Clinical Characteristics and Surgical Outcomes of Patients Presenting With Meningiomas Arising Predominantly From the Floor of the Middle Fossa

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BACKGROUND: Little is known regarding meningiomas that primarily arise from the floor of the middle fossa as opposed to the sphenoid wing, the cavernous sinus, the anterior petrous ridge, or the lateral convexity dura.

OBJECTIVE: Given the relative paucity of literature addressing this disease entity, we review the University of California at San Francisco (UCSF) experience with these tumors.

METHODS: Between 1991 and 2006, 1228 patients were seen by neurosurgeons at UCSF for meningiomas of which 17 (1.1%) patients met our criteria for a "middle fossa floor" meningioma, of which 15 underwent first-time surgery and were included in this series. The most common presenting symptoms were headache (9 patients), seizures (6 patients), trigeminal nerve dysfunction (5 patients), hearing loss (5 patients), gait disturbance (5 patients), and cognitive decline (3 patients). All patients underwent surgical resection via frontotemporal craniotomy, with or without orbitozygomatic osteotomy.

RESULTS: We were able to achieve a Simpson grade 1 or 2 resection in 10 of 15 patients (67%). The operative morbidity was clustered in 5 patients, as 10 of 15 patients (67%) experienced no operative morbidity. There were 4 known clinical recurrences in this group at 5 years median follow-up. All patients had either higher grade tumors, or received a Simpson grade 3 or higher resection.

CONCLUSION: We present the clinical characteristics and surgical outcome of a series of patients presenting with meningiomas primarily arising from the concave floor of the middle cranial fossa. Given the relatively uncommon nature of these lesions, more investigation into the clinical behavior of this entity is warranted.

KEY WORDS: Craniotomy, Meningioma, Middle fossa, Outcomes.

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Taken as a whole, the middle cranial fossa and its complex bony and meningeal boundaries are a common site of origin for meningiomas. Conceptually, this complex region can be simplistically represented as a rectangular open bowl rising to terminate in 3 distinct "ridges" and an open back. The 3 ridges include the sphenoid wing anteriorly, the cavernous sinus medially, and the convexity dura laterally; the open back is that portion posterior to the petrous ridge that includes the tentorium. In this analogy, the concavity of this bowl is made up of the floor of the middle fossa.

The clinical behavior of meningiomas originating from each of these "ridges" and the tentorium is well described, but very little is known regarding meningiomas that primarily arise from the floor of the middle fossa. We were able to identify only 4 reports documenting the clinical outcome of a total of 18 cases of primarily middle fossa floor meningiomas reported in the literature.[1-4] Clarification of the exact point of dural attachment is not a trivial point, because the goal of most surgery for meningiomas is removal of the tumor, with its dural and bony attachments, and cognitively misclassifying these tumors preoperatively could lead to inadequate surgical resection and recurrence.

Given the relative paucity of literature addressing this disease entity relative to our perception of the frequency of these lesions, we reviewed the University of California at San Francisco (UCSF) experience with these tumors.

