In 1957, Simpson published a seminal paper defining the risk factors for recurrence following surgical treatment of intracranial meningiomas. Given that Simpson’s study was published more than 50 years ago, preceding image guidance technology and MR imaging, the authors reviewed their own experience with surgical treatment of Grade I meningiomas to determine if Simpson’s grading scale is still relevant to modern neurosurgical practice.

Methods. From this cohort, the authors evaluated all patients undergoing craniotomy for resection of a histologically proven WHO Grade I meningioma as their initial therapy. Clinical information was retrospectively reconstructed using patient medical records and radiological data. Recurrence analysis was performed using the Kaplan-Meier method.

Results. The 5-year recurrence/progression-free survival for all patients receiving a Simpson Grade I, II, III, or IV resection was 95, 85, 88, and 81%, respectively (p = not significant, log-rank test). Kaplan-Meier analysis revealed no significant difference in recurrence-free survival between patients receiving a Simpson Grade I, II, III, or IV resection. Analysis limited to meningiomas arising from the skull base (excluding the cavernous sinus) similarly found no significant benefit to Simpson Grade I or II resection, and the survival curves were nearly superimposed.

Conclusions. In this study of a cohort of patients undergoing surgery for WHO Grade I meningiomas, the authors demonstrate that the benefit of more aggressive attempts to resect the tumor with dura and underlying bone was negligible compared with simply removing the entire tumor, or even leaving small amounts of tumor attached to critical structures. The authors believe that these data reflect an evolution in the nature of meningioma surgery over the past 2 decades, and bring into question the relevance of using Simpson’s grading system as the sole predictor of recurrence. (DOI: 10.3171/2010.3.JNS091971)

Key Words. meningioma • Simpson grade • resection • recurrent meningioma

In 1957, Simpson published a seminal paper defining the risk factors for recurrence following surgical treatment of intracranial meningiomas. In doing so, he established the neurosurgical dogma that cure of meningiomas could only be ensured by aggressive removal of not only the tumor in its entirety, but also the involved dura and debridement of the underlying involved bone. A large number of subsequent efforts have been aimed at validating the principle that clinical success in meningioma surgery is equivalent to removal down to the involved bone, with recurrence being the consequence of failing to achieve this extent of resection.

Needless to say, a great many things about the practice of neurosurgery have changed since 1957. Not only does Simpson’s grading system for resection predate the introduction of the operative microscope and microsurgical techniques, but the last 2 decades have seen a great number of additional advances that facilitate meningioma removal. Magnetic resonance imaging technology has improved dramatically, facilitating ever-improving image guidance technology, which has become a routine part of brain tumor operations, allowing for a measure of objective assessment of the extent of tumor resection. Removal tools such as the CUSA (Integra LifeSciences) and Sonopet (Miwatec), and improved bipolar electrocauteries make removal of firm and adherent tumor much easier and safer than in previous years. Microscope technology has continued to improve, allowing better visualization of the planes between tumor and normal structures, and in some cases allowing a greater extent of resec-

Abbreviations used in this paper: CUSA = Cavitron Ultrasonic Aspirator; UCSF = University of California, San Francisco.
tion than previously was feasible. Few would argue that these advances have had a trivial impact on meningioma surgery, especially in difficult-to-access locations at the skull base.\textsuperscript{3}

Furthermore, the clinical significance of meningioma recurrence is markedly different in 2009 than it was in the 1950s, 1960s, and 1970s. Stereotactic radiosurgery has been repeatedly demonstrated to be a safe and effective treatment for control of small asymptomatic meningiomas.\textsuperscript{7,9,10} Given the wide availability of MR imaging technology, many recurrences of Grade I meningioma are detected as small increases in tumor size between imaging studies and can be effectively managed with stereotactic radiosurgery.\textsuperscript{7,9,10} Given that Simpson's study was published more than 50 years ago and many key confirmatory studies are case series of patients undergoing surgery in the decades preceding image guidance technology\textsuperscript{8,25} as well as other more recent innovations, we reviewed our own experience with surgical treatment of Grade I meningiomas to determine if Simpson's grading scale is still relevant to modern neurosurgical practice.

