Tumor characteristics guiding selection of channel-based versus open microscopic approaches for resection of atrial intraventricular meningiomas: patient series

Jeffrey J. Feng, MS,1,2 Stephanie K. Cheok, MD,1,3 Mark S. Shiroishi, MD,4 and Gabriel Zada, MD1

 Departments of 1Neurological Surgery and 4Radiology, Keck School of Medicine of USC, Los Angeles, California; 2Western Michigan University Homer Stryker M.D. School of Medicine, Kalamazoo, Michigan; and 3Department of Neurological Surgery, Medical College of Wisconsin Milwaukee, Wisconsin

BACKGROUND Atrial intraventricular meningiomas (AIMs) are relatively rare and typically deep-seated tumors that can mandate resection. Compared with transsulcal or transcortical open microscopic approaches, port- or channel-based exoscopic approaches have facilitated a less invasive alternative of tumor access and resection. The authors present a case series of seven patients with AIMs who underwent open microscopic versus channel-based exoscopic resection by a senior neurosurgeon at their institution between 2012 and 2022 to understand patient and tumor features that lent themselves to selection of a particular approach.

OBSERVATIONS In the patients harboring three AIMs selected for channel-based resection, the average AIM diameter (2.9 vs 5.2 cm) was smaller, the AIMs were deeper from the cortical surface (2.5 vs 1.1 cm), and the patients had a shorter average postoperative length of stay (3.3 vs 5.8 days) compared with the four patients who underwent open resection. Gross-total resection was achieved in all cases. Complications for both groups included transient homonymous hemianopsia and aphasia. No recurrences were identified over the follow-up period.

LESSONS The authors demonstrate that channel-based exoscopic resection is safe and effective for AIMs 3 cm in diameter and over 2 cm deep. This may help guide neurosurgeons in future approach selection based on tumor features, including size/volume, location, and depth from cortical surface.

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KEYWORDS case series; channel-based; exoscope; intraventricular meningioma; subcortical neurosurgery; tumor resection

The atrium is by far the most common location of intraventricular meningiomas (80%), which account for 0.5%–3.0% of all meningiomas.1 Atrial intraventricular meningiomas (AIMs) often grow insidiously until they reach a relatively large size2,3 (>3 cm), often leaving resection as the main treatment modality available, as stereotactic radiosurgery (SRS) is often reserved for smaller tumors with diameters <3 cm.1,4,5 When resection is indicated, several approach options are available to the neurosurgeon. Microsurgical resection through a transsulcal or transcortical approach to the atrium has classically been the standard operative management.6,7 For the past decade or so, however, approaches to deep subcortical and ventricular zones have been facilitated using a tubular retractor or port, often in combination with an extracorporeal telescope (exoscope).8 Irrespective of approach, the location and anatomical configuration of AIMs require safe navigation through the subcortical space9–12, violation of which can cause postoperative visual, motor, and/or cognitive deficits.7 Proposed benefits of a tubular, port, or channel-based retractor include the reduction in collateral injury to surrounding white matter tracts,13–21 improved surgeon ergonomics,22,23 less tissue breach into the surgical field, improved visualization, and versatility when used in adjunct with other approaches and techniques (e.g., endoscope-assisted or fluorescence-guided resection).24–26 As this is a relatively recent technology, the tumor features lending themselves to selection of channel-based exoscopic surgery for AIMs are not yet well defined.23,26 We present a descriptive case series of seven AIMs that underwent either complete open microscopic or channel-based exoscopic resection to identify and further understand patient or tumor features supporting the selection of one approach over the other.
Study Description

Design and Population

Retrospective data were collected on all meningioma tumor operations performed by a single senior surgeon at our institution, located in a large metropolitan area, from January 1, 2012, to August 1, 2022. Patient inclusion criteria were adults (age ≥18 years) who presented with at least one neurological symptom and had at least one preoperative and postoperative outpatient visit with corresponding magnetic resonance imaging (MRI) of the brain (Fig. 1) demonstrating the presence of an atrial AIM. Exclusion criteria were pediatric patients, reoperations on recurrent tumor, and other types and locations of intracranial tumors. Institutional review board approval was obtained for analysis of patient medical charts without the need for patient consent, given minimal risk to subjects, deidentification of patient data, and lack of biological specimens collected or interventions performed specifically for this retrospective study. This case series has been reported in line with the Preferred Reporting of Case Series in Surgery Guideline.27

