



## Minimally Invasive Transsulcal Resection of Intraventricular and Periventricular Lesions Through a Tubular Retractor System: Multicentric Experience and Results

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■ **BACKGROUND:** Conventional approaches to deep-seated cerebral lesions range from biopsy to transcortical or transcallosal resection. Although the former does not reduce tumor burden, the latter are more invasive and associated with greater potential for irreparable injury to normal brain. Disconnection syndrome, hemiparesis, hemianesthesia, or aphasia is not uncommon after such surgery, especially when lesion is large. By contrast, the transsulcal parafascicular approach uses naturally existing corridors and a tubular retractor to minimize brain injury.

■ **METHODS:** A retrospective review of patients undergoing minimally invasive transsulcal parafascicular resection of ventricular and periventricular lesions, across 5 independent centers, was conducted.

■ **RESULTS:** Twenty patients with lesions located in the lateral ventricle ( $n = 9$ ), the third ventricle ( $n = 6$ ) and periventricular region ( $n = 4$ ) are described in this report. Average age was 64 years (8 male/12 female). The average depth from cortical surface was 4.37 cm. A 13.5-mm-diameter tubular retractor (BrainPath [NICO Corporation, Indianapolis, Indiana, USA]) of differing lengths was used, aided by neuronavigation. Gross total resection was obtained in 17 patients. Pathologies included colloid cyst, subependymoma, glioma, meningioma, central neurocytoma, lymphoma, and metastasis. Three patients experienced transient morbidity: memory loss (2), hemiparesis (1). One patient died 3 months postoperatively as a result of unrelated pulmonary illness. Follow-up ranged from 6 to 27 months (average, 12 months).

■ **CONCLUSIONS:** This technique is safe and effective for the treatment of intraventricular and periventricular lesions. Surgery-related morbidity is minimal and often transient. Lesions are satisfactorily resected and residuum occurs only when the neoplasm involves vital structures. The tubular retractor minimizes trauma to brain incident in the surgeon's path.

### INTRODUCTION

Surgical management of deep-seated cerebral lesions has always presented special challenges to the neurosurgeon. By virtue of their location, in and around the ventricles, these lesions present distinct difficulties associated with resection.<sup>1</sup> Vital neurovascular structures are close and increased depth of the surgical corridor reduces degrees of freedom and instrument maneuverability. In addition, reaching ventricular regions requires significant brain tissue sacrifice, in the process of performing transcortical and transcallosal access.<sup>2,3</sup> Morbidity associated with these techniques can be as high as 70%, with about half of the patients having more than 1 complication.<sup>4,5</sup> A minimally invasive transsulcal approach to intraventricular and periventricular lesions minimizes collateral injury to the brain en route to the lesion.<sup>6</sup> Further, use of a tubular retractor system prevents instrument-related injury to gyral banks that line the sulcus of interest.<sup>7-9</sup> Accordingly, we present our initial experience with this technique to treat these lesions, focusing on the outcome of this surgical approach and a review of comparable techniques.

### Key words

- Intraventricular tumors
- Parafascicular dissection
- Transsulcal approach
- Tubular retraction system

### Abbreviations and Acronyms

**DTI:** Diffusion tensor imaging  
**SLF:** Superior longitudinal fasciculus

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## METHODS

### Patient Group

A retrospective review of hospital medical records and radiologic imaging of patients with intraventricular or periventricular lesions was performed. Patients who underwent minimally invasive, transsulcal resection of these lesions through a tubular retractor system with a minimum 6-month follow-up period were included in this study. Information regarding demography, presentation, depth of lesion, extent of resection, postoperative outcome, and morbidity was collected across all participating centers. Approval from the institutional review board was obtained at individual centers.

### Surgical Technique

All procedures were performed using frameless stereotactic navigation and the choice of intubation was dependent on the individual surgeon's preference. Based on preoperative imaging including diffusion tensor imaging (DTI) and intraoperative navigation, a focused craniotomy was performed over the sulcus of interest for subcortical approach. DTI permits identification of association and projection fibers. The trajectory from target sulcus to the lesion is not necessarily the shortest but rather the route with the least transgression of white matter fascicles. After craniotomy, the arachnoid over the selected sulcus was opened with sharp dissection and the sulcus minimally deepened by separating lining gyral banks with blunt dissection. Through this opening, a 13.5-mm (internal diameter) tubular retractor sheath with distally tapering inner obturator (BrainPath system [NICO Corporation, Indianapolis, Indiana, USA]) is inserted along the preplanned trajectory (Figure 1). The tip of the obturator was specifically designed to gently dilate the path to the lesion. The length of the BrainPath was selected depending on the depth of the lesion from the cortical surface. After removing the inner cannula, with the help of a hooklike device, the sheath is fixed to preset Greenberg retractor bars and arms (Codman Neuro, Raynham, Massachusetts, USA). Subsequent resection was performed with a side-cutting aspirator (Myriad [NICO Corporation]) with visualization through either an operating microscope or a table-mounted exoscope (Karl Storz, Culver City, California, USA) on a self-retaining holder (Mitaka Point Setter [Karl Storz]). The exoscope, contrary to the endoscope, is held high up, away from the region of interest. It is also attached to an external light source (endoscopes have an internal light supply) that moves together with the exoscope. The diameter of the port allowed for both binocular vision and bimanual handling of the tissues. The direction of the port can be altered gently, to give more coverage of the lesion, to aid in complete resection.

