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Object. Microsurgical removal is the preferred treatment for most deep-seated. intraaxial tumors in the pediatric population. The feasibility of surgery as an option has improved with advances in surgical technology and technique Tubular retractors disperse retraction forces over a greater surface area than do conventional retractors, which can lower the risk of ischemic complications. The authors describe their experience utilizing a new tubular retractor system specifically designed for cranial applications in conjunction with frameless neuronavigation.

Method. The Vycor ViewSite retractor was usued in 4 pediatric patients (ages 15 months and 9, 10, and 16 years) with deep-seated intraaxial tumors. The lesions included a papillary tumor of the pineal region, a low-grade astrocytoma in the occipital lobe, a dysembryoplastic neuroepithelial tumor arising from the basal ganglia, and an intraventricular low-grade glioma. the extent of white matter damage along the surgical trajectory (based on T2 or FLAIR and diffusion restriction/apparent diffusion coefficient signals) and the extent of resection were assessed on postoperative imaging.

Results. Satisfactory resection or biopsy was achieved in all patients. A comparison of pre - and postoperative MR imaging studies revealed evidence of white matter damage along the surgical trajectory in 1 patient. None of the patients demonstrated new neurological deficits postoperatively.

Conclusions. Obtaining surgical access to deep-seated, intraaxial tumors is challenging. In this small series of pediatric patients, the combination of the ViewSite tubular retractor and frameless neuronavigation facilitated the surgical approach. The combination of these technologies adds to the armamentarium to safely approach tumors in deep locations. (DOI: 10.3171/2011.2.PEDS10515)

KEY WORDS • Viewsite tubular retractor • minimally invasive neurosurgery • pediatric brain tumor • intraventricular glioma • frameless stereotaxy • diffusion tensor imaging • functional MR imaging

The use of tubular retractors in cranial surgery has been one technique used to gain access to deep-seated lesions while minimizing the effects seen with excessive retraction. The first reported use of tubular retractors for brain tumors was documented by Kelly et al. in 1987.[11] Prior to the widespread use of MR imaging, Kelly[9] and colleagues[10,11,13] used frame-based stereotactic CT to create a volumetric plan of deep lession to surgically access them. In their setup, a metal tubular retractor was placed on the Leksell frame to provide retraction and to create a surgical corridor. Although this technique was very successful in the hands of selected surgeons, it was not widely adopted due in part to the diminishing role of frame-based neuronavigation, [5,9,10,13]

As technology has improved and as frameless stereotaxy has come into widespread use, a variety of modifications to the tubular retractor design have arisen.[3,5,8,14,15,19] The ViewSite tubular retractor (Vycor Medical, Inc.) is one such model that is made of plastic and was specifically designed for cranial applications. Use of this retractor system has been documented in one adult series but

[redacted]

Abbreviations used in this paper: DNET = dysembryoplastic neuroepithelial tumor; DT = diffusion tensor; DW = diffusion-weighted; fMR = funtional MR.

has not been reported in any pediatric patients.8 In this article, we relate our experience using the ViewSite bular retractor system in conjunction with frameless neurnavigation (BrainLab) to approach deep-seated tumors in 4 pediatric patients.

Methods

Patient Population

Three boys (ages 15 months and 10 and 16 years) and 1 girl (9 years old) underwent either resection or excisional biopsy of interaaxial lesions utilizing the ViewSite tubular retractor. The lesions ranged in location from the pineal region, basal ganglia, and occipital lobe to the atrium of the lateral ventricle.

Retractor System and Surgical Technique

The ViewSite tubular retrtactor is a clear plastic retractor that is available in 3 lengths (3, 5, and 7 cm) and 4 widths (12, 17, 21 and 28 mm). It is composed of plastic and has a tapered end and an inner obturator that is slightly longer and more closed than the retractor itself (Fig. 1). The distance from the surface of the brain to the tumor is measured on imaging to gauge which retractor length will be needed. Selection of the appropriate retractor width is important to maintain binocular vision under high-power microscopy. In the cases presented here, we used the 17- and 21-mm-wide retractors in the 5- and 7-cm lengths.

Preoperatively, the neuronavigation is registered and the surgical trajectory is planned to avoid eloquent parenchyma and critical vasculature. Funtional MR imaging and DT imaging were used in 1 case to avoid damaging functional cortex and the corticospinal white matter tracts while creating the surgical tract. the setup and registration of the neuronavigation was completed per routine process in the 3 older patients as they could be fixed in pins.