Data Collection and Statistical Analysis

The patients of interest were identified from a secured Research Electronic Data Capture (REDCap, Vanderbilt University) database and were queried on the hospital’s electronic medical record system. Demographic information, including age, sex, dates of surgery, and length of hospital stay (LOS), were collected. Surgical and clinical data, including history of present illness, medical history, preoperative and postoperative MRI, entry approach, surgical outcome, pathology, and postoperative clinical course, were reviewed. Size and location of the tumor and eventual extent of resection were determined from the MRI. When appropriate, descriptive statistics of the two cohorts of patients were performed using Prism version 9 (GraphPad Software) software. Patient information was deidentified in the reporting of this case series.

Operative Techniques

Day-of-surgery preoperative MRI including postcontrast T1-weighted and diffusion tensor imaging was performed for neuro-navigation in all patients. These imaging studies aided the selection of the site of safest entry to minimize damage to collateral structures, including surrounding vasculature, in planning for either approach.28–30 Parieto-occipital and temporo-occipital transcortical or transsulcal approaches were used, as these provide the most direct and shortest path to access these tumors while minimizing parenchymal disruption.3 Patients were positioned either supine with a large shoulder roll or prone based on whether a posterior temporal versus parieto-occipital site of entry was selected, respectively. The patient’s head was secured using a three-pin head clamp. General anesthesia with somatosensory evoked potential (SSEP) and motor evoked potential (MEP) neuro-monitoring was used to ensure the integrity of baseline neurological function throughout the surgery.31 Both microscopic and exoscopic approaches involved a craniotomy over the site of entry. Subsequent steps differed after the bone flap was separated from the underlying dura and are discussed in further detail below.

The critical phase of the open approach begins with a cruciate dural incision under microscopic visualization. Transsulcal entry and dissection of the subcortical white matter are performed, and an incision is made at the base of the sulcus followed by gentle dissection using bipolar forceps and a navigation probe with careful intent to preserve existing vasculature until the atrium and meningioma are reached. Malleable retractors versus dynamic retraction with cottonoids are used and adjusted as needed to obtain access to the lesion. The tumor capsule is identified and cauterized and then opened as widely as possible for initial debulking. The tumor is debulked with the use of suction and/or an ultrasonic aspirator, depending on tumor consistency, which is evaluated intraoperatively based on a 1–5 grading scale previously developed and validated by our research group.32,33 This technique allows the tumor capsule to ultimately be folded inward and to be more easily dissected from the surrounding subcortical white matter, ependyma, and choroid plexus vessels. A circumferential approach to dissecting the meningioma capsule from surrounding structures is typically performed in a lateral-to-medial fashion to separate it from the choroid plexus, surrounding ependyma, and parasitized tumor feeders that often enter medially from the posterior choroidal artery or smaller choroidal plexus branches. This continues until satisfactory resection and meticulous hemostasis are achieved. A ventricular drain is typically not

FIG. 1. Preoperative (A) and initial postoperative (B) postcontrast axial T1-weighted magnetic resonance imaging of patients who underwent channel-based exoscopic tumor resection (cases 1–3) and open microscopic tumor resection (cases 4–7). Multiple sequences are demonstrated to best enhance tumor visualization and based on availability and quality of images.
used. The dura is then reapproximated, and dural substitute is placed prior to replacement of the bone flap using titanium screws and plates. The galea and skin are then closed in standard fashion.

The channel-based exoscopic approach utilizes an exoscope that provides a magnified live video projection of the operative view on a separate display screen and a two-part round obturator and port retractor system (BrainPath, NICO Corporation),34 13.5 mm in diameter and 50 mm in length, that functions as a channel. Following elevation of a 2- to 2.5-cm-diameter bone flap, a small dural incision is made (13–15 mm), approximating the diameter of the tubular retractor. Microdissection creates an entry for the tubular retractor for transsulcal entry while preserving the surrounding vasculature and cortex. The neuro-navigation probe is then attached to the obturator above the port, which is then carefully tunneled along a prespecified trajectory with the obturator tip in place until it is docked in the ventricle and/or on the superficial surface of the meningioma capsule. The tubular retractor is then secured with a flexible Fukushima retractor. The obturator is removed, allowing the passage of microsurgical instruments and two-handed microdissection of the tumor under exoscopic visualization. Similar to the microscopic approach, the tumor consistency is assessed intraoperatively and then the AIM is internally debulked with the assistance of an ultrasonic or cutting aspiration device. Once in place, the tubular retractor can be gently maneuvered or toggled to visualize the edges of the tumor. When satisfactory resection and meticulous hemostasis is achieved, the tubular retractor is then slowly retracted, resection edges are inspected for bleeding, and the sulcus of entry is irrigated with antibiotic solution. Closure then proceeds in similar fashion to the microscopic approach.