PATIENTS AND METHODS

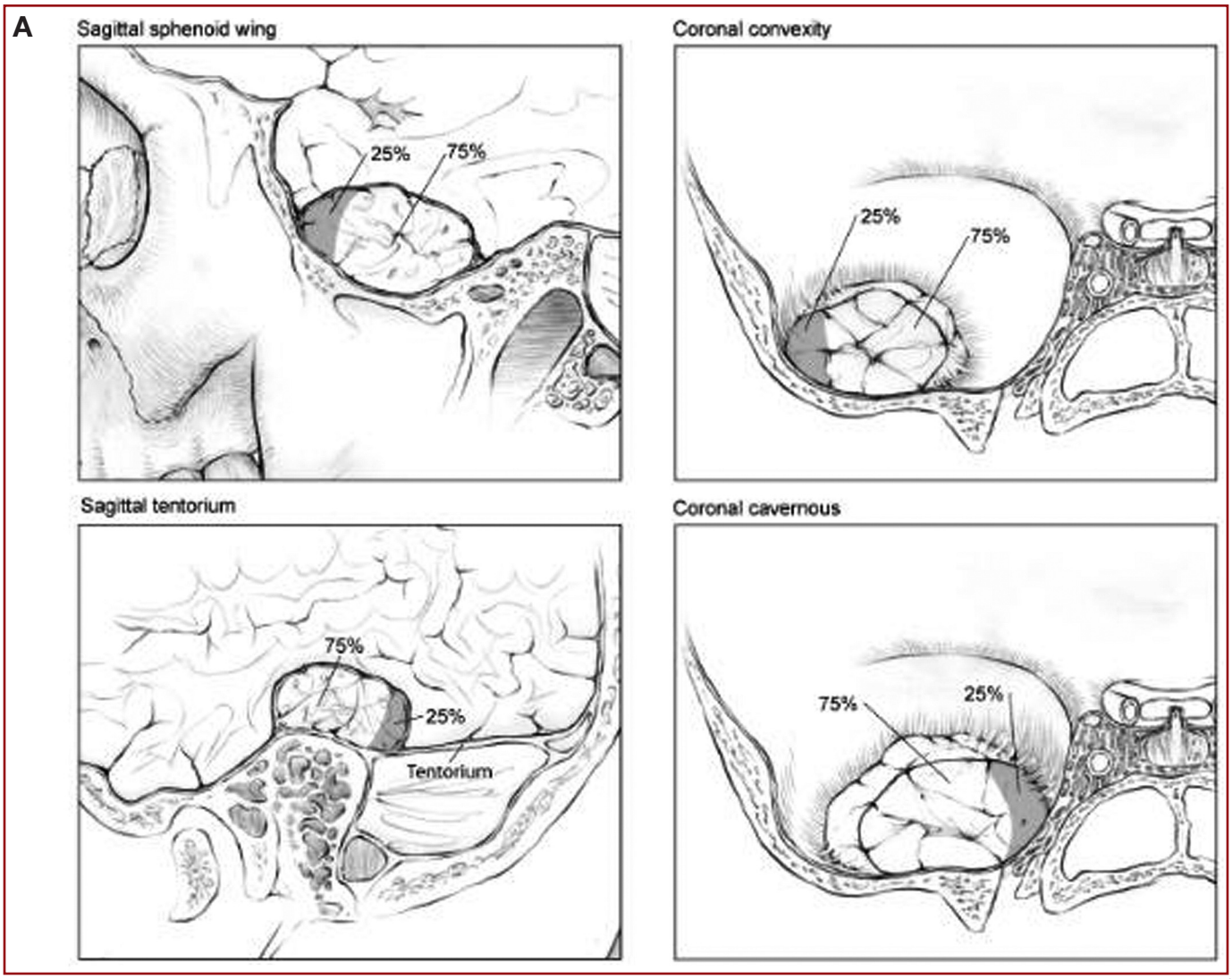
Identifying characteristics including name, diagnosis, and rough anatomic location of disease have been prospectively collected for all consenting patients undergoing neurosurgical evaluation at UCSF in a Committee for Human Research approved program since 1991 (CHR# H7828-29842-01). We searched this database for all patients with the diagnosis of meningioma, and retrospectively evaluated all patients whose tumors were in and around the middle cranial base for inclusion into this series.

We reviewed axial and coronal preoperative T1 weighted postcontrast magnetic resonance imaging (MRI) images to identify patients with tumors meeting our definition of a "middle fossa floor" meningioma. We defined a "middle fossa floor" meningioma as a histologically confirmed meningioma with greater than 75% of its radiographic attachment on the floor of the middle fossa with less than 25% of attachment on either the sphenoid wing, cavernous sinus, petrous ridge, or lateral convexity dura, which form the 4 anatomic boundaries of the middle fossa concavity as determined by MRI. These anatomic relationships are depicted schematically and radiographically in Figure 1.

Data for these patients were collected retrospectively by review of medical records, radiographic imaging, pathology reports, and clinical records. Of particular interest were preoperative symptoms, details from the operative report, Simpson grade of resection, clinical evidence of recurrence, postoperative medical and surgical complications, and subsequent therapies including radiosurgery.