The craniotomy is made with a margin of 2-3 cm to allow adjustment of the tubular retractor. the surgical tract can be made either transcortically or transsulcally. In our 4 cases, a transcortical approach was used. the surigical tract is planned using the pointer of the neuronavigation. The corticectomy is made superficially to match the width of the retractor and is progessively deepened. The ViewSite retractor has an elliptical shape and splits the deep matter when gently inserted, thereby minimizing the amount of parenchymal resection needed to reach a lesion. The retractor is inserted several millimeters deeper than the location of the lesion to prevent white matter from crowding the field upon removal of the central obturator. As the retractor is progressively deepened, the pointer of the neuronavigation is inserted into the lumen of the retractor to reconfirm the surgical trajectory. Once in the desired position the retractor is fixed in place using a self-retaining arm, such as a Leyla or Greenberg arm, and the introducer is removed to open the surgical working channel. If an adjustment is requirred, the introducer is replaced and the retractor is repositioned.

There were several special considerations in the 15-month-old patient harboring a papillary tumor of the pineal region. Given his age and skull characheristics, the DORO Multipurpose Skull Clamp (Pro Med Instruments, Inc.) with gel head and ear-ring attachments was used to fix the patient's head in place instead of using skull pins. The neuronavigation was then attached to the DORO clamp and registered. A transcortical transventricular approach through the right frontal horn was used to approach the tumor. Despite the young age of the patient, the brain parenchyma appeared to tolerate introduction of the retractor well on intraoperative inspection. It is important to keep in mind that the accuracy of the neuronavigation is probably affected when the patient is not fixed in pins.

The location of the tumor and its spatial relations can be confirmed both under direct microscopy and with the use of neuronavigation. Long bayoneted surgical instruments, such as those used for transphenoidal surgery, are particularly helpful to work through the tubular retractor space. When repositioning is necessary, the retractor is loosened and redirected with the introducer in the place, without fully withdrawing the retractor or resecting additional white matter. The neuronavigation is then used to reconfirm the surgical trajectory.

FIG. 1. The ViewSite tubular retractor. It is notable that the retractor is composed of plastic, has a tapered end, and has an inner obturator that is slightly longer and more closed than the retractor itself. Reprinted with permission from Vycor Medical, Inc.

Results

Preoperative and postoperative MR images were compared to determine the following outcomes: white matter manipulation (T2-weighted and/or FLAIR imaging changes), ischemic changes beyond the surgical path (DW imaging), and extent of resection. three patients demonstrated no T2, FLAIR, or DW imaging changes, whereas the 15-month-old patient with a papillary tumor in the pineal region did have T2-weighted, FLAIR, or DW imaging changes that extended beyond the surgical bed. The preoperative goals of surgery were met in all patients. Specifically, debulking of the third ventricle and tumor diagnosis were achieved in the 15-month-old patient with the pineal region tumor. Gross-total resection was achieved in the 9-year-old patient with an occipital low-grade glioma. A low-grade oligodendroglioma had been initially diagnosed in the 10-year-old patient with the left frontal DNET. This

TABLE 1: Summary of outcomes in 4 patients with deep-seated tumors treated using the ViewSite tubular retractor*

Case No.	Age, Sex	Diagnosis	Lesion Location	Ledion Size (cm)	Surgical Approach	Extent of Resection	T2/FLAIR Change	ADC/Diffusion Restriction
1	15 mos, M	papillary tumor	pineal region	3.2 x 3.4 x 2.6	frontal craniotomy	STR	yes	yes
2	9yrs, F	low-grade astrocytoma	lt occipital lobe	3.2 x 2.7 x 2.4	parietooccipital craniotomy	GTR	no	no
3	10 yrs, M	DNET	lt frontal & lt basal ganglia	5.0 x 4.3 x 4.2	frontal craniotomy	NTR	no	no
4	16 yrs, M	low-grade glioma	lt atrium of lat ventricle	3.5 x 20 x 2.8	parietoccipital craniotomy	GTR	no	no

* ADC = apparent diffusion coefficient; GTR = gross-total resection; NTR = near-total resection; STR = subtotal resection.

patient had worsening seizures despite medical therapy as well as mass effect on the ventricular system. Surgery was successful at decompressing the ventricular system and controlling seizures postoperatively, while also providing tissue for pathological diagnosis. Gross-total resection was achieved in the 16-year-old patient with theatrial lowgrade glioma (Table 1).