## RESULTS

### Demographics

We identified 20 patients with ventricular ( $n = 15$ ) and periventricular ( $n = 5$ ) lesions resected using the above-mentioned technique (Table 1). The average age of patients was 64 years, ranging from 19 to 74 years. There was a slight female predominance (12 females and 8 males). The most common presentation was headaches and short-term memory deficits (8 patients each). Two tumors were found incidentally and 1 on

routine surveillance. Other clinical findings included hemiparesis, hydrocephalus, ataxia, urinary incontinence, and aphasia.

### Pathology

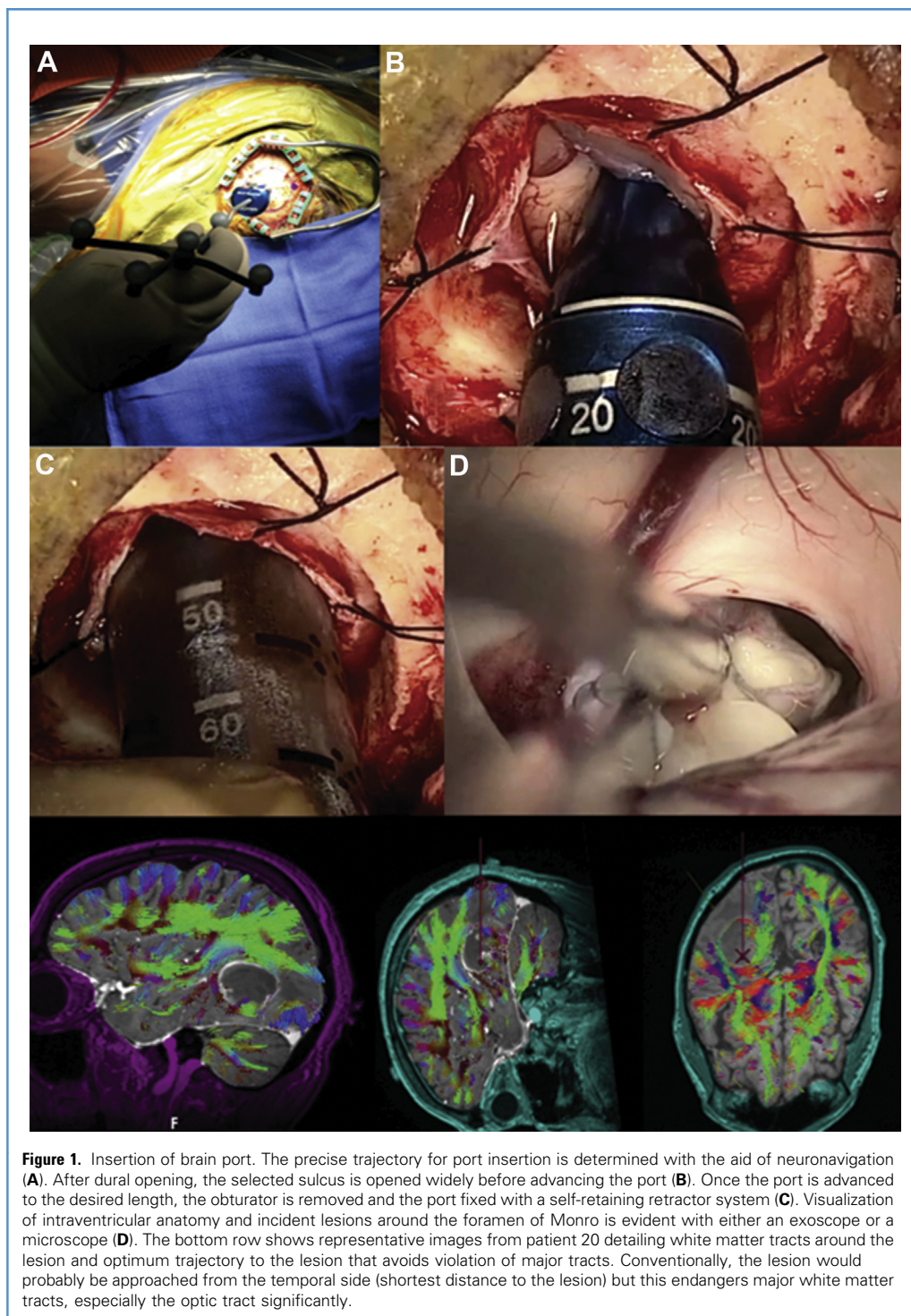
Regional division of the lesions consisted of 9 located in the lateral ventricle, 6 in the third ventricle, and 5 in the periventricular region (right frontal, left parietal, left thalamic metastasis, right parietal, and left thalamic high-grade glioma). Five colloid cysts were found exclusively in the third ventricle, and the sixth lesion in the same region was pilomyxoid astrocytoma. Lateral ventricular lesions included meningioma in 2 patients, subependymoma in 3 patients, 2 patients with high-grade glioma, a primary central nervous system lymphoma, a central neurocytoma, a low-grade glioma, and a high-grade glioma in individual patients. Lesion depth from the cortex ranged from 2.5 cm to 5.85 cm (average, 4.37 cm).

