according to specific anatomical structures; in the present study, three (23%) cases were located in the basal ganglia and posterior thalamus, three (23%) in cerebellum, three (23%) were intraventricular, two (15%) were in a deep frontal area, one (8%) temporo-occipital and one (8%) parieto-occipital. We attempt total macroscopic resection in 8 cases, subtotal in 3 cases, 1 intended partial removal and biopsy was done in 1 case. Surgical procedures were performed with microsurgical vision in all cases. Neuroendoscopic assistance was added to intraventricular (2) and posterior thalamus tumors (1), without macroscopic evidence of residual tumor. Mean tumor depth was 3.63 cm (range 1.8-5.2 cm), the average preoperative tumor volume for the series was 22.74 cm^3 (range 1.53-56.6 cm^3) and mean postoperative volume of tumors resected subtotal (STR) and partially (PR) was 3.79 cm^3 (range 0.78-11 cm^3). Tumor types included: 2 grade II astrocytomas, 2 grade III astrocytomas, 1 grade IV astrocytoma, 1 angioglioma, 1 ependymoma, 2 metastases (from breast and lung adenocarcinoma), 1 lymphoma, 2 immature teratomas and 1 radionecrosis. One patient of the series with an intraventricular tumor developed a cerebrospinal fluid fistula (CSF) through the surgical wound, which was resolved with conservative treatment. Another case of intraventricular tumor presented hydrocephalus as a complication, resolved with a ventriculoperitoneal shunt device.

Illustrative cases

Case 1

A 23-year-old male, with a previous diagnosis of anaplastic astrocytoma (by biopsy) and completed neoadjuvant therapy with temozolomide and subsequent radiotherapy. Seven months after ending treatment, presents with persistent headache and progressive left hemiparesis. A contrast-enhanced MRI showed a right posterior thalamic tumor with extension towards the cerebral peduncle and perilesional edema. The mass measured 4 x 4 x 3 cm, with a volume of 24.96 cm^3 and a depth of 4.5 cm. Spectroscopy revealed high levels of choline, consistent with tumor activation. Cerebral tractography showed a lateral displacement of the optic radiation in the right occipital region in relation to the tumor. A minimally invasive tumor excision was performed using the tubular retractor system (VBAS) (Figure 5) assisted by neuronavigation, achieving intended gross total removal (GTR) (Figure 6), with a histopathological report that confirmed the previous diagnosis, Ki67: 10%.

Case 2

A 12-year-old boy presented with a 3-month history of persistent headache, seizures and a mild left hemiparesis. Preoperative T1-weighted contrast-enhanced MRI showed a right posterior thalamic tumor in proximity to the internal capsule, measuring 2.5 x 2.5 x 2 cm, with a total volume of

Table 1. Series of patients treated surgically using tubular retractors

Case	Age (Gender)	Histopathologic diagnostic	Localization	Pre-operative tumor volume (cm^3)	Post-operative tumor volume (cm^3)	Depth (cm)	Technique	Surgical approach	Tumor resection	Complications
1	23 (m)	Anaplastic astrocytoma	Posterior thalamus with extension to cerebral peduncle	39.95	0	4.5	Microsurgery	Parieto-occipital	GTR*	-
2	12 (m)	Grade II astrocytoma	Thalamus	6.5	0	3.3	Microsurgery + endoscopy	Temporal	GTR	-
3	52 (f)	Anaplastic astrocytoma	Thalamus	1.53	0.78	3.8	Microsurgery	Frontal	STR†	-
4	48 (m)	Mixopapillary ependymoma	Intraventricular	24.36	0	4.2	Microsurgery + endoscopy	Frontal	GTR	-
5	17 (m)	Mature teratoma	Pineal region with ventricular extension	56.58	1.5	4.8	Microsurgery + endoscopy	Frontal	STR	CSF fistula
6	19 (m)	Grade II astrocytoma	Frontal	22.3	0	4.5	Microsurgery	Frontal	GTR	-
7	49 (m)	Lung adenocarcinoma	Frontal	40.4	0	3.8	Microsurgery	Frontal	GTR	-
8	48 (f)	Radionecrosis	Parieto-occipital	28.1	-	2.8	Microsurgery	Parietal	Biopsy	-
9	59 (f)	Breast adenocarcinoma	Cerebellum	23.6	0	3.5	Microsurgery	Suboccipital	GTR	-
10	75 (f)	Linfoma	Cerebellum	4.94	0	2.6	Microsurgery	Suboccipital	GTR	-
11	65 (f)	Grade IV astrocytoma	Temporo-occipital	18.86	1.88	1.8	Microsurgery	Temporo-occipital	STR	-
12	13 (m)	Mature teratoma	Pineal region with ventricular extension	50.31	11	5.2	Microsurgery	Occipital	PR‡	Hydrocephalus
13	33 (f)	Angioglioma	Cerebellum	20.36	0.32	2.4	Microsurgery	Transvermian	GTR	-