No patients experienced new, postoperative neurological deficits or seizure activity. Hydrocephalus due to a hematoma blocking the cerebral aqueduct did develop in the 15-month-old patient with the pineal region tumor. The clot was removed, and a third ventriculostomy was performed via the same surgical tract that was used previously. Although the hydrocephalus was temporarily controlled, the patient eventually required placement of a ventriculoperitoneal shunt.

Illustrative Case

History and Examination. This 16-year-old boy presented in March 2010 with headaches and nausea but was otherwise neurologically intact. An MR image was obtained and revealed a 3.5 x 2.0 x 2.8 - cm tumor in the atrium of the left lateral ventricle (Fig. 2). The boy subsequently underwent a biopsy in July 2010, which revealed a WHO Grade II ependymoma. Given this diagnosis, resection was recommended.

Operation. Preoperative fMR imaging was performed to map cortical function, and DT imaging was performed to map the corticospinal tracts (Fig. 3). A direct path was planned from the cortical surface, traversing the occipital temporal gyrus, to the atrium of the lateral ventricle while avoiding functional cortex and the underlying corticospinal tracts. the ViewSite retractor was placed and secured onto a Leyla bar (Fig. 4). The tumor was visualized, and resection was performed utilizing bipolar cautery, suction, and the NICO Myriad (NICO Corp.). The NICO Myriad is a non-heat generating, precision mechanical cutter that can be used through the ViewSite tubular retractor to resect deep tissue while maintaining full visualization of the cutting edge to avoid collateral damage.

Postoperative Course. Postoperatively, the patient was neurologically intact and asymptomatic. Gross-total resection was confirmed on MR imaging (Fig. 5).

Discussion

Deep-seated, intraaxial lesions have always been challenging to approach surgically. In the past, many deep-seated and centrally located tumors and vascular malformations were considered inoperable, primarily because an exact surgical trajectory was difficult to determine, the interface between normal tissue and the lesion was not always clear, and lesions frequently had irregular borders.[9]

Brain retraction systems combined with microsurgical techniques have made possible the removal of deep-seated intraaxial lesions. Since the introduction of the first self-retaining retraction system by Greenberg[6] in 1981, this self-retaining system and others like it, have come into widespread use in neurosurgery. However, the dangers of excessive retraction for prolonged periods of time have also been studied. Rosenørn and Diemer[18] showed that cortical infarction occurs when brain retraction pressures > 20 mm Hg are held for 15 minutes in a rat model. Additionally, regional cerebral blood flow is affected and can reach critical ischemic levels when brain retraction pressures exceed 20 min Hg.[2,17] In addition, systemic factors, such as acidosis, hypotension, and metabolic abnormalities, can increase the ischemic effect of high retraction pressures.[1,2] Although the risk of ischemia can be lowered by using intermittent instead of continuous retraction, it is not a practical strategy during resection of a complex, deep-seated lesion.[2,16]

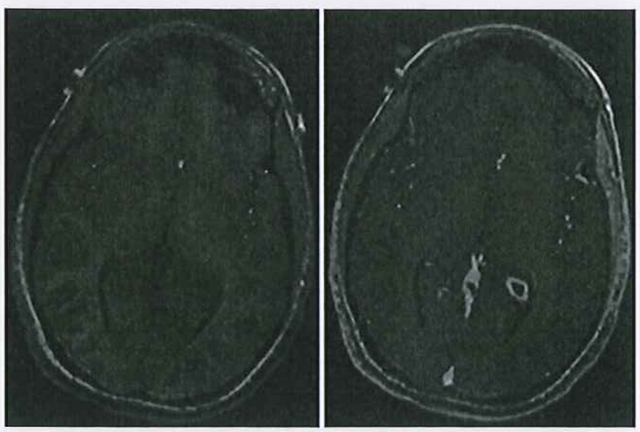

Fig. 2. Preoperativen T1-weighted MR imaging sequences **(left)** with contrast-enhancement **(right)** demonstarting an isointense tumor in the atrium of the left lateral ventricle with central contrast enhancement