**Patient Characteristics**

Of a total of 211 meningioma cases performed by the senior surgeon over the study duration, seven atrial intraventricular meningioma cases were identified and analyzed (Table 1, Fig. 1). All patients were female. Three AIMs were located on the left side, and the remaining four were on the right side. Six of the seven patients initially presented with headache as the primary symptom. Three patients underwent exoscopic channel-based resection, and four underwent conventional open transsulcal microscopic resection. None were deemed good candidates for SRS based on tumor growth, size, and/or patient preferences.

The mean patient age was 50.3 years (median, 47 years). Patients who were selected for channel-based exoscopic resection were younger (45 vs 54 years) than those undergoing open resection. Tumors that underwent exoscopic resection were, on average, smaller in diameter (2.9 vs 5.2 cm), deeper from the cortical surface (2.5 vs 1.1 cm) (Table 1), and had more firm consistency with higher consistency scores (3.3 vs 2.9). Patients undergoing channel-based resection also had a shorter average postoperative LOS (3.3 vs 5.8 days). Gross-total resection (GTR) was achieved in all seven cases, irrespective of approach method.

All meningiomas were World Health Organization (WHO) grade 1 or 2. Three in the microscopic group and one in the channel-based exoscopic group were WHO grade 2 tumors (Table 1).

**Surgical and Clinical Outcomes**

There were no intraoperative complications, including significant changes in SSEP or MEP monitoring from baseline. All patients have been followed postoperatively in the clinic, ranging from 4 to 85 months (median, 22 months). No recurrences or deaths were identified over the follow-up period (Table 2).

None of the patients experienced significant intraoperative blood loss, although one patient had an intraoperative ventriculostomy placed as a precaution because of an elevated risk of hydrocephalus given the large size of her tumor. The same patient also developed postoperative anemia that resolved with a single transfusion of packed red blood cells (Table 2).

Among the patients who underwent channel-based exoscopic resection, one patient with a left-sided AIM developed new right homonymous hemianopsia postoperatively that improved significantly in subsequent outpatient follow-up, and another patient with a left-sided AIM experienced immediate postoperative apraxia and aphasia that resolved at the time of discharge days later (Table 2).

Among the patients who underwent open microscopic resection, one patient with a left-sided AIM experienced postoperative mixed aphasia that resolved prior to discharge; another had headaches with nausea, vomiting, and anemia necessitating postoperative blood transfusion that resolved prior to discharge; and a third patient with a right-sided AIM had left homonymous hemianopsia that resolved on outpatient follow-up (Table 2).

All seven patients had significant improvement in or resolution of their presurgical symptoms in their postoperative visits. All three of the patients who had undergone channel-based exoscopic resection have received clinical follow-up for at least 3 years following surgery without signs of recurrence, with one patient having been monitored for over 7 years.

**Patient Informed Consent**

The necessary patient informed consent was obtained in this study.