*GTR (Gross total removal); †STR (Subtotal removal); ‡PR (partial removal).

6.5 cm^3 and a depth of 3.3 cm. Spectroscopy study showed moderate levels of choline activity. Minimally invasive tumor excision was scheduled using the same tubular retractor system (Figure 7) assisted by neuronavigation, achieving intended gross total removal (Figure 8). Pathology revealed a Grade II astrocytoma, Ki67: 2%.

Discussion

The main objective of minimally invasive surgery of intraparenchymal and intraventricular tumors is to reduce damage caused by prolonged brain retraction required to access these lesions. The introduction of neuronavigation systems has allowed the development of surgical techniques through small incisions, mini-craniotomies and in the planning of the surgical route, avoiding relevant nerve tracts, thus reducing secondary damage from the surgical process. Various innovations had been made in the design of instruments; in 1913 Thierry de Martel provided the design of malleable retractors. Retractors with handle, blunt tip and rigid spatulas were introduced by Cushing and Horsley in 1915[20]. By 1968, Gazi Yaşargil developed a flexible self-retaining retractor known as the Leyla retractor[21]. Other retractors and hand rest system for neurosurgery was introduced by Greenberg in 1981.[22] In 1988, the first reported use of tubular retractors for brain tumors was documented by Kelly and colleagues for the resection of intra-axial tumors[19,20], The removal of lesions through a tubular dilator assisted with stereotactic guidance and neuroendoscopy were subsequently reported in 1990 and 2005[23,24]. In 2011, Spena and Versari used balloon tips of Fogarty catheters to provide gentle brain retraction during surgery for the resection of skull base and midline tumors, as well as for anterior circulation aneurysms[17,25]. Tubular retractors made up of silicone were used by Yad and Sharda Yadav in 2011 for evacuation of intracerebral hematomas. The silicone was folded to make a small diameter tube so that it could be introduced through a small corticectomy, then the margins were gently and slowly retracted with a Killian nasal speculum. Silicone retractor held by tissue forceps was then introduced into the opened nasal speculum. Finally, forceps and speculum were removed leaving the tubular retractor in place, which returned to its normal tubular configuration after release[26]. There have been multiple studies regarding brain retraction and tissue injury. Rosenørn and Diemer found an increased incidence in cortical damage due to impaired microcirculation and neuronal damage[7,9,27,28]. Retractor pressure due to traditional retraction blades occludes blood vessels, reduces tissue perfusion and creates local ischemia leading to infarction. Animal studies have proven that a low external pressure of 25 mmHg may lead to electroencephalographic changes and blood–brain barrier disruption[7,8,9,29]. In 1992, Andrews monitored brain electrical activity in rats by performing brain retraction at a 30-mmHg pressure for 10 to 20 minutes and noticed a 50% decrease in the amplitude of evoked