Surgical Approach

Most of these tumors were approached via a standard frontotemporal (pterional) craniotomy or temporal craniotomy. When deemed necessary, a zygomatic arch osteotomy or orbitozygomatic osteotomy was added. In general, zygomatic arch osteotomy was used for more posteriorly positioned large tumors, whereas the orbitozygomatic osteotomy was used for anteriorly and medially positioned tumors. In some cases where the superior pole of the tumor was quite high (>5 cm. from the middle fossa floor) a limited inferior and middle temporal gyrus corticectomy was used to facilitate efficient removal and avoid the obvious extensive retraction of lateral temporal lobe. When possible, the base of the



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tumor was first detached from middle fossa floor attachments, thus devascularizing the tumor in the process. Standard internal debulking was then performed followed by peripheral dissection. Classification of the extent of resection was done by using the Simpson classification.

RESULTS

Patient Characteristics

Between 1991 and 2006, 1228 patients were seen by neurosurgeons at UCSF for meningiomas, of which 1034 patients underwent treatment of their lesion with either open surgery or radiosurgery at UCSF. Seventeen patients in this series met our criteria for having a middle fossa floor meningioma. Two of these patients had previous surgery, and were excluded because it was unclear where the initial site of their tumor was located.

The clinical characteristics of these patients are shown in Table 1. The median patient age at time of surgery was 57 years, and the male/female ratio was 6:9. The median volume of these tumors was 21 mL. Radiosurgery was offered as an option to patients with appropriately sized tumors; however, the patients in this series selected definitive surgical resection over radiosurgery.

All patients underwent at least 1 frontotemporal craniotomy for their meningioma at UCSF, 5 of these included the addition of an orbitozygomatic osteotomy. In all 15 cases, intraoperative findings confirmed the radiographic impression that these tumors arose predominantly from the dura of the middle fossa floor, with lesser attachments to surrounding ridges. Two patients had tumors with extension into the infratemporal fossa, and 1 of these patients also had extension into the pterygopalatine fossa. In 1 of these patients (patient 7), the dense adherence to nerves in the pterygopalatine fossa prevented gross total resection.

Three of 15 (20%) patients had a lumbar drain placed at the time of surgery. We found that with adequate craniectomy of the squamous temporal bone until the approach angle is flush with the middle fossa floor, lumbar cerebrospinal fluid drainage is usually unnecessary.

Ten patients underwent preoperative endovascular embolization. In all cases, the predominant blood supply to these tumors came from the internal maxillary artery, usually via the middle meningeal artery. In 1 case with infratemporal fossa extension, there was no middle meningeal artery noted on angiography, and the tumor was supplied directly off the internal maxillary artery.