### Outcome

Gross total resection was obtained in 17 of 20 patients (85%). Three patients who had neoplasm invade left basal ganglia (75% resection), left thalamus (87%), and hypothalamus (75%) underwent subtotal resection for functional preservation. Two patients, one with primary central nervous system lymphoma of the right occipital horn and another with lateral ventricular neurocytoma, underwent near total resection (97%). Patient follow-up averaged 12 months (range, 6–27 months). All patients were followed for a minimum 6 months postoperatively, and many for longer. Early morbidity related to surgery was seen in 3 patients. One had transient short-term memory loss, which resolved within a month. Another had transient hemiparesis postoperatively, which recovered completely. The third patient had worsening of preoperative memory deficit, which improved during the follow-up period. One patient with third ventricular astrocytoma required permanent cerebrospinal fluid diversion. There was 1 death in the cohort; a 66-year-old man with non-small-cell lung cancer metastasis to the right frontal lobe (periventricular) developed an unrelated fatal pulmonary fungal infection in the third postoperative month.

### Illustrative Cases

**Case 1.** A 43-year-old woman presented to an out-of-state emergency department with altered mental status, recent memory loss, and paraphasic speech errors. She had recently been more forgetful of everyday activities and conversations, but on the day of presentation became drowsy and was unable to speak clearly and coherently. Initial imaging showed a left thalamic ring-enhancing lesion causing hydrocephalus from a posterior third ventricular obstruction (Figure 2). After placement of an external ventricular drain to treat hydrocephalus, the patient was airlifted to the referral institution. She underwent minimally invasive transsulcal resection of this mass, and histopathologic examination revealed it to be a high-grade glioma. Fusion of preoperative DTI and intraoperative navigation helped to select a trajectory to the tumor that did not traverse major white matter tracts. Immediately after surgery, the patient had significant improvement in memory and language function. After the external ventricular drain was removed, she was discharged to a rehabilitation facility in improved neurologic status. She further underwent standard chemoradiation for her tumor, and follow-up imaging 8 months after her initial surgery did not show any recurrent tumor growth.



The patient recovered well enough to be back at home independently, caring for her children.

**Case 2.** A 54-year-old woman was seen in neurosurgical consultation regarding an enlarging right atrial (lateral ventricular) tumor, which appeared consistent with benign meningioma on magnetic

resonance imaging (Figure 3). The patient was known to harbor this lesion, which was monitored with serial imaging at yearly intervals. She was offered surgical resection, when 2 consecutive surveillance studies showed sustained growth, considering the risks involved in removing a large, symptomatic mass. The lesion was approached through a transsulcal parafascicular path and removed using the

Table 1. Patient Demographics and Treatment Details

Patient Number	Age/Sex	Preoperative Deficits	Location	Lesion Depth (cm)	Extent of Resection	Lesion Pathology	Postoperative Deficits
1	20/F	Headache	Left lateral ventricle	4	97%	Central neurocytoma	None
2	48/M	Severe short-term memory deficit	Third ventricle	5.5	GTR	Colloid cyst	No new deficits
3	23/M	Moderate short-term memory deficit	Third ventricle	5.5	GTR	Colloid cyst	No new deficits
4	60/M	Severe short-term memory loss, ataxia, urinary incontinence	Third ventricle	5.5	GTR	Colloid cyst	No new deficits
5	31/F	Obtunded, hydrocephalus	Third ventricle	5.5	GTR	Colloid cyst	No new deficits
6	62/F	Confusion, memory loss	Third ventricle	5.59	GTR	Colloid cyst	None
7	50/M	Hydrocephalus	Intraventricular	4	GTR	High-grade glioma	No new deficits
8	43/F	Hydrocephalus, aphasia, amnesia, weakness	Left thalamic	4.2	87%	High-grade glioma	No new deficits
9	54/F	Headaches, memory deficit, left-sided weakness	Intraventricular	4.29	GTR	Low-grade astrocytoma	No new deficits
10	29/F	None	Left lateral ventricle (atrial)	3.5	GTR	Meningioma	None
11	54/F	None	Right lateral ventricle (atrial)	4.5	GTR	Meningioma	None
12	58/F	On routine surveillance	Left parietal	2	GTR	Metastatic tumor	No new deficits
13	66/M	Hydrocephalus, left-sided weakness,	Right basal ganglia	3.73	75%	Metastatic tumor	Left-sided weakness
14	19/M	Headaches, hydrocephalus	Third ventricle	4.4	GTR	Pilomyxoid astrocytoma	None
15	50/F	Short-term memory difficulties, mild	Right occipital horn	3.6	97%	Primary CNS lymphoma	None
16	53/F	Lightheadedness and dizziness	Intraventricular	4.38	GTR	Subependymoma	Short-term memory loss
17	74/M	Mild short-term memory deficit	Left lateral, third ventricles	4.5	75%	Subependymoma	Short-term memory loss
18	55/M	Right-sided weakness, hydrocephalus	Left lateral ventricle	5.85	GTR	Subependymoma	None
19	46/F	Aphasia, right-sided weakness, hydrocephalus	Left thalamic	3.7	GTR	Metastatic tumor	None
20	70/M	Headache	Right periatrinal	4	GTR	High-grade glioma	None

F, female; M, male; GTR, gross total resection; CNS, central nervous system.