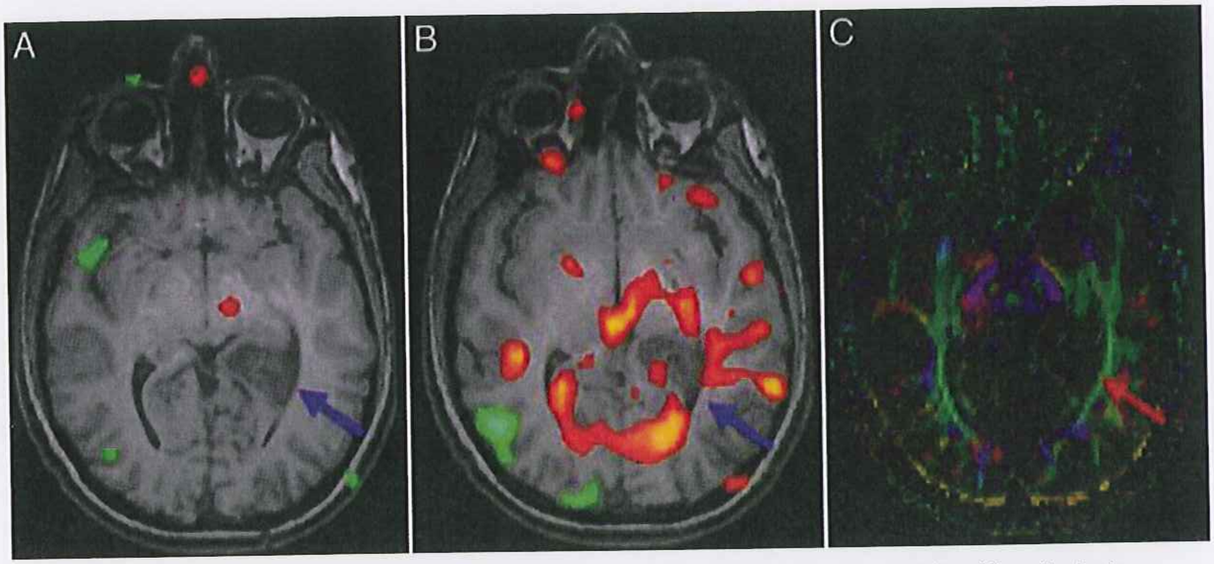

Fig. 3. Preoperative fMR images used to map cortical function, and DT images used to map underlying while matter tracts. Functional MR images demonstrating the cortical map for motor function (**A**) and word production (**B**, *orange areas*) and the proposed surgical corridor *(blue arows)*. Diffusion tensor images (**C**) visualizing the corticospinal tracts (*blue*). The propsed surgical corridor *(red arrow)* avoids critical word production areas, motor cortex, and the corticospinal tract.

Tubular retractors afford the advantage of a greater distribution of forces on surrounding white matter. In the study by Ogura and colleagues[14] the brain retraction pressure was < 10 mm Hg with the use of a tubular retractor. Tubular retractor designs have changed significantly since the first use of these instruments: Metal tubular retractors were initially used in conjunction with the Leksell frame

Fig. 4. The ViewSite tubular retractor initially introduced into the operative corridor. It is attached to a flexible arm and secured to a Leyla bar for stabilization. Alternatively, the Greenberg system can also be used for stabilization.

with excellent surgical outcomes.[4,9-11,13,15] Other modifications utilizing tubular retractors include combining them with frameless neuronavigation, allowing the retractor to be secured only by the brain,changing the composition of the retractor from metal to polyester, utilizing progressively dilating tubes, and spinal retractors for cranail applications.[3,7,14,15]