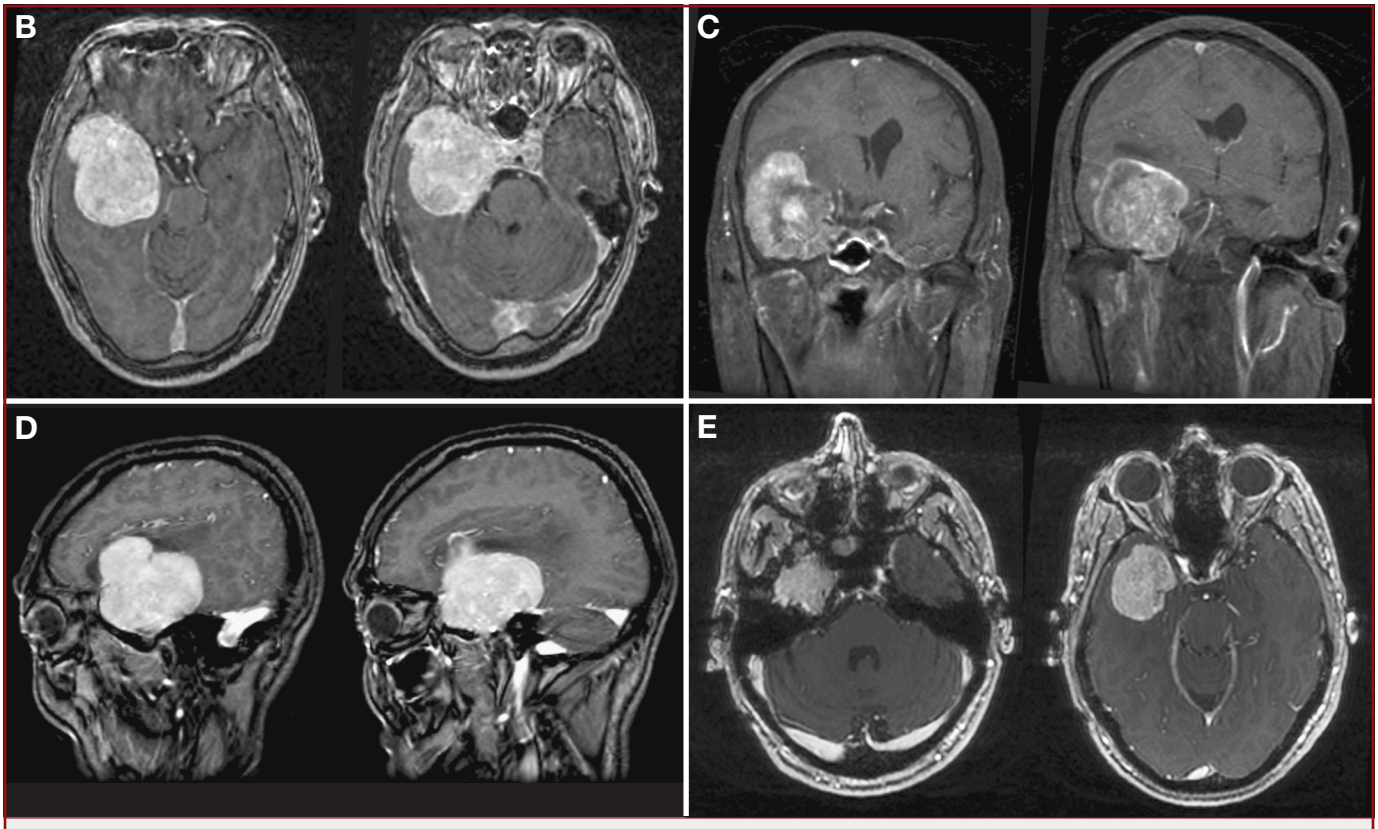

FIGURE 1. **A**, *artistic representation depicting the distinction between middle fossa floor meningiomas, and other meningiomas of the middle cranial base. Axial (***B***), coronal (***C***), and sagittal (***D***) post-gadolinium T1-weighted MR images depicting a patient in this series. A minor degree of cavernous sinus invasion is noted, but the majority of this tumor arises from the middle fossa floor, and intraoperatively, the association between the tumor and the cavernous sinus was minor.* **E**, *axial post-gadolinium T1-weighted MR images from another patient in this series whose tumor arose purely from the middle fossa floor, provided for comparison.*

TABLE 1. Clinical Characteristics of the 15 Patients in This Series[a]

