Predictors of Visual Outcome Following Surgical Resection of Medial Sphenoid Wing Meningiomas

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Abstract

Objective Medial sphenoid wing meningiomas (SWMs) are relatively common tumors that are associated with significant morbidity and mortality, primarily from their anatomic proximity to many critical neurological and vascular structures. A major complication is visual deterioration. This study aimed to identify predictors of visual outcome following medial SWM resection.

Design Retrospective, stepwise multivariate proportional hazards regression analysis.

Setting Johns Hopkins Hospital.

Participants All patients who underwent medial SWM resection from 1998 to 2009.

Main Outcome Measures Visual function.

Results Sixty-five medial SWM resections were performed. After multivariate proportional hazards regression analysis, preoperative visual decline (relative risk [RR] 95% confidence interval [CI]; 13.431 [2.601 to 46.077], $p = 0.006$), subtotal resection (RR [95% CI]; 3.717 [1.204 to 13.889], $p = 0.02$), and repeat surgery (RR [95% CI]; 5.681 [1.278 to 19.802], $p = 0.03$) were found to be independent predictors of visual decline at last follow-up. Tumor recurrence and postoperative radiation therapy trended toward, but did not reach statistical significance.

Conclusion These findings advocate for early and aggressive surgical intervention for patients with medial SWMs to maximize the likelihood of subsequent visual preservation. This may provide patients and physicians with prognostic information that may guide medical and surgical therapy for patients with medial SWMs.

Keywords
- sphenoid wing
- meningioma
- vision loss
- risk factors
- outcomes

Introduction

Meningiomas are relatively common neoplasms that arise from arachnoid cap cells and account for ~20% of all primary intracranial tumors.[1–3] Eighteen percent of meningiomas occur along the sphenoid wing,[4] placing them at a complex anatomical location among critical neurological and vascular structures, including the optic nerve, cavernous sinus, and internal carotid and middle cerebral arteries (►**Fig. 1**).[5–9] Consequently, these tumors are responsible for a great deal of morbidity and mortality, including but not limited to headache, loss of vision, ischemic attacks, and diplopia from paresis of one or more extraocular muscles.[9–13]

Cushing and Eisenhardt first described the surgical resection of sphenoid wing meningiomas (SWMs) in 1938.[4] Since then, different surgical approaches have been devised to access the sphenoid wing, such as a frontotemporal/pterional,[14–16] frontotemporal-orbitozygomatic,[8,14,17] and

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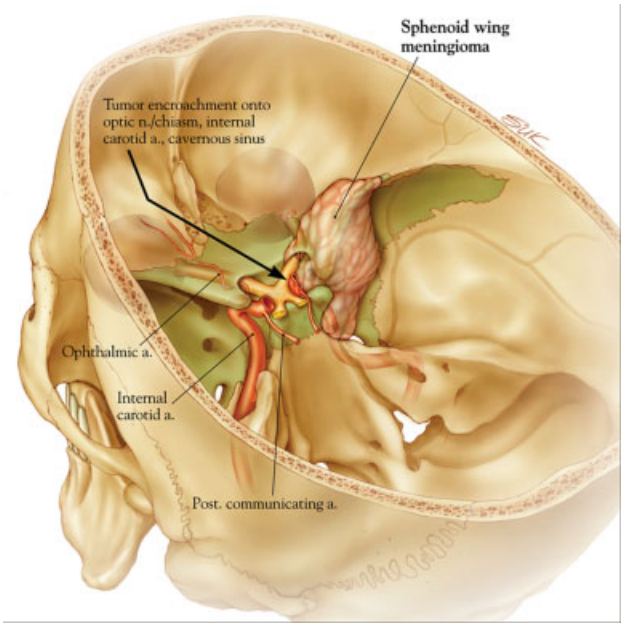

Figure 1 Illustration demonstrating a representative sphenoid wing meningioma with involvement of the optic nerve, as well as the cavernous sinus and internal carotid artery.

supraorbital-pterional approach,[18] among others. In spite of these developments, as well as advancements in neuroimaging and microsurgical techniques, surgical morbidity and mortality remain unacceptably high.[4,11,19–21] Vision loss is arguably one of the most feared sources of morbidity.[22–28] Vision loss has been reported to occur in 20 to 35% of cases in some series.[22–26] Prior studies evaluating risk factors for vision loss are sparse and limited by their small numbers, failure to create uniform patient populations, and lack of multivariate analyses to ascertain independent associations.

This study was designed to explore risk factors for visual decline in patients undergoing medial SWM resection. Medial SWMs, unlike their more lateral counterparts, have a different risk prolife based on their anatomic location.[5–9] One of these risks is injury to the optic nerve and subsequent visual decline. Understanding the factors associated with visual decline may promote the development of new therapeutic and surgical strategies, as well as aid in clinical decision making. Consequently, these SWMs are responsible for a great deal of morbidity and mortality, including but not limited to headaches, loss of vision, ischemic attacks, and diplopia from involvement of one or more of the ocular motor nerves.