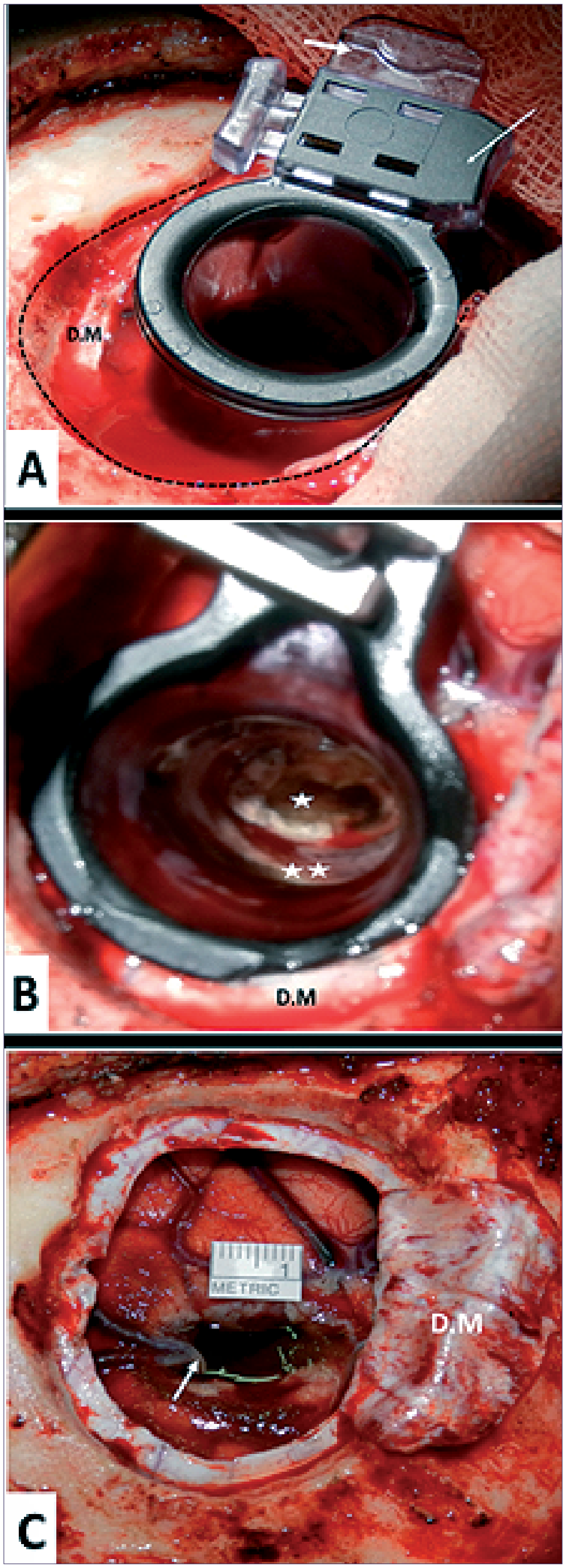

Figure 5. Tubular retractor system positioned: (A) Introducer before being removed with latch locking system (white long arrow) and fixation (white short arrow) to the edge of the craniotomy; (B) Surgical view of the tumor (white star) and brain tissue (two white stars) through the access port; (C) Top view after removal of the device with corticectomy < 1.5 cm and preserved cortical venous structures (white arrow). D.M: dura mater.