Pt	Age, y	Sex	Side	Tumor Site	Size, cm	Recurrent	WHO Grade	Preop Embo?	OZ Oste-0tomy?	Simpson Grade	XRT?
1	37	F	L	Middle fossa	4.6 × 4.8 × 5.5	No	1	Yes	No	2	No
2	49	M	R	Middle fossa	4.0 × 3.1 × 3.9	No	1	Yes	Yes	1	No
3	57	M	R	Middle fossa	5.1 × 3.9 × 3.4	No	1	Yes	No	2	No
4	55	F	L	Middle Fossa	2.5 × 2.1 × 1.9	No	1	Yes	No	1	No
5	70	F	L	Middle fossa	2.7 × 2.6 × 2.8	No	1	Yes	No	2	No
6	43	F	R	Middle fossa with infratemporal extension	4.7 × 3.8 × 4.3	No	2	No	Yes	1	No
7	68	M	L	Middle fossa	4.4 × 4.2 × 4.0	Yes	2	No	No	4	Yes
8	45	F	L	Middle Fossa	2.0 × 1.8 × 2.3	No	1	No	No	1	No
9	68	F	R	Middle fossa, sphenoid wing	2.5 × 3.0 × 2.2	No	1	Yes	No	2	No
10	77	F	L	Middle fossa, sphenoid wing	4.0 × 3.6 × 2.9	No	1	Yes	Yes	2	No
11	51	F	L	Middle fossa, cavemous sinus	2.8 × 1.3 × 1.5	No	1	No	Yes	4	Yes
12	63	M	R	Middle fossa, cavemous sinus	5.4 × 5.3 × 5.5	No	2	Yes	No	4	Yes
13	28	F	R	Middle fossa, cavemous sinus	2.1 × 2.0 × 1.5	No	1	No	No	4	No
14	48	F	R	Middle fossa, petrous ridge	4.0 × 3.5 × 2.5	No	1	Yes	No	3	Yes
15	77	M	L	Middle fossa, petrous ridge	3.5 × 2.8 × 1.5	No	2	Yes	No	1	No

[a] WHO, World Health Organization; Preop Embo, preoperative embolization; OZ, orbitozygomatic; XRT, radiotherapy.

In 1 case, the tumor had a small supply from the ascending pharyngeal artery. In 1 case, the tumor received a minor supply from the anterior choroidal artery. In the other 8 cases, the tumor's sole blood supply was the internal maxillary artery.

Presenting Symptoms

Headache was the most common presenting symptom in this series, being present in 60% of patients. Six of 15 (40%) patients presented with seizures. It was not surprising that trigeminal nerve dysfunction (either numbness, palsy, or neuralgia) was also common, present in 33% of patients. Also common were gait disturbance (5 patients) and cognitive decline (3 patients). Only 5 patients had no objective neurological deficit on presentation. These symptoms are presented in Table 2.

Interestingly, hearing loss was a common symptom, as 5 patients demonstrated audiographic evidence of hearing loss on presentation.

Surgical Outcome

Median length of stay (including preoperative embolization, when applicable) for these patients was 6 days (range, 3-15 days). We were able to achieve a Simpson grade 1 or 2 resection in 10 of 15 patients (67%). Four of 15 patients (26%) had tumors demonstrating World Health Organization grade 2 histology. Two of these patients received subtotal (Simpson grade 4) resections due to firm adherence to cranial nerves or cavernous sinus invasion. Three of 5 patients receiving a Simpson grade 3 or 4 resection had tumors that involved the cavernous sinus in part. Four of 5 of these patients underwent subsequent radiotherapy.

There was no early postoperative mortality in this series. The operative morbidity was clustered in 5 patients, because 10 of 15 patients (67%) experienced no operative morbidity (Table 3). Two patients experienced new neurological deficits postoperatively, and 3 patients experienced worsening of preexisting neurological deficits. In 3 cases, these deficits were transient and had resolved by the 6 months follow-up. Significant neurosurgical complications occurred in 2 of the 15 patients, including cerebrospinal fluid leak, wound infection, and entrapment of an oculomotor muscle. This latter complication not surprisingly occurred in 1 of the 5 patients who underwent orbitozygomatic osteotomy. One patient experienced a significant medical complication (urosepsis resolving with antibiotics) postoperatively.

To date, we have followed up these patients for a median of 5 years (range, 1-15 years). There have been 4 known clinical recurrences in this group. Three recurrences were treated with stereotactic radiosurgery, and 1 patient with a World Health Organization grade 2 tumor received repeat surgery and external beam radiotherapy. It was not surprising that all of the patients with recurrence had either higher grade tumors (2 patients), or received a Simpson grade 3 or higher resection (Table 4).

