Risk profile associated with convexity meningioma resection in the modern neurosurgical era

Clinical article

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Object. Although meningiomas are commonly found along the supratentorial convexity, the risk profile associated with this subset of lesions in the modern neurosurgical era is unknown.

Methods. The authors retrospectively reviewed the clinical course of patients with supratentorial convexity meningiomas treated during the past 10 years. All patients had undergone MR imaging within 72 hours after surgery and at least 1 year of clinical follow-up. Patients with multiple meningiomas, hemangiopericytomas, malignant meningiomas, or tumor-prone syndromes were excluded from analysis.

Results. Between 1997 and 2007, 141 consecutive patients (median age 48 years, range 18–95 years) underwent resection of a supratentorial convexity meningioma. The most common signs or symptoms at presentation were headache (48%), seizures (34%), and weakness (21%). The mean tumor volume was 146.3 cm³ (range 1–512 cm³). There were no intraoperative complications or deaths. Medical or neurosurgical morbidity was noted in the postoperative course of 14 patients, equating to a 10% overall complication rate. Postoperative surgical complications included hematoma requiring evacuation, CSF leakage, and operative site infection. Medical complications included pulmonary embolus and deep vein thrombosis requiring treatment. A Simpson Grade 0 or 1 resection was achieved in 122 patients (87%). One hundred six tumors (75%) were WHO Grade I, whereas 35 (25%) were WHO Grade II. The median clinical follow-up was 2.9 years (range 1–10 years), and the median radiographic follow-up was 3.7 years (range 1–10 years). Six patients (4%) had radiographic evidence of tumor recurrence, with 3 (2%) undergoing repeat resection.

Conclusions. With the conservative recommendations for surgery for asymptomatic meningiomas and the advent of radiosurgery during the past 10 years, microsurgically treated convexity meningiomas are now typically large in size. Nevertheless, the patient’s clinical course following microsurgical removal of these lesions is expected to be uncomplicated. The authors’ findings provide a defined risk profile associated with the resection of supratentorial convexity meningiomas in the modern neurosurgical era. (DOI: 10.3171/2009.6.JNS081490)

Key Words • convexity meningioma • risk profile • microsurgical removal

Convexity meningiomas are among the most common extraaxial tumors encountered in neurosurgery, yet most large studies of these lesions are at least 2 decades old. In the interim, advances in diagnostic imaging, intraoperative technology, and nonsurgical treatment modalities have changed the face of neurosurgical oncology. Our current understanding of meningioma biology has similarly evolved. Histopathological criteria for meningioma grading and diagnosis have refined atypical and malignant meningioma categories, while new prognostic factors, including tumor proliferative indices, chromosomal aberrations, and growth factor receptor profiles, now enable risk stratification for meningioma progression and recurrence. Perhaps most importantly, stereotactic radiosurgery has emerged as a new standard of care for many patients with meningioma, and thus has altered the patient population undergoing microsurgical removal.

Some of the largest studies on convexity meningiomas in the literature bear little resemblance to modern neurosurgical experience. For example, Olivecrona’s experience with 112 convexity meningiomas, published in 1967, reveals a 25% incidence of new-onset postoperative epilepsy. Similarly, Flyger’s series of 94 convexity meningiomas demonstrated a new-onset postoperative epilepsy rate of 9.6%. In contrast, seizure disorders attributable to microsurgical removal are rarely encountered in the modern era, likely due to advances in microsurgical technique as well as the routine use of postoperative antiepileptics.

Surprisingly few studies have been published in the radiosurgery era. Yamasaki et al. have described their experience following Simpson Grade 1 resections in 54 patients with convexity meningiomas. Six patients (11.1%) in this series had evidence of recurrent tumor on follow-up, with vascular endothelial growth factor expression...
pression and a high MIB–1 labeling index—both found to be predictors of recurrence. In another study by Morokoff et al.,21 163 convexity meningiomas were treated over a 19-year period with a remarkably low morbidity profile.