**Methods**

**Patient Population**

All patients undergoing neurosurgical intervention at UCSF are prospectively enrolled in a database. Using this database, we identified all patients between 1991 and 2008 who underwent evaluation and treatment for meningioma at our institution. From this cohort, we retrospectively evaluated all patients undergoing craniotomy for resection of a histologically proven WHO Grade I meningioma as their initial therapy. We excluded all patients with any other intracranial tumor history, or eventual histological diagnoses of Grade II or III meningioma or hemangiopericytoma at the time of recurrence. We excluded all patients whose initial surgery at UCSF was for a recurrent meningioma, or who had previously undergone stereotactic radiosurgery for their tumor. We excluded all patients with neurofibromatosis Type 2. We also excluded all patients in whom the tumor involved the cavernous sinus in whole or part given that we do not attempt gross-total resections for these lesions at our institution. This study was approved by the UCSF Committee on Human Research under the approval number H7828–29842–03.

**Microsurgical Technique and Perioperative Management**

Preoperative evaluation of all patients included T1- and T2-weighted MR imaging with and without contrast. Use of contrast allows visualization of the extent of tumor, while T2-weighted images may display the arachnoid layer around the tumor and adjacent brain edema, the latter giving some indication of adhesion to the surrounding parenchyma. Preoperative embolization was performed for larger tumors based on the discretion of the treating surgeon, and when the supplying vessels were accessible for intravascular occlusion using polyvinyl alcohol particles. The goal of preoperative embolization was to reduce tumor vascularity and intraoperative blood loss. Surgery was only performed under the benefits of general anesthesia and endotracheal intubation. All surgeries performed after 1993 benefitted from the use of surgical navigation systems of a variety of types and manufacturers, while those performed earlier relied on the use of a larger craniotomy as was the standard for that time. A standard microsurgical technique was used. When necessary, tumors were debulked with use of the CUSA and or the Sonopet (Miwatec). On completion of the tumor debulking and/or removal, the bone flap was replaced and the scalp was reapproximated. When appropriate, tumor-involved bone was removed, and cranioplasty was done with titanium mesh and/or methylmethacrylate.

Intraoperatively, all patients received Decadron (10 mg), mannitol (1 g/kg), and ceftriaxone (1 or 2 g) at the time of incision. Postoperatively, all patients were cared for in a neurointensive care unit for 1 day before returning to the ward. Patients routinely underwent postoperative MR imaging with contrast prior to discharge from the hospital. The duration and intervals of follow-up were variable and were based on the discretion of the treating surgeon. Patients with known residual tumor or documented tumor growth were typically further investigated with annual MR imaging for several years postoperatively.

**Data Collection and Analysis**

Clinical information was retrospectively reconstructed using patient medical records, radiological data, and pathological specimens from UCSF and outside medical facilities. All clinical assessments were performed by a neurosurgeon. The preoperative, postcontrast T1-weighted MR imaging study was reviewed to confirm tumor location. Central pathology review was performed on the basis of the WHO II guidelines.

In each case, extent of resection was analyzed using the Simpson Grading scale (Table 1). This information was obtained from the surgeon’s assessment found in the operative note. In most cases, the Simpson grade was stated in the operative report. When not specifically stated, the details of the operative report were analyzed, and if clear from the report, a Simpson grade was assigned. If not, the patient was excluded from further analysis. The Simpson grade was cross-checked against the results of the postoperative MR imaging study and if residual disease was detected, the Simpson grade was corrected to Grade IV. Recurrences were found using yearly MR imaging with follow-up defined as the date of the last imaging study and were defined as any change in the size of the enhancement, which is limited by the resolution of current MR imaging at our institution. Recurrence/progression was defined as documented significant growth of the tumor noted on follow-up imaging. Patients undergoing immediate postoperative treatment with stereotactic radiosurgery for residual disease were excluded from further analysis.

Outcomes were subanalyzed according to the principal point of tumor attachment. All data were compiled onto an electronic database and cross-checked for accuracy before being subject to any statistical analysis.