DISCUSSION

Meningiomas arising primarily from the floor of the middle fossa are an uncommon occurrence, representing only 1.1% of all meningiomas in our series of meningiomas. Yet, many of these tumors in the past may have been grouped with other meningiomas

TABLE 2. Presenting Symptoms and Preoperative Neurological Deficits of the 15 Patients in This Series[a]

Patient	Presenting Symptom	Presenting Deficit
1	Headache, seizures, gait disturbance, diplopia	None
2	Headache, seizures, face numbness	CN V3 palsy
3	Headache, gait disturbance, cognitive	Left-sided weakness
4	Hearing loss, pulsatile tinnitus	Hearing loss
5	Cognitive decline	None
6	Headache, seizures, face pain, hearing loss	Hearing loss
7	Headaches, dysphasia	CN V1 palsy
8	Headache, vertigo, cognitive decline	Hearing Loss
9	Headache	None
10	Headache, cognitive decline	Hearing loss
11	Headache, seizure, face numbness	CN V2 and CN VI palsies
12	Face pain	CN V1 palsy
13	Face numbness, gait disturbance	None
14	Seizures	None
15	Seizures	Hearing loss

[a] CN, cranial nerve.

TABLE 3. Clinical Outcome for the 15 Patients in This Series[a]

Patient	Length of Stay, d	New Neurological Deficit	Surgical Complications	Medical Complications	Follow-up, y	Recurrence?
1	7	None	None	None	5	No
2	3	None	None	None	2.5	No
3	12	Homonymous hemianopsia (transient)	None	Urosepsis	8	No
4	15	New ataxia and memory loss	Wound infection Symptomatic lumbar drain leak Evacuation of subdural hygroma	None	7	Yes
5	6	None	None	None	2.5	No
6	4	None	None	None	5	No
7	8	Worse dysphasia, worse CN V1 palsy	None	None	5	Yes
8	4	None	None	None	1	No
9	6	None	None	None	13	No
10	3	None	None	None	5	No
11	5	Worse diplopia	Entrapment of superior rectus and levator palpebrae superioris muscles, requiring surgical release	None	7	No
12	6	None	None	None	8	Yes
13	3	CN V1-3 numbness	None	None	1	No
14	8	None	None	None	15	Yes
15	6	None	None	None	10	No

[a] CN, cranial nerve.

TABLE 4. Summary of Outcomes in This Series[a]

Pathology	
WHO I	11
WHO II	4
WHO III	0
Imaging results	
GTR	11/15
STR	4/15
Surgical results	
GTR	
Simpson I	5/15
Simpson II	5/15
Simpson III	1/15
STR	
Simpson IV	4/15
Simpson V	0/15

[a] WHO, World Health Organization; GTR, gross total resection; STR, subtotal resection.

of the convexity dura, sphenoid wing, lateral wall of the cavernous sinus, and tentorium. In our definition, more than 75% of the tumor attachments must be based on the central floor of the middle cranial fossa, an open bowl with 3 walls consisting of the frontotemporal convexity laterally, the sphenoid wing anteriorly, and the lateral wall of the cavernous sinus medially. We found that our radiographic prediction of the tumor's principle site of origin was uniformly confirmed intraoperatively, and that preoperative angiography consistently identified the internal maxillary artery, via the middle meningeal artery, as the blood supply to these tumors. This latter finding strongly suggests that these tumors arise from the middle fossa dura primarily, because none of these tumors had any attachments to the convexity dura.

One goal of this study was to introduce the concept of "middle fossa floor" meningiomas as a clinical entity distinct from meningiomas arising from the sphenoid wing, cavernous sinus, convexity, or petrous ridge. We believe that such a distinction is more than mere semantics, because the recognition that meningiomas can arise predominantly from the floor of the middle fossa has important clinical and surgical implications. Most importantly, given that the goal of most meningioma surgeries is to achieve complete removal of the tumor with its dural and bony attachments (ie,. Simpson grade 1 resection), it would be a mistake for a surgeon to mentally classify a tumor as a "sphenoid wing" meningioma, when it is truly a middle fossa meningioma, and to approach the case with the plan of primarily addressing the attachments of the tumor at the sphenoid wing, when greater than 50% of the tumor attachment lies on the floor of the middle fossa.