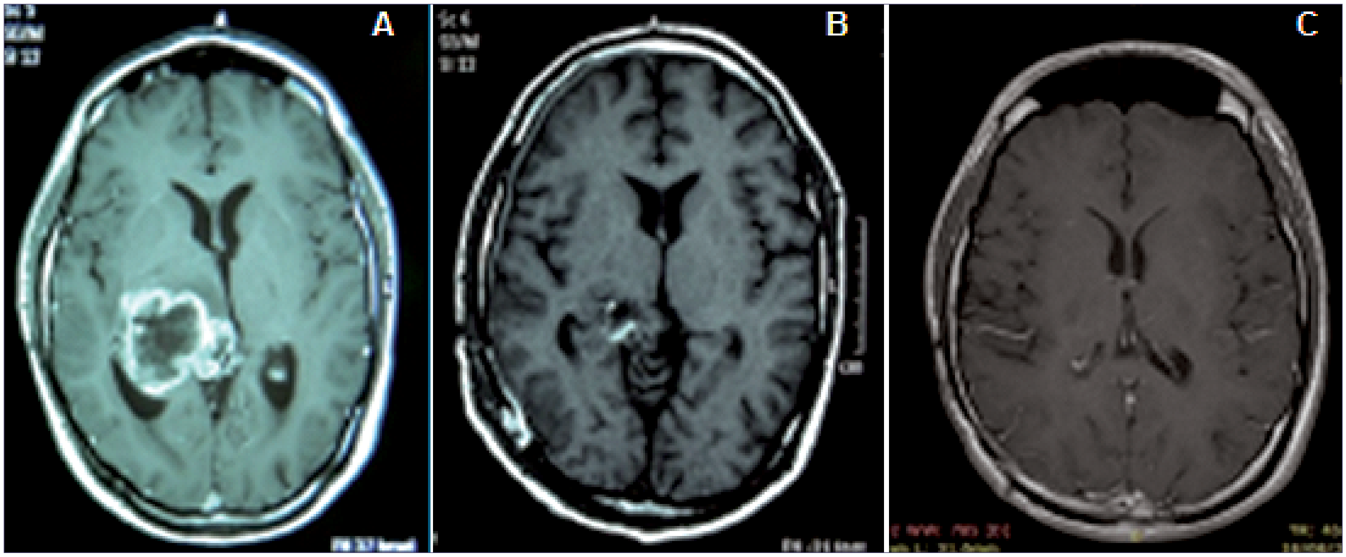

Figure 6. T1W gadolinium-enhanced axial MRI: (A) Preoperative image showing a heterogeneous tumor with peripheral contrast enhancement and central necrosis in the posterior thalamic region; (B) Postoperative, showing gross total resection; (C) Seven months after second line chemotherapy with no tumor recurrence.

potentials, recovering within 5 to 10 minutes after releasing the retraction. This early loss of evoked potentials was associated with decreased blood pressure, decreased regional brain blood flow and decreased $PaCO_2$[10,19]. Other systemic intraoperative factors such as hypotension and blood loss, may increase vulnerability of cortical injury associated with hypoperfusion[6,9,10,12,19]. Prolonged retraction of brain tissue may cause irreversible damage; therefore, when the retraction is required, brain damage should be minimized[6,7,9,28]. The newer tubular retractor systems work minimizing these side effects, attempting to minimize retraction pressure and thus local brain tissue injury when resecting deep-seated lesions and traversing white matter tracts[29], through the reduction of pressure on the retracted tissue by distributing it evenly over the entire surface of the cylinder. Published data exists in which tubular retractor system was used to excise diverse pathologies including neoplastic, infectious and vascular lesions[30]. Thus, this technique has allowed the resection of deep lesions that are traditionally accessed through extensive craniotomies and surgical approaches, through normal brain tissue. The advantage of using the transparent tubular retractors is that it produces less damage to the cerebral cortex, displacing only the white fibers statically or dynamically. The instruments do not interfere with endoscopic or microsurgical viewing angle, with preserved lighting during introduction to the field. Through the port microsurgical instruments can be used and the same neurosurgical principles apply. The described tubular retractor has the ideal characteristics necessary for this type of procedure. The purpose of this work is to describe the surgical technique in addition to those presented in the literature for intra-axial and intraventricular tumors. Regarding the results of this case series, the technique does not modify the natural evolution of the disease nor survival rate; in other words, the objective is to reduce morbidity associated with conventional surgical procedures. This technique could also be useful in patients with inconclusive biopsy results, where an adequate amount of tissue is needed for diagnosis. The advantage is the direct vision to take the sample, and without a doubt sampling the pathological tissue. We believe that research studies comparing microsurgical technique with endoscopic assistance should be performed; although microsurgery is preferred over endoscopic approach for these cases.