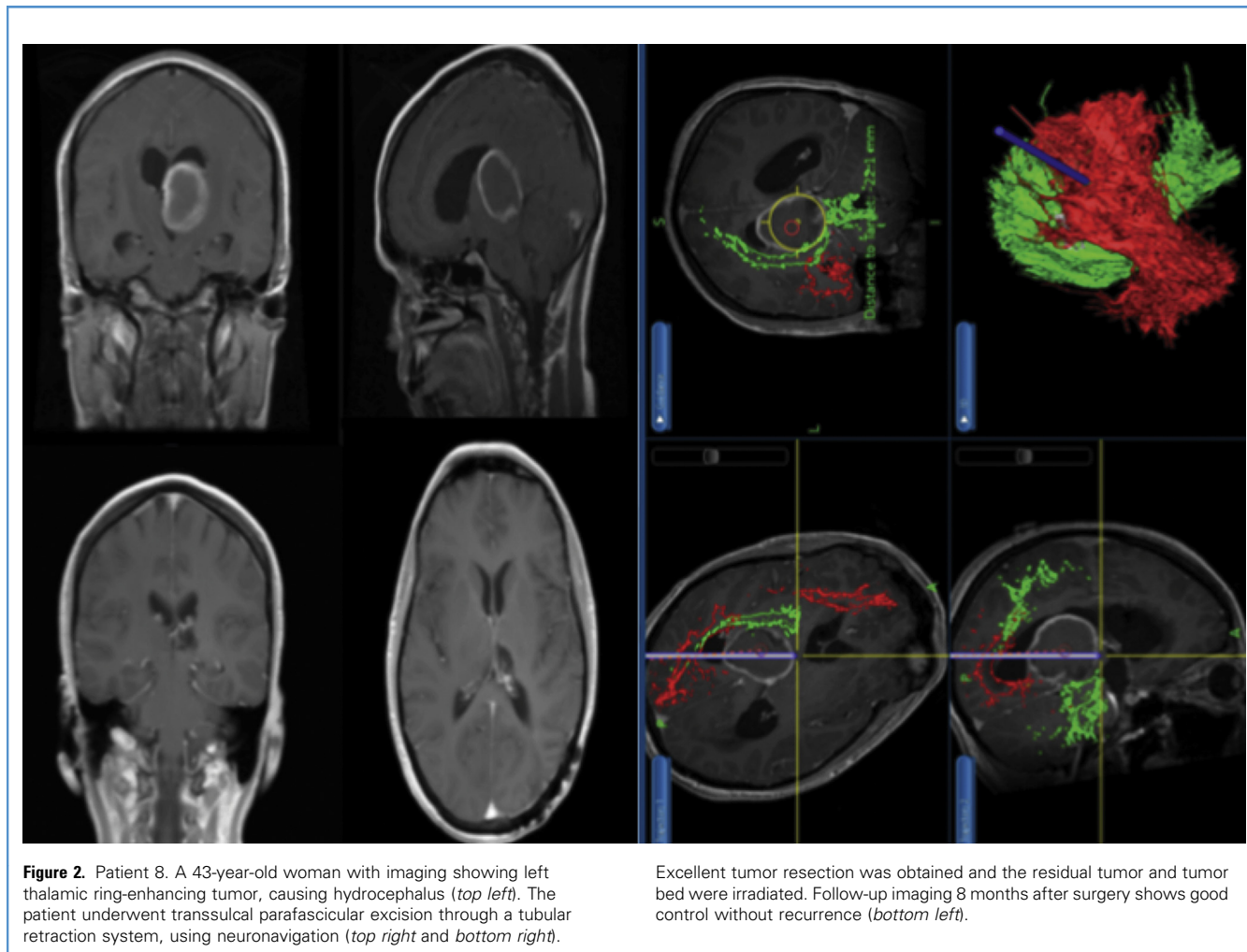
tubular retraction system. The right atrium was entered through the intraparietal sulcus and the lesion was removed in total, after initial internal decompression. The patient was discharged on the second postoperative day and continued to do well during her follow-up visits and with no recurrence on magnetic resonance imaging at 8 months.