We retrospectively reviewed our experience with supratentorial convexity meningiomas resected during the past 10 years in an effort to characterize this patient population in the modern neurosurgical era, examine the risk profile associated with microsurgical removal, and highlight the technical nuances that optimize patient outcome.

Methods

Patient Population and Outcome Assessment

One hundred forty-one consecutive patients with supratentorial convexity meningiomas treated during the past 10 years were included in this study. These patients were adults (age \( \geq 18 \) years) who had undergone surgery at the University of California, San Francisco, between 1997 and 2007, preoperative and postoperative (< 72 hours after surgery) MR imaging, and at least 1 year of clinical follow-up. Patients with multiple meningiomas, hemangiopericytomas, malignant meningiomas, or tumor-prone syndromes were excluded from our analysis. Magnetic resonance images were reviewed for each patient to confirm the diagnosis of a convexity meningioma, which was defined as a lesion with an attachment located primarily at the convexity dura. Tumors originating from the cranial base, falx, tentorium, and sphenoid wing were excluded, as were all infratentorial tumors. Lesions associated with both the convexity dura as well as a dural sinus were included if > 50% of the attachment was associated with the convexity and the epicenter of the tumor was convexity dura. Central pathology review was performed on the basis of the WHO guidelines.16 Clinical data were collected from patient records and telephone interviews. All clinical assessments were performed by a neurosurgeon. In each case, the extent of resection and Simpson resection grade15,25 were determined using a combination of the surgeon’s assessment and MR imaging. The Committee on Human Research at the University of California, San Francisco, approved this study.

Microsurgical Technique and Perioperative Management

Standard craniotomies overlying the lesion were used in all cases, as was a microsurgical technique using loupe magnification or the operating microscope or a combination of the 2. Intraoperative neuronavigation was used as a matter of routine to minimize the skin incision and craniotomy while attempting a Simpson Grade 0 or 1 resection. In cases in which the dural attachment involved the sinus, a Simpson Grade 2 resection was the operative goal. Preoperative embolization was considered for all large tumors, although often the vascular supply for these larger lesions included pial supply. In general, en bloc resection was not attempted because of tumor size, and instead the meningioma was debulked from within using a Cavitron ultrasonic aspirator (Valleylab) or, more recently, a Sonopet ultrasonic aspirator (Miwatec). Careful attention was paid to identifying and respecting the arachnoid plane at the tumor-brain interface, which facilitates complete resection and minimizes pial vessel injury. Whenever possible, involved dura was resected with a 2-cm circumferential margin, and the dura was closed with either a pericranial graft or the artificial dura substitute. For lesions with bony invasion, the craniectomy site was repaired using a combination of titanium mesh and methylmethacrylate. This composite cranioplasty technique was applied given that the craniectomy defects tended to be large and the resultant construct provided strength in compression and tension.

Intraoperatively, all patients received Decadron (10 mg), mannitol (1 g/kg), and ceftriaxone (1 or 2 g) at the time of incision. After surgery, all patients were cared for in a neurointensive care unit for 1 day before returning to the ward. On postoperative Day 2, a prophylactic dose of enoxaparin (40 mg subcutaneously each day) was initiated in all patients and was continued for 1 week. The routine use of venous thrombosis prophylaxis was not started until after 2001.1 The incidence of postoperative intracranial hemorrhage was no different in the patient groups before or after prophylaxis was begun (data not shown). Regardless of the preoperative seizure history, all patients were also loaded with an antiepileptic agent at the time of surgery (Dilantin initially, Keppra more recently), which was continued for 1 week postoperatively and then discontinued.