**Statistical Analysis**

Recurrence analysis was performed using the Kap-
Simpson grade and meningioma outcome

TABLE 1: Classification of extent of meningioma resection based on the Simpson classification

<table>
<thead>
<tr>
<th>Simpson Grade</th>
<th>Definition</th>
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<tbody>
<tr>
<td>I</td>
<td>macroscopically complete tumor resection w/ removal of affected dura &amp; underlying bone</td>
</tr>
<tr>
<td>II</td>
<td>macroscopically complete tumor resection w/ coagulation of affected dura only</td>
</tr>
<tr>
<td>III</td>
<td>macroscopically complete tumor resection w/o removal of affected dura or underlying bone</td>
</tr>
<tr>
<td>IV</td>
<td>subtotal tumor resection</td>
</tr>
<tr>
<td>V</td>
<td>decompression w/o or w/ biopsy</td>
</tr>
</tbody>
</table>

Patient Demographics

Between 1991 and 2008, 879 patients underwent first-time craniotomy for meningioma at UCSF. A total of 373 patients meeting inclusion criteria underwent an initial resection for WHO Grade I meningioma at UCSF with the Simpson grade clearly delineated in the operative report. Demographic characteristics of these patients can be seen in Table 2. There was no significant difference between mean age, sex distribution, or frequency of preoperative embolization between patients undergoing Simpson Grades I, II, III, and IV resections.

Skull base meningiomas were overrepresented in this cohort, and convexity meningiomas were underrepresented, largely due to more detailed operative reports in the skull base cases. As expected, a much smaller percentage of skull base tumors were resected with Simpson Grade I or II resections than tumors of the convexity or falx. Gross-total resections (Simpson Grade I, II, or III) were achieved in 70% of cases.

The Relationship Between Simpson Grade and Recurrence After Resection of WHO Grade I Meningiomas

The median length of follow-up for all patients was 3.7 years and ranged from 6 months to 18 years. The length of follow-up did not differ significantly between different tumor locations or different Simpson grades.

The 5-year recurrence/progression-free survival for all patients receiving Simpson Grades I, II, III, and IV resections was 95, 85, 88, and 81%, respectively (p = not significant, chi-square test). Kaplan-Meier analysis revealed no significant difference in recurrence-free survival between patients undergoing a Simpson Grade I, II, III, or IV resection (Fig. 1 upper). Another subgroup analysis (126 patients: Simpson Grade I [24 patients], Grade II [37 patients], Grade III [19 patients], and Grade IV [46 patients]) limited to patients with more than 4 years of follow-up similarly demonstrated no difference in recurrence-free survival (p = not significant, log-rank test) (Fig. 1 lower). We did not observe any recurrences in patients with more than 8 years of follow-up without prior recurrence (33 patients: Simpson Grade I [6 patients], Grade II [3 patients], Grade III [9 patients], and Grade IV [15 patients]).

Kaplan-Meier analysis for recurrence-free survival limited to convexity meningiomas demonstrated no significant beneficial effect of more aggressive resections, although subjectively subtotal resections (Simpson Grade IV) seemed to have a higher recurrence rate (Fig. 2A). Similarly, analysis limited to falx/parasagittal meningiomas demonstrated no significant beneficial effect of more aggressive resections, although subjectively subtotal resections (Simpson Grade IV) seemed to have a higher recurrence rate. Interestingly, there were no recurrences noted in Simpson Grade I or III meningiomas (Fig. 2B).

Analysis limited to meningiomas arising from the skull base (excluding cavernous sinus) similarly found no significant benefit to Simpson Grade I or II resection, and the survival curves were nearly superimposed (Fig. 2C).

The Effect of Embolization on Recurrence of Subtotally Resected Meningiomas

To study the possibility that our frequent use of preoperative embolization might have impacted the rates of meningioma recurrence in our series, we repeated our analysis with patients undergoing preoperative embolization (266 patients: Simpson Grade I [62 patients], Grade II [75 patients], Grade III [46 patients], and Grade IV [83 patients]). Limiting this analysis to the patients with more than 4 years of postoperative follow-up did not lead to statistical significance (Fig. 3). While no statistically significant between-group differences were noted in either analysis, a suggestion of worsened tumor control rates was noted in patients with Simpson Grade IV resection who did not undergo preoperative embolization, suggesting the possibility of a minor beneficial effect of embolization, which our analysis was not powered to detect.