**Case 3.** A 19-year-old otherwise healthy man presented with an acute episode of dizziness that caused him to fall and a 1-day history of severe headache. He had had 2 previous episodes of similar headache over the preceding 6 months. Imaging demonstrated a nonenhancing third ventricular tumor, extending into the left lateral ventricle with obstructive hydrocephalus (Figure 4). The patient underwent a minimally invasive transsulcal resection of this mass, which revealed a pilomyxoid astrocytoma (World Health Organization grade II). The transsulcal corridor was

planned via neuronavigation to minimize injury to descending and associated white matter tracts. Gross total resection was accomplished, as demonstrated by postoperative imaging. He was discharged home on the fourth postoperative day, with no neurologic morbidity, but presented shortly after with hydrocephalus requiring permanent diversion. Follow-up imaging 6 months after surgery did not show any recurrence; and the patient was clinically at base line.

## DISCUSSION

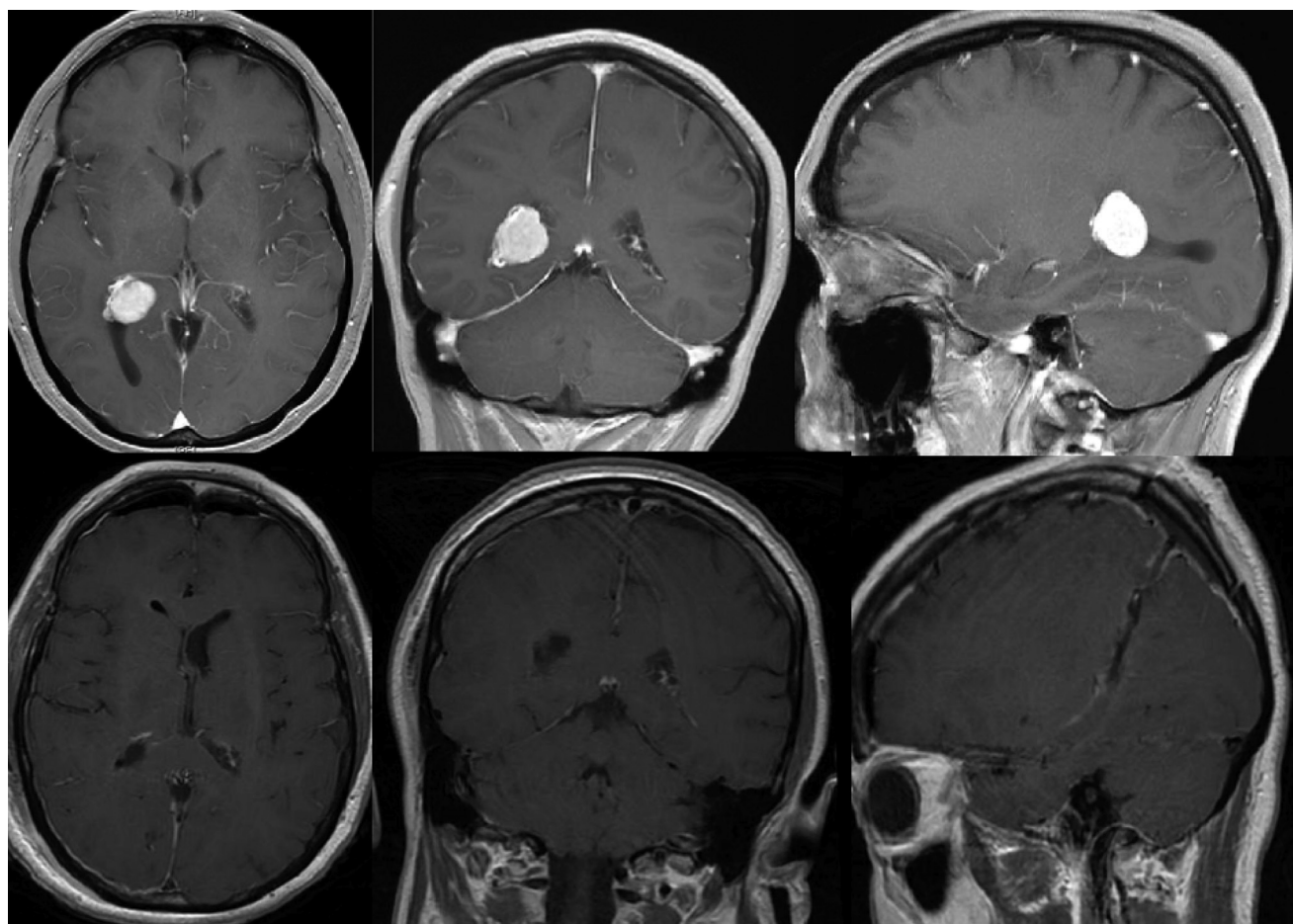
Intraventricular and periventricular lesions are not infrequent in neurosurgical practice. Management of these lesions has evolved over time; with developments in various aspects of surgical and nonsurgical modalities, although cytoreduction continues to be the mainstay in oncologic care and cure. Moreover, patients with



lesions (including nonneoplastic) that are symptomatic neurologically should benefit from surgical resection or decompression. The application of microsurgical procedures and techniques and advent of self-retaining retractors have revolutionized cerebral surgery.<sup>10,11</sup> Brain retraction has disadvantages; especially with flat-blade retractors, brain retraction edema and infarct is a well-defined entity with both radiologic and clinical features.<sup>12</sup> The use of a tubular retractor allows equal distribution of pressure on the surrounding brain; however, flat-blade retractors exert maximum pressure on the edges.<sup>13,14</sup> This significant difference is amplified when large deep lesions are resected over long hours. In addition, although conventional retractors are often placed after transcortical or transcallosal brain tissue removal, the tubular retractors are inserted with sequential dilation of a track that displaces white matter fiber tracts.<sup>15,16</sup>