Conclusion

A minimally invasive approach with tubular retractors could be advantageous for tumor resection in deep regions. A small corticectomy is required due to a longitudinal cut and folding technique of the retractor, providing a direct path to the tumor, minimizing brain injury with a 360-degree dispersion pattern and without adhering to the brain. It facilitates microsurgical dissection and offers a detailed visualization of surrounding tissue through its transparency. The technique is simple, safe and effective and can be done using microscope or endoscope as needed.

Disclosure

The authors report no conflict of interest concerning the materials or methods used in this study or the findings specified in this paper.

No financial disclosures.

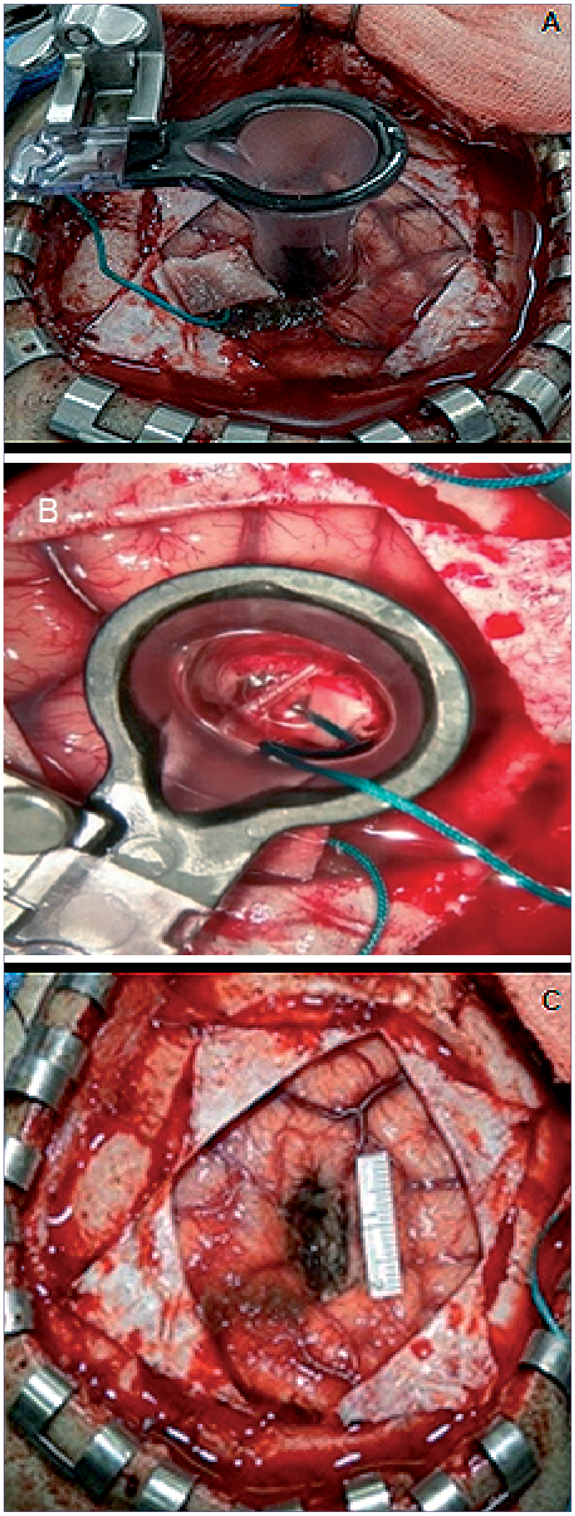

Figure 7. (A) Tubular retractor system positioned; (B) Top view showing a deep artery (black arrow) located in the surgical area; (C) View after removal of the device.