Results

Patient and Tumor Characteristics

Of the 141 patients selected for this study, the median age at presentation was 48 years (range 18–95 years; Table 1). Ninety-two patients (65%) were female and 49 (35%) were male. Most patients presented with signs and symptoms attributable to mass effect and the tumor site, including headache (48%), seizure (34%), and hemipare-
Microsurgical removal of convexity meningiomas

**TABLE 2: Lesion characteristics**

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>lt-sided/rt-sided</td>
<td>72:69</td>
</tr>
<tr>
<td>mean vol in cm³ (range)</td>
<td>146.3 (1–512)</td>
</tr>
<tr>
<td>median max tumor dimension in cm</td>
<td>5.2</td>
</tr>
<tr>
<td>tumor location on convexity dura (%)</td>
<td></td>
</tr>
<tr>
<td>anterior</td>
<td>74 (52)</td>
</tr>
<tr>
<td>posterior</td>
<td>15 (11)</td>
</tr>
<tr>
<td>temporal</td>
<td>28 (20)</td>
</tr>
<tr>
<td>median</td>
<td>24 (17)</td>
</tr>
<tr>
<td>WHO tumor grade (%)</td>
<td></td>
</tr>
<tr>
<td>I</td>
<td>106 (75)</td>
</tr>
<tr>
<td>II</td>
<td>35 (25)</td>
</tr>
</tbody>
</table>

sis (21%). Twenty patients (14%) were asymptomatic, but serial MR imaging demonstrated growth > 2 mm in a single calendar year. Thirty-one patients (22%) had undergone previous treatment of their meningiomas, including resection (13 patients [9%]) and stereotactic or whole-brain irradiation (18 patients [13%]).

Sixty-nine tumors (49%) were right-sided and 72 (51%) were left-sided (Table 2). Tumor location corresponded to the relative surface area of the supratentorial dura, with the most common location being along the anterior convexity (74 lesions [52%]), followed by the temporal convexity (28 lesions [20%]), median convexity (24 lesions [17%]), and posterior convexity (15 lesions [11%]). The mean tumor volume was 146.3 cm³ (range 1–512 cm³), and 95% of all tumors had a maximal diameter of at least 3 cm (Fig. 1).

**Microsurgical Outcome and Tumor Recurrence**

One hundred forty-four operations were performed in these 141 patients. Forty-eight patients (34%) underwent preoperative embolization, with the most common embolized vessels being the middle meningeal and superficial temporal arteries. A Simpson Grade 0 or 1 resection was achieved in 122 patients (87%), with a Simpson Grade 2 in the remaining 19 patients (13%; Table 3). All 19 patients with Simpson Grade 2 resections had a portion of their tumor’s dural attachment involved with a dural sinus wall. In these cases, an intrasinus resection 26,27 was not pursued in favor of dural leaflet coagulation along the course of important segments of venous sinuses.

The pathology of these tumors was benign in 106 cases (75%) and atypical in 35 cases (25%). As mentioned above, anaplastic or malignant meningiomas were excluded from this study. The median age of patients with a benign histology was 45 years, whereas the median age of those with an atypical histology was 62 years.

The median clinical follow-up time was 2.9 years (range 1–10 years), and the median radiographic follow-up time was 3.7 years (range 1–10 years). Overall, 135 patients (96%) have demonstrated no clinical or radiographic evidence of recurrence to date. Of the 6 patients (4%) with radiographic recurrence, none were symptomatic and 3 (2%) proceeded to a repeat microsurgical removal after showing evidence of steady lesion growth. All patients with recurrent tumors underwent postoperative stereotactic radiotherapy, and in cases in which the tumor was re-resected, irradiation was delayed until after the second resection. The mean time to recurrence was 11 months (range 7–27 months). All 3 re-resected tumors demonstrated WHO Grade II histology, as they did at the time of the first craniotomy. Overall, no Grade I tumors recurred, whereas 6 (17%) of 35 Grade II tumors recurred according to radiography studies. Five of 6 recurrent meningiomas initially showed a Simpson Grade 2 resection, and 1 a Simpson Grade 3 resection. In each case, this less extensive resection was attributed to direct dural sinus infiltration, precluding a Simpson Grade 0 or 1 resection.