Neuroendoscopy, advocated in recent years as a superior alternative to microsurgery, also has some fallacies. Although endoscopic resection has shown reduced morbidity and faster recuperation, it still has unique difficulties because there are limited instruments appropriate for resecting tumors completely

and hence it is considered more suitable for cystic lesions, particularly in enlarged ventricles.<sup>17-19</sup> Vascular control during endoscopy can be precarious: even insignificant bleeding can obscure visibility; and, unlike the usual medium of air, neuroendoscopic procedures are performed under a liquid medium.<sup>20</sup> Neuroendoscopy is not useful in cases of periventricular lesions, except for biopsy, and even with ventricular tumors, it is known to have higher recurrence rates.<sup>17,20</sup> In addition, despite being least invasive, neuroendoscopic resection of ventricular tumors has significant morbidity, such as hemorrhage, infection, cranial nerve deficits, and hormonal dysfunction.<sup>19,21,22</sup> Use of DTI markedly improves the preservation of subcortical white matter tracts. Lesions in and around the foramen of Monro were approached by widening the superior frontal sulcus. Apart from the pyramidal tract, care is also taken to maintain the integrity of the superior longitudinal fascicle (SLF), which commonly is a victim of collateral injury during such an approach to the ventricles with flat-blade retractors. The anterior part of the SLF in the dominant hemisphere has been associated with speech and motor planning and there are contradictory reports about posterior SLF



**Figure 3.** Patient 11. Preoperative (top) and postoperative images (bottom) images of a 54-year-old woman who underwent transsulcal parafascicular resection of an enlarging right atrial meningioma. The sagittal postoperative

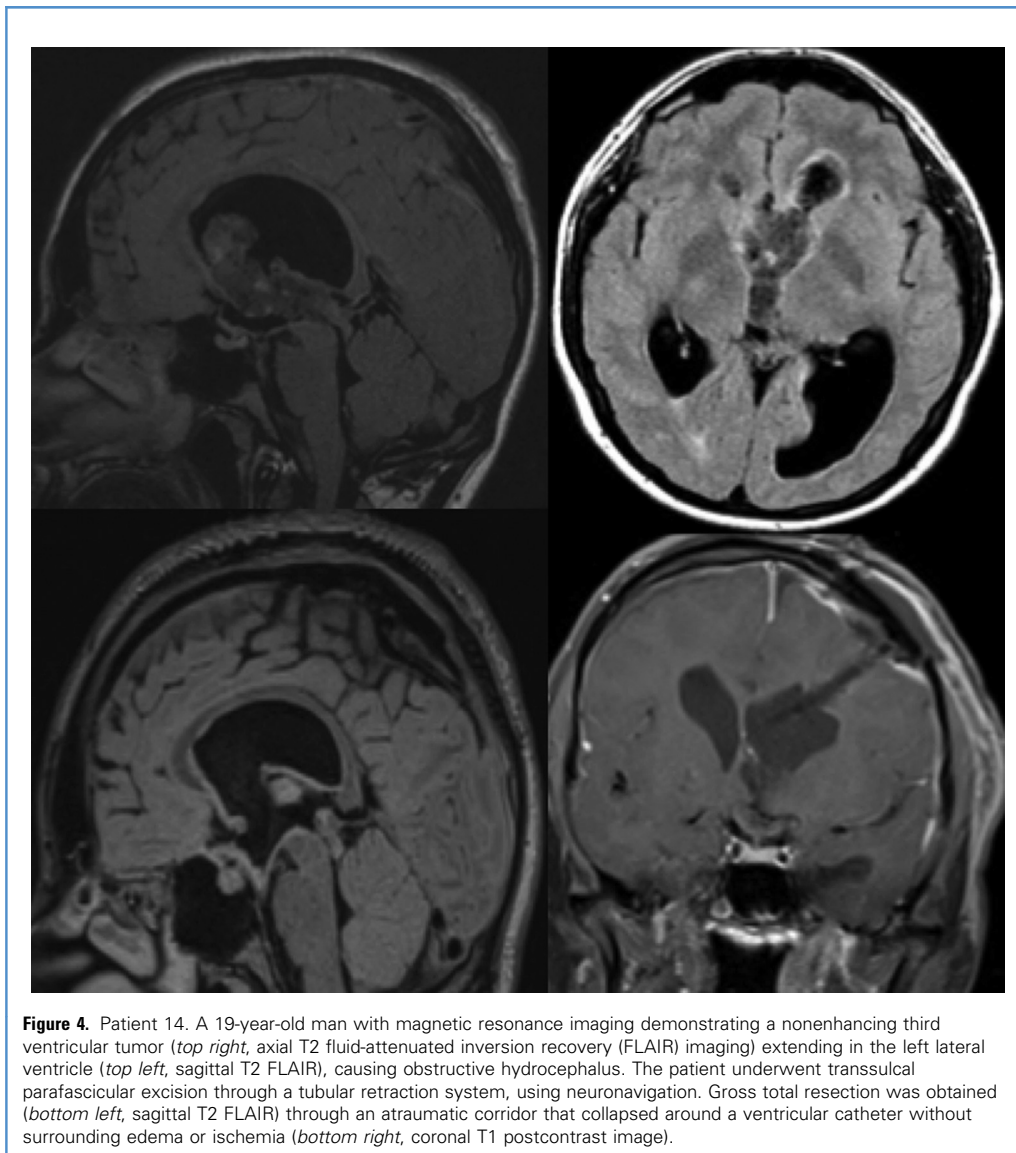
image on the bottom right shows the trajectory taken by the tubular retractor. As seen in these images, gross total resection was performed without any problems.