### TABLE 1. Patient demographics, surgery approach, tumor size, pathology, and consistency for all seven patients

<table>
<thead>
<tr>
<th>Case No.</th>
<th>Age (yrs)/Sex</th>
<th>Approach</th>
<th>Region</th>
<th>Tumor Diameter, cm</th>
<th>Tumor Depth, cm</th>
<th>WHO Grade</th>
<th>Consistency Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>34/F</td>
<td>Channel</td>
<td>Lt temporal occipital</td>
<td>2.7</td>
<td>2.6</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>2</td>
<td>47/F</td>
<td>Channel</td>
<td>Lt parietal occipital</td>
<td>2.9</td>
<td>2.8</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>3</td>
<td>54/F</td>
<td>Channel</td>
<td>Rt parietal occipital</td>
<td>3.1</td>
<td>2.0</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>4</td>
<td>39/F</td>
<td>Conventional</td>
<td>Lt parietal occipital</td>
<td>5.1</td>
<td>1.6</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>5</td>
<td>20/F</td>
<td>Conventional</td>
<td>Rt temporal occipital</td>
<td>6.3</td>
<td>0.9</td>
<td>2</td>
<td>2–5</td>
</tr>
<tr>
<td>6</td>
<td>79/F</td>
<td>Conventional</td>
<td>Rt temporal occipital</td>
<td>5.0</td>
<td>1.8</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>7</td>
<td>79/F</td>
<td>Conventional</td>
<td>Rt temporal occipital</td>
<td>4.4</td>
<td>0.4</td>
<td>2</td>
<td>4</td>
</tr>
</tbody>
</table>
Discussion

Observations

The deep-seated location of atrial meningiomas presents multiple operative challenges to conventional approaches, with brain retraction being one of the most formidable. In recent years, channel-based approaches often coupled with exoscopic visualization are technologies that have become available to neurosurgeons. Our aim was to explore and describe patient and tumor characteristics lending themselves to the selection of channel-based exoscopic versus open microscopic resection in this small retrospective case series. As minimally invasive port- and channel-based approaches continue to evolve rapidly, findings from this study may help guide neurosurgeons in approach selection based on tumor features including size/volume, location, and depth from the cortical surface.

Channel-based approaches for AIMs were selected for smaller tumors (≤2 cm) that were deeper from the cortical surface (>2 cm). As expected, LOS was shorter for the port-based group, which is likely more a function of the initial tumor size and less related exclusively to the particular approach.

Appropriate case selection for the channel-based exoscopic approach is vital to the success of the surgery. The size of a tumor itself must be considered in preoperative planning. Our cases used one type of port, which had a maximum diameter of 13.5 mm. Tumors with a greater diameter than that of a port can be safely resected through debulking rather than removal en bloc, but the ability of the surgeon to do so is also dependent on the consistency and attachment of the tumor, which are often difficult to predict or determine with certainty beforehand. Jamshidi et al.10 documented GTR of three channel-based intraventricular meningioma resections measuring >4 cm; one was staged as two surgeries. The largest diameter tumor that underwent channel-based exoscopic resection in our series was 3.1 cm, compared with the smallest diameter tumor that underwent conventional microscopic resection at 4.4 cm. With larger tumor sizes, the benefit of a less invasive, channel-based approach needs to be weighed against the increased difficulty of visualizing or reaching tumor margins through the comparatively narrow port opening and the additional need for manipulation of the port. Larger meningiomas come closer to the cortical surface due to slow and expansive radial growth; therefore, the inverse association between tumor size and cortical depth is consistent with our case selection for each surgical approach.

Lin et al.9 demonstrated the safety and feasibility of the exoscopic approach in four patients with atrial meningiomas across three institutions in surgeries performed by different surgeons. In contrast, the single-center and single-surgeon nature of this study may limit bias and variability in aspects involving the selection of surgical approach, especially given the low number of patients in our study, although external validity should be further studied. An established uniform protocol of patient evaluation, preoperative and intraoperative planning, and postoperative management may limit confounding effects involved in the selection of channel-based exoscopic and open microscopic approaches. Unique to our study is long-term (>7 years) follow-up in one patient who underwent channel-based exoscopic resection who demonstrated a positive outcome with GTR without recurrence.

The versatility of the exoscopic approach when used in adjunct with other approaches and techniques is of growing interest and worthy of further investigation. The exoscope, because of its position outside of the body, is attached to a holder arm that remains stationary as the tubular retractor itself, when docked into the brain, can be adjusted in variable angles to obtain needed exposure without imparting significant additional stress to surrounding brain tissue. Despite this, the field of view that the exoscope provides does

### TABLE 2. Clinical presentation, including preoperative and postoperative symptoms, of all seven patients included in our study