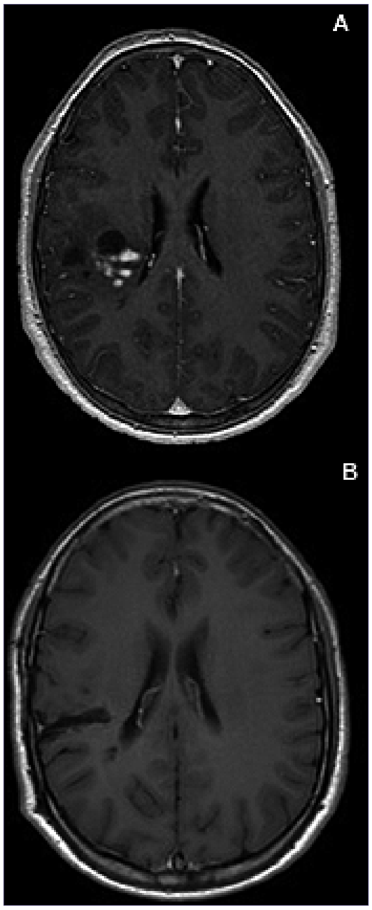

Figure 8. T1W gadolinium-enhanced axial MRI: (A) Preoperative thalamic tumor with a cystic component; (B) Postoperative, demonstrating gross total resection of the tumor.