involvement in semantic language processing.<sup>23,24</sup> Approaching atrial or peri-atrial lesions, especially in the dominant hemisphere, can lead to development of aphasia. In our approach, these lesions were reached by parting the intraparietal sulcus, thereby preserving surrounding fiber tracts of great significance (Figure 5).

Previously published reports<sup>7,14,15</sup> have discussed use of retractors in transcortical resection of lateral ventricular tumors, but the transsulcal route minimizes brain injury during resection. Opening of sulci and fissures has placed even unreachable regions of the brain within the neurosurgeon's grasp. Patient morbidity is decreased through less potential injury to the critical white matter tracts and vascular pedicles of both cortical and subcortical structures.<sup>3,19</sup> Coupled with advances in neuronavigation and exoscope technology, the transsulcal insertion of a port system allows a working corridor, to run alongside white matter tracts and not through them. This is highlighted by reports of transsulcal approaches to deeper lesions, without an encircling retractor, which show a morbidity profile similar to that of the transcortical technique.<sup>1</sup> There could be a few reasons for this. First, deeper

lesions need a retractor system to keep the track open, and flat-blade retractors exert exponential pressure on the tissue that is being retracted.<sup>12</sup> Second, in the conventional retractor systems, introduction of instruments and surgeon movements are continuously transmitted to the banks lining the approach. This often causes further injury to adjacent brain structures and could prove costly in eloquent locations.

Various tubular retractor systems have been developed in recent decades. An ideal system should possess a particular set of qualities that make it unique and applicable. A retractor with a small internal diameter precludes bimanual operations and at times even binocular vision, whereas too large an opening is counterintuitive to minimizing brain injury and negates the advantage of the approach.<sup>25-27</sup> Second, the technique of insertion should be easy and uncomplicated and involve gradual dilation of the surgical corridor, without the serial use of increasingly large dilators.<sup>16</sup> Our system uses frameless stereotaxy to plan and execute the trajectory, thereby avoiding the inconvenience of operating through stereotactic frames.<sup>10,13,28</sup> In addition, the