**Morbidity Profile**

No deaths occurred within 30 days of resection, although 5 patients died of unrelated causes in the ensuing years since their operation. There was no incidence of intraoperative complications; however, medical or neurosurgical morbidity was noted in the postoperative course of 14 patients (Table 4)—which was equal to a 10% overall complication rate, with a nearly even distribution of medical and neurosurgical complications. Medical complic-
tions occurred in 6 patients (4.2%) who had a pulmonary embolism requiring anticoagulation (2 patients [1.4%]) or a deep venous thrombosis requiring anticoagulation (6 patients [4.2%]) or both. Surgical complications (8 patients [5.6%]) included CSF leakage (2 patients [1.4%]), epidural hematoma requiring evacuation (2 patients [1.4%]), and wound infection requiring antibiotics (5 patients [3.5%]). Among patients with wound infections, only 2 required reoperation for wound washout; however, in both cases the bone flap was left in place and the patient was successfully treated with an indwelling antibiotic irrigation system. Among all patients, there was no incidence of postoperative myocardial infarction, meningitis, hydrocephalus, new-onset seizures, or new or worsened neurological deficits. There were no significant differences in medical or neurosurgical morbidity rates among anterior, median, posterior, and temporal convexity sites.

**Discussion**

In the modern neurosurgical literature, few reports describe the expected outcome for patients with convexity meningiomas treated using resection. Publications from decades ago, while critical to our understanding of the natural history of convexity meningiomas, do not reflect the surgical and nonsurgical management strategies currently in practice for this patient population. The present study captures a contemporary experience with convexity meningiomas and defines the morbidity profile associated with modern-day practice. Our patient population, most with large or giant meningiomas, reflects a combination of conventional patient selection criteria and the impact of radiosurgery as a treatment option for most patients.

Our findings are directly or indirectly the result of several developments over the past 2 decades in the field of meningioma surgery. Perhaps most notably, the ubiquitous nature of CT and MR imaging has increasingly allowed early detection of convexity meningiomas and easy surveillance of tumor growth and proliferative potential. As a consequence, many convexity meningiomas are diagnosed while they are small and an easy target for radiation therapy. This circumstance, in turn, has altered the composition of patients undergoing resection and thus many tumors subjected to resection are larger than in previous years.

**Table 4: Medical and neurosurgical morbidity**

<table>
<thead>
<tr>
<th>Complication</th>
<th>No. of Patients (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>medical</td>
<td></td>
</tr>
<tr>
<td>deep venous thrombosis</td>
<td>6 (4.2)</td>
</tr>
<tr>
<td>pulmonary embolus</td>
<td>2 (1.4)</td>
</tr>
<tr>
<td>neurosurgical</td>
<td></td>
</tr>
<tr>
<td>CSF leak</td>
<td>2 (1.4)</td>
</tr>
<tr>
<td>postop hematoma</td>
<td>2 (1.4)</td>
</tr>
<tr>
<td>wound infection</td>
<td>5 (3.5)</td>
</tr>
</tbody>
</table>

**Fig. 2.** Images demonstrating microdissection of the tumor-brain interface. The morbidity profile for convexity meningiomas, such as the lateral convexity mass seen in this preoperative axial contrast-enhanced T1-weighted MR image (A), is primarily driven by the extent to which there is meticulous microdissection of the tumor-brain interface. For larger tumors, the arachnoid plane at this interface is often ill-defined, making dissection difficult. Despite achieving a Simpson Grade 0 resection, shown on this postoperative axial contrast-enhanced T1-weighted MR image (B), small pial vessel injury can occur, as demonstrated on this postoperative axial diffusion weighted MR image (C), leading to potential deficits.

Furthermore, the detailed anatomical information provided by routine preoperative MR imaging—and in some cases, angiography—has improved operative outcomes by defining critical vasculature in and around the tumor. This technological edge combined with the routine use of an operative microscope and neuronavigational guidance has changed the face of convexity meningioma surgical outcomes. For example, new-onset postoperative epilepsy, a relatively common phenomenon in prior decades, is now exceedingly rare and was not seen in our study. While this result may, in part, be attributed to the use of perioperative antiepileptic agents, it is also likely a consequence of meticulous microdissection at the tumor–brain arachnoid interface. Failure to respect this plane can lead to small pial vessel injury and neurological deficit (Fig. 2).