It is likely that many cases of "Middle Fossa" meningiomas have been reported previously, aggregated into other series of meningiomas such as sphenoid wing meningiomas. Perhaps this results from the lack of a previously defined firm definition for what, in fact, constitutes a "middle fossa floor" meningioma. We suspect that one reason there are so few dedicated reports about this clinical entity is that authors frequently do not distinguish between middle fossa floor meningiomas and other middle fossa tumors such as sphenoid wing meningiomas.[4-27] We believe that there is a significant difference in the surgical approach to these 2 tumors. Although many lateral sphenoid wing meningiomas can be properly excised at their dural base by use of a pterional or orbitozygomatic approach, we use a more posterior subtemporal approach to many of these tumors. The skin incision and craniotomy are placed further posteriorly than for a sphenoid wing meningioma, and the craniectomy of the squamous temporal bone is continued until flush with the middle fossa floor to approach this lesion subtemporally. The role of zygomatic arch osteotomy in these cases is primarily to achieve a flatter trajectory along the middle fossa floor. This would be less important for a true sphenoid wing meningioma.

In addition, given the relative distance between the attachment point of these tumors and cranial nerves, or other pressure sensitive structures, these tumors behave clinically different from other meningiomas, in that they seem to grow rather large before diagnosis, and frequently present with nonspecific symptoms. Given their large size at diagnosis, it is not surprising that the morbidity of resecting these tumors is not trivial, with one third of these patients having at least 1 notable postoperative complication.

In our series, patients presented with at least 10 different signs or symptoms, and no single sign or symptom was found in more than 60% of patients. Many patients had multiple symptoms. Even trigeminal nerve dysfunction, which would be expected to be very common given the anatomic location of these tumors, occurred in only 33% of our patients. Most likely this heterogeneity results from the central location of these tumors in the middle fossa, placing them in proximity with a large variety of intracranial structures, such as the temporal lobe, multiple cranial nerves, and the superior orbital fissure.

The largest previous series of these tumors (11 patients), published in 1994, predates the widespread use of image guidance technology and stereotactic radiosurgery.[3] Thus, this report represents the first attempt to report surgical outcomes for these lesions given the techniques most neurosurgeons currently use to resect these lesions. Nearly identically to our report, they reported an incidence of headache in 55% of their patients, and cognitive changes in 36%. Their incidence of auditory complaints was also similar to ours. However, they did not report any preoperative trigeminal nerve dysfunction in their series, which differs from our experience. In either case, trigeminal dysfunction appears to be less common than the anatomic location of these tumors would suggest.

We report the clinical characteristics and surgical outcome of a group of patients presenting with meningiomas primarily arising from the concave floor of the middle cranial fossa. Given the uncommon nature of these lesions, we were only able to indentify 15 patients with these tumors over 18 years of experience at a high-volume center. Thus, we are not able to definitively demonstrate a clinical course for these lesions that is truly distinct from

other more well known meningioma classes (ie, sphenoid wing, cavernous sinus, etc). More investigation into the clinical behavior of this entity is necessary before we can draw meaningful conclusions about the clinical behavior of these lesions. However, we believe that it is critical for surgeons to recognize the possibility of middle fossa floor attachment preoperatively, and to include plans to address this attachment in their preoperative planning.

Disclosure

The authors have no personal financial or institutional interest in any of the drugs, materials, or devices described in this article.

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COMMENT

The thorough study by Sughrue et al describes a small series of patients with meningiomas specifically arising from the floor of the middle fossa. The authors have attempted to differentiate such tumors from meningiomas that arise from surrounding structures, such as the sphenoid wing, the cavernous sinus, the petrous ridge, and the dural convexity. Defining the origin of such tumors is helpful because it may change the surgical approach and modify the extent of resection and the Simpson grade. Moreover, the spatial configuration of middle fossa meningiomas may present specific surgical challenges when they invade the infratemporal and pterygopalatine fossae.

An important message in this article is that middle fossa meningiomas present with unique anatomic features that may prevent the surgeon from performing a complete resection. In such cases, much like meningiomas arising from other locations, radiotherapy becomes critical in controlling the tumor.

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