References

1. Ricard D, Idbaih A, Ducray F, Lahutte M, Hoang-Xuan K, Delattre J. Primary brain tumours in adults. Lancet 2012;379(9830):1984–96. doi: 10.1016/S0140-6736(11)61346-9
2. McGirt M, Chaichana K, Attenello F, Weingart J, Than K, Burger P, et al. Extent of surgical resection is independently associated with survival in patients with hemispheric infiltrating low-grade gliomas. Neurosurgery 2008;63(4):700–7. doi: 10.1227/01.NEU.0000325729.41085.73
3. Li Y, Suki D, Sawaya R. The influence of maximum safe resection of glioblastoma on survival in 1229 patients: Can we do better than gross-total resection?. J Neurosurg 2016;124(4):977–988. https://doi.org/10.3171/2015.5.JNS142087
4. Wang X, Yang L, Zhang H, Yan Z, She L. Microsurgical and endoscopic posterior transcortical keyhole approach to the atrium of the lateral ventricle: A cadaveric study. J Neurol Surg A Cent Eur Neurosurg 2015;76(4):261-7. doi: 10.1055/s-0034-1393928
5. Bander E, Jones S, Kovanlikaya I, Schwartz T. Utility of tubular retractors to minimize surgical brain injury in the removal of deep intraparenchymal lesions: a quantitative analysis of FLAIR hyperintensity and apparent diffusion coefficient maps. J Neurosurg 2016;124(4):1053-60. doi: 10.3171/2015.4.JNS142576.
6. Donaghy R, Numoto M, Wallman L, Flanagan M. Pressure measurement beneath retractors for protection of delicate tissues. Am J Surg 1972;123(4):429-31. doi: 10.1016/0002-9610(72)90195-x
7. Rosenørn J, Diemer N. Reduction of regional cerebral blood flow during brain retraction pressure in the rat. J Neurosurg 1982;56(6):826-9. doi: 10.3171/jns.1982.56.6.0826
8. Rosenørn J, Diemer N. The risk of cerebral damage during graded brain retractor pressure in the rat. J Neurosurg 1985;63(4):608-11. doi: 10.3171/jns.1985.63.4.0608
9. Rosenorn J, Diemer N. The influence of intermittent versus continuos brain retractor pressure on regional cerebral blood flow and neuropathology in the rat. Acta Neurochir (Wien) 1988;93(1-2):13-7. doi: 10.1007/BF01409896
10. Andrews R, Bringas J. A review of brain retraction and recommendations for minimizing intraoperative brain injury. Neurosurgery 1993;33(6):1052-63. doi: 10.1227/00006123-199312000-00014
11. Albin M, Bunegin L. The insidiousness of brain retractor pressure: another ¨smoking gun¨?. Anesth Analg 2003;96(1):306-7.
12. Zhong J, Dujovny M, Perlin A, Perez-Arjona E, Park H, Diaz F. Brain retraction injury. Neurol Res 2003;25(8):831-8. doi: 10.1179/016164103771953925
13. Orringer D, Golby A, Jolesz F. Neuronavigation in the surgical management of brain tumors: current and future trends. Expert Rev Med Devices 2012;9(5):491–500. doi:10.1586/erd.12.42
14. Kis D, Máté A, Kincses Z, Vörös E, Barzó P. The role of probabilistic tractography in the surgical treatment of thalamic gliomas. Neurosurgery 2014;10(2):262–272. doi:10.1227/NEU.0000000000000333
15. Hong C, Prevedello D, Elder J. Comparison of endoscope- versus microscope-assisted resection of deep-seated intracranial lesions using a minimally invasive port retractor system. J Neurosurg 2016;124(3):799-810. doi: 10.3171/2015.1.JNS14111
16. Cohen-Gadol A. Minitubular transcortical microsurgical approach for gross total resection of third ventricular colloid cysts: Technique and assessment. World Neurosurg 2013;79(1):7–10. doi:10.1016/j.wneu.2011.03.045
17. Assina R, Rubino S, Sarris C, Gandhi C, Prestigiacomo C. The history of brain retractors throughout the development of neurological surgery. Neurosurg Focus 2014;36(4):1-12.
18. Eichberg D, Buttrick S, Brusko D, Ivan M, Starke R, Komotar R. Use of Tubular Retractor for Resection of Deep-Seated Cerebral Tumors and Colloid Cysts: Single Surgeon Experience and Review of the Literature. World Neurosurg 2018;112:e50-e60. doi: 10.1016/j.wneu.2017.12.023
19. Kelly P, Goerss S, Kall B. The stereotaxic retractor in computer-assisted stereotaxic microsurgery. Technical note. J Neurosurg 1988;69(2): 301–06. doi: 10.3171/jns.1988.69.2.0301
20. Dujovny M, Onyekachi I, Perlin A, Ryder T. Brain retractor systems. Neurol Res 2010;32(7):675-83. doi: 10.1179/016164110X12644252260439
21. Yasargil M, Fox J. The microsurgical approach to acoustic neurinomas. Surg Neurol 1974;2(6):393-8.
22. Greenberg I. Self-retaining retractor and handrest system for neurosurgery. Neurosurgery 1981;8(2):205-8. doi: 10.1227/00006123-198102000-00009
23. Harris A, Hadjipanayis C, Lunsford L, Lunsford A, Kassam A. Microsurgical removal of intraventricular lesion using endoscopy visualization and stereotactic guidance. Neurosurgery 2005;56(1):125-32. doi: 10.1227/01.neu.0000146227.75138.08
24. Otsuki T, Jokura H, Yoshimoto T. Stereotactic guiding tube for open-system endoscopy: a new approach for the stereotactic endoscopic resection of intra-axial brain tumors. Neurosurgery 1990;27(2):326-30.
25. Spena G, Versari P: Bubbles in the head: a new method for brain retraction during craniotomy. Acta Neurochir (Wien) 2011;153(9):1807-11. doi: 10.1007/s00701-011-1085-3
26. Yadav Y, Yadav S, Sherekar S, Parihar V. A new minimally invasive tubular brain retractor system for surgery of deep intracerebral hematoma. Neurol India 2011;59(1):74-7. doi: 10.4103/0028-3886.76870
27. Ajlan A, Kalani M, Harsh G. Endoscopic transtubular resection of a colloid cyst. Neurosciences (Riyadh) 2014;19(1):43–46.
28. Greenfield J, Cobb W, Tsouris A, Schwartz T. Stereotactic minimally invasive tubular retractor system for deep brain lesions. Neurosurgery 2008;63(4):334-9. doi: 10.1227/01.neu.0000334741.61745.72
29. Shashivadhanan S. Transparent Tubular Retractor in Cranial Surgery: A Retrospective Analysis. Indian J Neurosurg 2019;8(1):13–16. doi: 10.1055/s-0039-1698844
30. Chen C, Caruso J, Starke R, Ding D, Buell T, Crowley W, et al. Endoport-assisted micro-surgical treatment of a ruptured periventricular aneurysm. Case Rep Neurol Med 2016;2016:8654262. doi: 10.1155/2016/8654262