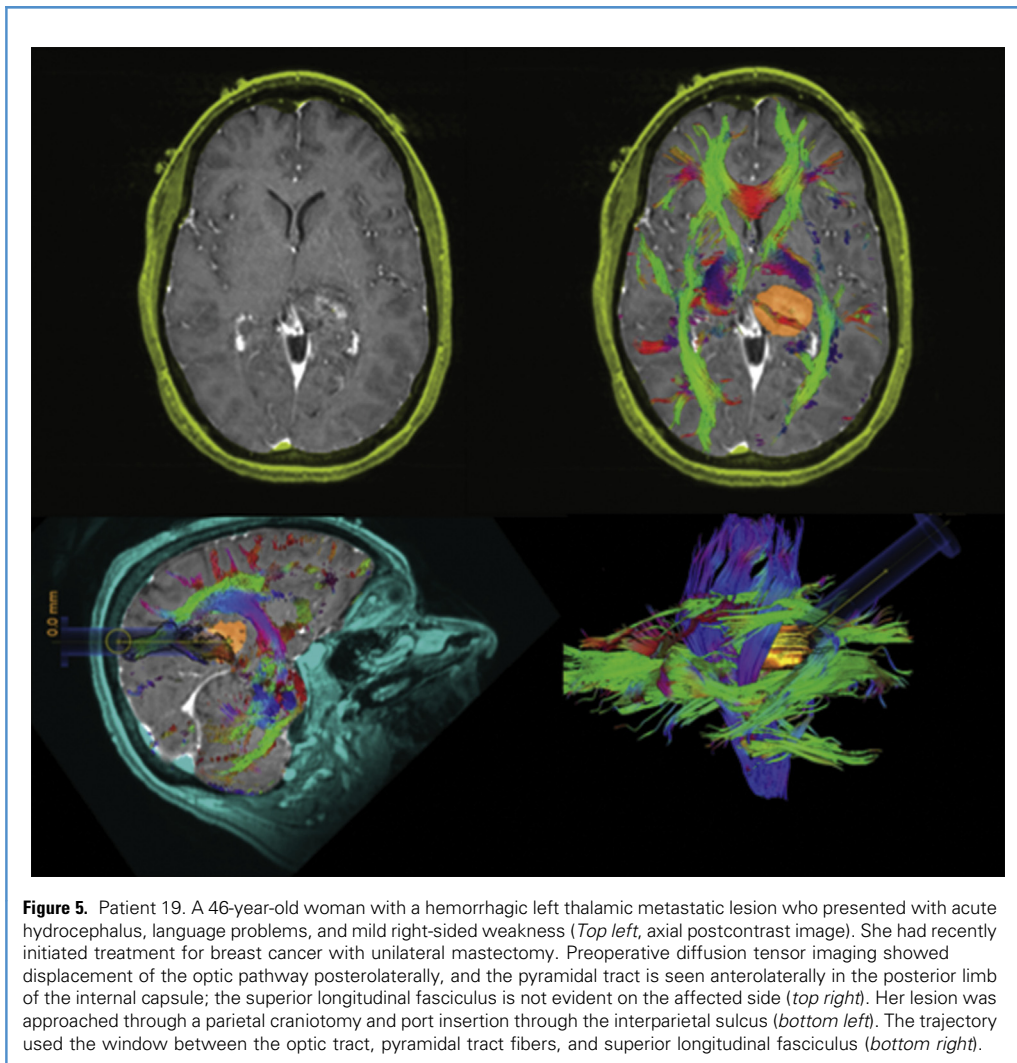
BrainPath sheath has a fixed diameter along its length and is transparent, allowing continuous inspection of tissue that is being retracted during the procedure.<sup>7,15</sup> With this system, we find ease in using multiple resection tools such as the Myriad (side-cutting aspirator [NICO Corporation]), ultrasonic aspirator and bipolar cautery device; simultaneously wielding suction in the nondominant hand, without being constrained by limited space.<sup>29</sup>

Multiple groups have previously used various individual components of our technique, in addressing ventricular and periventricular lesions. Few centers have reported their experience with the tubular retractor but, based on their descriptions, lesions were reached by performing craniotomy to accommodate the retractor system.<sup>14,25,30</sup> As highlighted, we did not require any such maneuvers to position our retractor. Conversely, some investigators<sup>1,31</sup> have reported their use of a transsulcal approach to ventricular tumors but with conventional retractor systems. Our

technique of a transsulcal approach and use of a tubular retractor system is unique and not comparable with either combination mentioned earlier. Moreover, individual surgeons had the opportunity of using either a microscope or an exoscope or both, depending on the depth of the lesion and need for three-dimensional vision.

#### Limitations

Our study has drawbacks. Being a retrospective study, it is subject to biases and, in addition, selection of patients for this technique was dependent on individual surgeon's discretion. Because all consecutive patients who presented with ventricular or periventricular disease were operated on with this technique, we believe that some of these limitations have been overcome. In addition, an appraisal of surgical shortcomings (both incomplete resection and postoperative neurologic deficit) has been presented. Another



**Figure 5.** Patient 19. A 46-year-old woman with a hemorrhagic left thalamic metastatic lesion who presented with acute hydrocephalus, language problems, and mild right-sided weakness (*Top left*, axial postcontrast image). She had recently initiated treatment for breast cancer with unilateral mastectomy. Preoperative diffusion tensor imaging showed displacement of the optic pathway posterolaterally, and the pyramidal tract is seen anterolaterally in the posterior limb of the internal capsule; the superior longitudinal fasciculus is not evident on the affected side (*top right*). Her lesion was approached through a parietal craniotomy and port insertion through the interparietal sulcus (*bottom left*). The trajectory used the window between the optic tract, pyramidal tract fibers, and superior longitudinal fasciculus (*bottom right*).

point of contention has been the short follow-up period offered in our study. We primarily wished to perform a proof of principle study with this technique and in this regard, we feel our follow-up period is sufficient to enumerate both complications from this technique and possible recovery from neurologic deficits. Most importantly, we intend to present a novel technique in resecting deep cerebral lesions and discuss nuances of such an approach, which we believe the study achieves.

## CONCLUSIONS

Minimally invasive transsulcal parafascicular resection of ventricular and periventricular lesions using tubular retractors, inserted with the aid of neuronavigation, is an amalgam of recent advances in various compartments pertaining to surgery of the human cerebrum. Use of frameless stereotaxy minimizes surgical

invasiveness and also executes the procedure with precision; choosing a transsulcal parafascicular trajectory reduces the amount of brain traversed to reach these lesions and deployment of tubular retraction provides the greatest protection to displaced neural tissue. Development of innovative resection tools such as side-cutting aspirator and ablative lasers further enhances the efficiency of lesion removal. Surgical and neurologic morbidity is comparable with other invasive approaches such as transcortical and transcallosal resection; with maintained bimanual lesion resection and improved hemostasis and visualization through the medium of air.

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