Discussion

It has been taught for many decades that successful...
surgical treatment of meningiomas requires complete removal of the gross tumor bulk, resection of all affected dura, and debridement of the affected underlying bone. While first elucidated by Simpson in 1957, subsequent series have echoed the importance of removing tissue down to the affected hyperostotic bone. Many subsequent series have reached similar conclusions; however, these studies largely or partially analyzed tumor control in patients undergoing surgery prior to the 1990s, a decade that saw the introduction of many innovations central to the way we perform meningioma surgery today.

For example, in a series of patients undergoing surgery in the 1960s and 1970s, Jääskeläinen demonstrated that recurrence rates in patients with gross totally resected meningiomas were as high as 34–56% if bony invasion and soft-tumor consistency were present. Similarly, in a cohort undergoing surgery in the 1970s and 1980s, Stafford...
Simpson grade and meningioma outcome

![Graph](image)

**Fig. 3.** Kaplan-Meier analysis depicting recurrence-free survival in patients undergoing surgery without preoperative embolization.

and colleagues\(^2\) demonstrated that recurrence rates with subtotal resection were as high as 39% at 5 years and 61% at 10 years. These recurrence rates clearly exceed those we observed in our cohort. There are few studies that have specifically focused on recurrence rates in patients undergoing surgery in the past 20 years.\(^6\) Perhaps the most notable such study was reported by Pollock and colleagues,\(^2\) who reported on a cohort of patients undergoing surgery between 1990 and 1997. They observed very high tumor control rates with Simpson Grade I resection (96%), with tumor control rates approximating our rates for Grade II resections (82%). Their recurrence rates for patients undergoing Grades III and IV resections were significantly higher than those reported by Simpson for similar rates of resection, with 66% of patients demonstrating tumor recurrence within 7 years of surgery. However, it should be noted that the conclusions drawn in this combined gross-total and subtotal resection group were based on 12 patients, compared with 171 patients with this extent of resection in the present study.

In this study of a cohort of patients undergoing surgery for Grade I meningiomas with the benefits of current technological advancements such as image guidance, preoperative embolization,\(^6\) improved preoperative imaging, improved microscopic visualization, and improved tools for tumor removal,\(^2\) we demonstrated that the benefit of more aggressive attempts to resect the tumor with dura and underlying bone was negligible compared with simply removing the entire tumor, or even leaving small amounts of tumor attached to critical structures. There are many potential explanations why our results differ from those reported by other groups. We believe that these data in part reflect an evolution in the nature of residual meningiomas over the past 2 decades. Almost certainly, the biology of Grade I meningiomas has changed little during this period; however, our ability to achieve increasingly aggressive degrees of tumor resection likely has altered significantly, making the distinction between Grades I and IV less relevant than in previous periods. While “subtotal resection” 30 years ago might have implied fairly significant tumor remnants left behind, the tumor remnants in our Simpson Grade IV resections generally were small portions of tumors that were adherent to critical structures such as vessels and cranial nerves. Furthermore, with image guidance technology, it is likely that we mistakenly leave behind fewer significant tumor portions than our predecessors did, meaning a larger percentage of our Simpson Grade III resections are true gross-total resections than those in years past. Also, with the combination of preoperative endovascular embolization and improved technique,\(^6\) it is possible that many of the small adherent tumor remnants that are intentionally left behind are devascularized and may go on to completely or partially infarct and involute. A suggestion of minor improvement in tumor control in patients receiving Grade IV resections after embolization supports this concept.

Additionally, it is important to note that the WHO grading criteria for meningiomas have changed in the past decade, largely expanding the fraction of tumors that qualify as higher grade tumors.\(^2\) Given our use of the new grading criteria in this study, and that the Grade I tumors we operated on in this series likely differ from even fairly recent studies, these tumors are less likely as a group to recur than Grade I tumors in previous eras. Histopathology and immunohistochemistry have improved in parallel throughout this period, meaning we are more likely to correctly identify higher grade neoplasms\(^2\) and exclude them from this analysis of benign meningiomas. Taken together, we believe these data suggest that the Simpson grading scale does not accurately predict the risk of early recurrence in current neurosurgical practice.