Our experience suggests that, when selecting patients on the basis of symptomatology and/or documented growth, the typical convexity meningioma undergoing neurosurgical removal is large and, as a consequence, not infrequently adherent to the pial surface of the brain or a sinus wall in its lateral extensions. Achieving a Simpson Grade 0 or 1 resection in these patients is therefore less likely and may account for the our relatively low rate of...
Simpson Grade 0 or 1 resection (87%) as compared with that in a recently published study of 163 convexity meningiomas, one-fifth of which were incidentally diagnosed. In that study, the “vast majority” of patients had undergone a Simpson Grade 1 resection, which we assume implies > 90% resection.\(^{21}\) Although operating on incidental meningiomas in the absence of documented growth remains controversial, our understanding of meningioma natural history suggests that 63% will not progress in size and 94% will remain asymptomatic in the first several years of clinical and radiographic follow-up.\(^{34}\) Therefore, therapeutic intervention of any type, whether radiosurgery or microsurgery, can safely be withheld pending documented growth or development of symptoms specific to the tumor site. This recommendation is especially true for small meningiomas, but when a patient presents with a large meningioma, issues related to his or her current age, life expectancy, anesthetic risks, and the probability of tumor growth for noncalcified tumors, all of these factors enter into the equation when deciding on a course of management.

Convexity meningioma recurrence happens almost exclusively among atypical and malignant histologies. Morokoff et al.\(^{21}\) have described a 1.8% 5-year recurrence rate for WHO Grade I histology, 27.2% for Grade II, and 50% for Grade III, assuming an equal extent of resection for each subgroup. Comparatively, our 0% rate of recurrence for Grade I tumors and 17% recurrence rate for Grade II lesions are within range of reported results, considering our relatively shorter clinical and radiographic follow-up intervals. Moreover, given our high rate of Simpson Grade 0 resections of WHO Grade I tumors, it remains possible that patients with these lesions will have a recurrence rate lower than the reported 1.8%.

For larger convexity meningiomas, one technical nuance that can facilitate resection in cases of significant mass effect is decompressing the tumor internally prior to a complete dural opening (Fig. 3). In these cases, we begin with a cruciate dural opening centered over the tumor, using image guidance to avoid exposing the adjacent cortex. The convexity dura is detached from the underlying tumor by using bipolar electrocautery and scissors. A combination of sharp dissection and ultrasonic aspiration is then used to internally debulk the tumor. Once adequate decompression is achieved, dural opening is completed and the brain-tumor interface is easily dissected without the risk of normal tissue damage from mass effect.

When the tumor densely adheres to the dura and cranium, another option is to perform a central craniectomy prior to the craniotomy (Fig. 4). With this approach, neuronavigation is used to drill a trough circumferentially around the dural attachment. A craniotomy is then undertaken, leaving the central bony island attached to the tumor during the course of the dissection. Following the resection, the bone flap is reconstructed using a combination of titanium mesh and methylmethacrylate. In our experience, this combined bone flap reconstruction provides the highest level of reinforcement, as it resists both tensile (mesh) and compressive (methylmethacrylate) forces.
Conclusions

In the modern neurosurgical era—when meningiomas are often managed conservatively and radiosurgical treatment is an established alternative—we are seeing a predominance of large or giant convexity meningiomas treated with resection. It remains our practice that incidentally discovered meningiomas are monitored with serial imaging and resected only when they are symptomatic or growing, regardless of their size. Our data suggest that the current morbidity profile for these convexity meningiomas includes a 10% overall complication rate and at least a 4% recurrence rate over nearly 4 years. Many of the previously reported neurological morbidities, such as new-onset postoperative epilepsy, have all but disappeared in current practice.

Disclaimer

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

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References


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