<table>
<thead>
<tr>
<th>Case No.</th>
<th>Side</th>
<th>Preop Symptoms</th>
<th>Postop Course</th>
<th>LOS (days)</th>
<th>Length of FU (mos)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Lt</td>
<td>Memory, speech</td>
<td>Rt homonymous hemianopsia (improved)</td>
<td>3</td>
<td>85</td>
</tr>
<tr>
<td>2</td>
<td>Lt</td>
<td>Headache, rt homonymous hemianopsia</td>
<td>Apraxia, aphasia (resolved)</td>
<td>3</td>
<td>21</td>
</tr>
<tr>
<td>3</td>
<td>Rt</td>
<td>Headache, dizziness</td>
<td>None</td>
<td>4</td>
<td>24</td>
</tr>
<tr>
<td>4</td>
<td>Lt</td>
<td>Headache, rt visual deficit</td>
<td>Mixed aphasia (resolved)</td>
<td>6</td>
<td>70</td>
</tr>
<tr>
<td>5</td>
<td>Rt</td>
<td>Headache, neck pain, visual acuity</td>
<td>EVD for hydrocephalus, anemia, imbalance (resolved)</td>
<td>9</td>
<td>22</td>
</tr>
<tr>
<td>6</td>
<td>Rt</td>
<td>Headache</td>
<td>Lt homonymous hemianopsia (resolved)</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>7</td>
<td>Rt</td>
<td>Headache, lt-sided weakness</td>
<td>None</td>
<td>4</td>
<td>4</td>
</tr>
</tbody>
</table>

EVD = external ventricular drain; FU = follow-up.
have limitations, especially when viewing cavity walls surrounding the port to confirm GTR in more adherent (generally higher grade) meningiomas. This is where the adjunct use of an angled endoscope can provide enhanced visualization of a resection cavity when passed through the port, which has been termed the exoscopic-to-endoscopic approach.28

Lessons
The surgical management of atrial meningiomas remains mainly microsurgical, especially for larger tumors approaching the cortical surface. In selected patients with smaller and deeper-situated tumors, however, a channel-based exoscopic approach provides sufficient exposure to achieve complete resection while providing potential reduction of collateral injury to normal brain tissue and improved surgeon ergonomics. In our study, patients who underwent exoscopic resection had smaller tumors and an overall shorter LOS in the hospital. The small sample size and heterogeneous group limit the ability to make statistical comparisons; however, both traditional microsurgical and emerging exoscopic approaches are effective and safe surgeries for resection of atrial meningiomas.

The small sample size (n = 7) also limits the generalizability of our results. While there is selection bias inherent to the study, our focus was to better understand and characterize the selection process and selected variables in consideration of each approach rather than a head-to-head comparison of approaches as we feel they both are complementary in the management of AIsMs. The patients who underwent microscopic resection had larger meningiomas, which likely reflected the complexity of the resections and increased the risk of postoperative complications independent of approach effect. Our two study groups were therefore heterogeneous. Tumors that are hard in consistency and unable to be significantly removed piecemeal through a tubular retractor may potentially necessitate the use of conventional spatula retractors and a larger cortical and subcortical operative access.36 Patients also had varying comorbidities and functional status at baseline; the cause of some prolonged inpatient stays, particularly in the microscopic group, for example, was due to the management of other preexisting medical conditions rather than directly arising from complications from the meningioma surgery itself.

In conclusion, our case series demonstrates that channel-based exoscopic approaches are a feasible and safe alternative to conventional resection under the operative microscope for smaller, deeper-situated AIsMs. The primary benefit is a reduced risk of retraction injury and greater visualization to an extent given the 360° brain retraction and ability to adjust the port trajectory. As limited studies using the exoscopic approach for atrial meningiomas currently exist in the literature, further comparison studies involving a larger pool of patients with similar baseline characteristics may better elucidate specific indications for each approach.

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References


Disclosures

Dr. Zada reported personal fees for consulting from Integra outside the submitted work.

Author Contributions

Conception and design: Feng, Shiroishi, Zada. Acquisition of data: Feng, Shiroishi. Zada. Analysis and interpretation of data: Feng, Shiroishi. Drafting of the article: all authors. Critically revising the article: all authors. Reviewed submitted version of the manuscript: all authors. Approved the final version of the manuscript on behalf of all authors: Feng. Statistical analysis: Feng. Study supervision: Cheok, Zada.

Supplemental Information

Previous Presentations

The abstract was presented at the 2023 North American Skull Base Society (NASBS) Annual Meeting in Tampa, Florida, on February 17, 2023.

Correspondence

Jeffrey J. Feng: Keck School of Medicine of USC, Los Angeles, CA. jeffreyjfeng@gmail.com.