It is important to note that Simpson’s and similar studies demonstrating a benefit to bony and dural resection were performed during a period that predated modern skull base surgery, and thus this grading scale was largely used to judge recurrence rates for convexity and falcaline meningiomas.\(^2\) As practices have changed, skull base meningiomas have begun to make up a significant portion of our practice over the past 20 years. In general, bony and dural resection is much more straightforward for lesions arising from or near the calvaria than it is for lesions at the cranial base.\(^2\) Thus, while obtaining a Simpson Grade I resection of a convexity meningioma involves removal of hyperostotic bone from the bone flap and sewing in a dural patch for skull base lesions,\(^2\) this often involves drilling out the dura and bone of the skull base, with risk of nerve injury and a significant risk of complex CSF leaks. Furthermore, it is much more difficult to ensure that all hyperostotic bone and involved dura is removed in these deep and often complex resection spaces. Many have questioned the predictive value for the Simpson scale at the skull base.\(^2\) While our data suggested a small but nonsignificant benefit for aggressive resections of convexity tumors, there was no suggestion of improved outcomes for better Simpson grade resections of skull base tumors. This supports the contention that newer methods for preoperatively and postoperatively grading these lesions that are site specific and based on anatomical features of the tumor are probably needed.\(^2\) Thus, while we still believe the goal of surgery should be...
to remove as much tumor as possible, we would discourage overly heroic efforts to remove all potentially affected areas of bone and dura, simply to achieve a higher Simpson grade of resection.

There are limitations to our study that should be acknowledged. Most notably, because we desired to study outcomes in the most recent era of neurosurgery, our follow-up length is by necessity shorter than previous studies on this topic that examined older data sets. Many patients underwent surgery in the last decade, and while they do not seem to have a high rate of recurrence at 5 years, we have less data at 10 years. This is an unavoidable tradeoff in a study that seeks to outline outcomes obtained using our most up-to-date surgical techniques. Furthermore, this is a retrospective study and subject to all the limitations of data collection inherent in such studies.

Conclusions

Despite the aforementioned limitations, we have shown that patients undergoing Simpson Grades III and IV resections using modern, state-of-the-art techniques, achieve rates of recurrence similar to patients who have more aggressive debridement of bone and affected dura. While our length of follow-up is by necessity less than that in other studies of this type, it should be noted that the recurrence rates at 5 years in our cohort are low regardless of the degree of resection. Given the widespread access to high-quality neuroimaging and the excellent rates of tumor control reported for stereotactic radiosurgery for Grade I meningiomas, it is likely that small asymptomatic recurrences can be followed with serial imaging and treated with radiosurgery to control tumors that demonstrate growth on imaging. Thus, while our study cannot definitively rule out a benefit to bony resection, the benefit of the addition of bony resection over gross-total resection of the soft-tissue component alone is in all likelihood very modest. Thus, in cases in which a Simpson Grade II resection is easily obtained, it might be beneficial to do so. However, in cases in which even a remote risk of injury to the patient would be necessary to drill out the hyperostosis and dura in an area where there is an increased risk of neurological or vascular injury, or CSF leak, it hardly seems justified to subject them to this risk to improve the rate of recurrence by a few percent, especially in the era of radiosurgery. Further work is necessary to identify better predictors of recurrence as this prognostication is important for determining plans for follow-up or adjuvant radiosurgery or radiotherapy.

Disclosure

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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Author contributions to the study and manuscript preparation include the following. Conception and design: AT Parsa, ME Sughrue, M McDermott. Acquisition of data: ME Sughrue, AJ Kane, G Shangari. Analysis and interpretation of data: AT Parsa, ME Sughrue. Drafting the article: ME Sughrue, AJ Kane, MJ Rutkowski. Critically revising the article: AT Parsa, ME Sughrue, AJ Kane, MJ Rutkowski, M McDermott, MS Berger. Reviewed final version of the manuscript and approved it for submission: all authors. Statistical analysis: ME Sughrue. Study supervision: AT Parsa, ME Sughrue, MS Berger.

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