In the pediatric population, the use of tubular retrac-

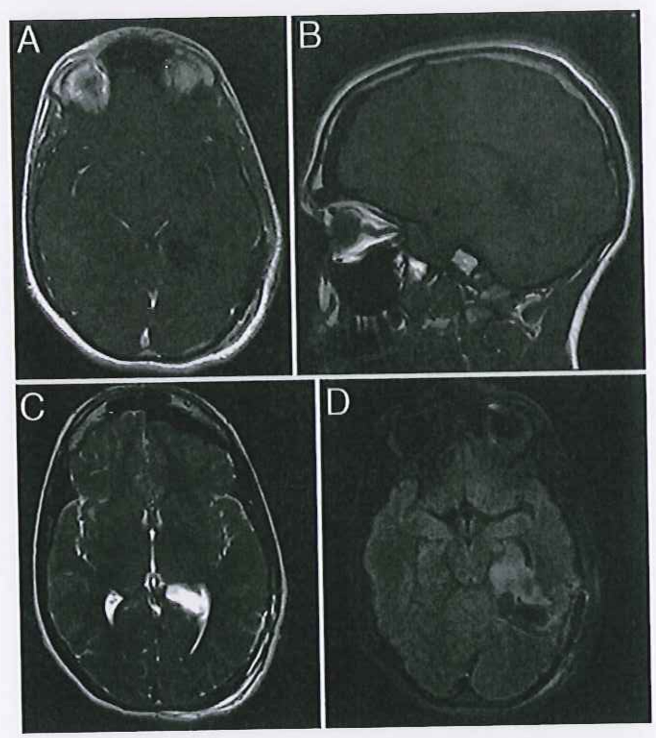

Fig. 5. Postoperative axial (**A**) and sagittal (**B**) T1-weighted MR images demonstrating gross-total resection of the left atrial tumor. Axial T2-weighted (**C**) or FLAIR (**D**) MR images demonstrating no charges.

tors without the assistance of frame-based navigation for intracranial lesions has been reported in 2 cases.[5,14] In 1 case, Fahim et al.[5] used a spinal tubular retractor (MetRx) to resect an arteriovenous malformation in a 12-year-old boy. The disadvantage of this metal retractor is that it can conduct electricity and is not easily adjustable. Additionally, only the tissue at the end of the retractor is visible, while the surrounding tissues cannot be visualized through the opaque metal. In the case described by Ogura and colleagues,[14] a biopsy of an intraventricular tumor was performed in an 18-year-old boy through a retractor composed of rolled up, transparent polyester film secured by 2 aneurysm clips. Although the surgeons were successful in their goals of surgery, it is not clear to what extent this prototype could be used in cases requiring more extensive tumor resection.

We found that the ViewSite tubular retractor has several advantages over previous designs. First, it is composed of plastic and has a tapered end, which prevents electrical transmission and allows adjacent tissue to be visualized. Additionally, when inserted carefully, it mobilizes tissue by seperation and does not result in any visible parenchymal damage during surgery. It can also be secured onto a self-retracting arm, such as the Greenberg or Leyla bar systems, to prevent shift of the operative field. When approaching irregular lesions, the retractor can easily be moved and repositioned. Finally, the retractor can easily be used with frameless neuronavigation, which precludes the need for frame-based neuronavigation.

Use of the ViewSite tubular retractor in a series of 16 adult patients has been reported by herrera et al.[8] These authors used it in 2 cases for intracerebral hematoma evacuation, in 1 case for for drainage of a deep-seated cyst, and in 13 cases of intraaxial tumors. Intraoperative neuronavigation was used to localize all deep intracerebral lesions. Of 13 tumors, 9 were totally removed and 4 were subtotally removed. Which was confirmed on postoperative MR imaging in 12 cases. No hematomas were observed along the retractor tract on postoperative imaging, and no other postoperative complications were noted.

The use of fMR and DT imaging to map out functional cortex and critical white matter tract courses has been shown to be useful when surgically approaching deep-seated intraaxial lesions.[12] In the case of a 16-year-old patient with an intraventricular low-grade glioma that we presented, fMR and DT imaging were indispensable in avoiding functional cortex and the corticospinal tracts. Studying the white matter tracts preoperatively may also help in deciding the feastibility of a particular surgical approach.

Conclusions

The treatment of deep-seated intraaxial lesions is challenging. In the pediatric population, weighing out long-term sequelae of all treatment modalities is critically important given that life expectancy can be long if a complete cure is achieved. Microsurgical removal is gener-ally the preferred treatment option when possible. Other treatments, such as radiotherapy and chemotherapy, can have long-lasting sequelae and are generally used when surgical options are impossible. However, microsurgery for deep-seated intraaxial locations can carry great risk, which must be carefully considered. the advancement of minimally invasive technologies and techniques continues to improve the feastibility of surgical approaches to these lesions. In our small series of pediatric patients, the combination of the ViewSite tubular retractor and frameless neuronavigation facilitated our surgical approach. The combination of these technologies adds to the armamentarium to safely approach tumors in deep locations. Future studies must focus on surgical outcomes in larger series of patients while utilizing these technological advancements to establish their exact indications.

Disclusure

The authors report no conflict of interest concerning the materials or methods used in this study or the findings specified in this paper.
Author contributions to the study and manuscript preparation include the following. Conception and design: VR Recinos, PF Recinos, Raza. Critically revising the article: all authors. reviewed final version of the manuscript and approved it for submission: all authors. Administrative/technical/material support: VR Recinos. Study supervision: VR Recinos.

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