Methods

Patient Selection

We retrospectively reviewed the medical records of all patients who underwent surgery for SWMs at the Johns Hopkins Hospital between 1998 and 2009. Study approval was obtained from the Johns Hopkins Medicine Institutional Review Board (#5299). Information collected included patient demographics, comorbidities, medications, presenting symptoms, preoperative magnetic resonance imaging (MRI) and computed tomographic (CT) findings, intraoperative pathologic findings, and postoperative neurological function. For MRI and CT assessment, tumor involvement was defined as tumor displacement, encasement, or invasion of local neurological or vascular structures. Only lesions originating from the medial sphenoid wing were included in the study. Medial sphenoid wing involvement was defined as tumor originating from the medial third of the sphenoid wing, or clinoid process. Meningiomas originating on the lateral aspect of the sphenoid wing, tuberculum sellae, diaphragma sellae, and/or planum sphenoidale were excluded from analysis. Comprehensive ophthalmologic exams were recorded at the time of diagnosis, immediately preoperatively, immediately following surgical resection, and at last follow-up by an independent neuro-ophthalmologist.

Visual Acuity

To minimize observer bias and errors associated with retrospective patient classification, the patient's visual acuity at last follow-up was used as the simplified outcome measure by an independent neuro-ophthalmologist. This basic functional measurement was uniformly included in all clinical documentation because it has been demonstrated to be a critical quality-of-life indicator.[29] For the purpose of this study, decreased visual acuity was defined as a worsening by two or more lines of Snellen acuity or a change from 20/400 to counting fingers, counting fingers to hand movements, hand movements to light perception (LP), or LP to no light perception (NLP).[26] Improved visual acuity, conversely, was defined as improving by two or more lines of Snellen acuity or a change from NLP to LP, LP to hand movements, hand movements to counting fingers, or counting fingers to 20/400.[26] Visual preservation was defined as a maintenance or improvement of visual acuity at last follow-up. Other variables known to affect outcome following SWM resection were also recorded in the dataset.

Statistical Analysis

Univariate analysis (JMP 9, SAS Institute, Carey, NC, USA) was first performed to evaluate associations between radiographic, preoperative, operative, and pathologic variables with postoperative visual preservation at last follow-up. All variables associated with postoperative visual preservation ($p < 0.10$) in univariate analysis were then included in a stepwise multivariate proportional hazards regression model (JMP 9). Summary data were presented as mean ± standard deviation for parametric data and as median [interquartile range (IQR)] for nonparametric data; $p < 0.05$ in all analyses were considered statistically significant.

Results

Patient Characteristics

The cohort summary data are outlined in ►**Table 1**. A total of 65 patients underwent medial SWM resection during the reviewed period. The mean age at presentation was 55.7 ± 13.0 years. In addition, 46 (71%) were female,

Table 1 Summary of Characteristics in 81 Patients with Medial Sphenoid Wing Meningiomas

Characteristics	No. of Patients (%)
Age (mean ± standard deviation)	55.7 ± 13.0
Female	46 (71%)
Comorbidities	
Smoker	18 (28%)
Hypertension	23 (35%)
Coronary artery disease	12 (18%)
Diabetes mellitus	5 (8%)
Presenting symptoms	
Headache	32 (49%)
Visual deterioration	36 (55%)
Double vision	3 (5%)
Proptosis	9 (14%)
Eye swelling	3 (5%)
Facial pain	9 (14%)
Seizure	14 (22%)
Mental disturbance	12 (19%)
Prior treatment	
Prior resection	6 (9%)
Radiation treatment	3 (5%)
Radiographic involvement	
Optic nerve	24 (40%)
Cavernous sinus	21 (32%)
Extracavernous ICA	17 (26%)
MCA	23 (35%)
ACA	8 (12%)
Orbital bone/optic canal	10 (15%)
Cyst	13 (20%)
Edema	30 (46%)
Hyperostosis	18 (28%)
En plaque	4 (6%)
Pathology	
WHO grade I	62 (95%)
Atypical (WHO grade II)	3 (5%)
WHO grade III	0 (0%)

ACA, anterior cerebral artery; ICA, internal carotid artery; MCA, middle cerebral artery; WHO, World Health Organization.

18 (28%) were smokers, 12 (18%) had a history of coronary artery disease, 23 (35%) were on medication for hypertension, and 5 (8%) had diabetes. The median (IQR) duration of symptoms prior to diagnosis was 7 (3 to 21) months. The most common symptoms at the time of diagnosis were headache (49%) and visual decline (55%). Other symptoms included double vision (5%), proptosis (14%), eye swelling (5%), facial pain (14%), mental status changes (19%), and seizure (22%). Of the 65 patients in this series, six (9%) had undergone prior SWM resection and three (5%) had undergone prior radiation therapy.

The average size of the tumor as determined by neuroimaging was 3.4 ± 1.6 cm. A representative example is demonstrated in ►**Figs. 1** and **2**. There was evidence of neurological and vascular involvement in many patients: 24 (40%) involved the optic nerve, 21 (32%) the cavernous sinus; 17 (26%) the extracavernous internal carotid artery (ICA), 23 (35%) the middle cerebral artery (MCA), and eight (12%) the anterior cerebral artery (ACA). There were 13 (20%) cases with associated cysts, 30 (46%) with adjacent brain edema, 18 (28%) with hyperostosis, and four (6%) with an en plaque component. Pathologically, 62 (95%) were World Health Organization (WHO) grade I, three (5%) were atypical (WHO grade II), and none (0%) were WHO grade III.

Outcome

The outcomes following SWM resection are outlined in ►**Table 2**. Forty-two (65%) patients were considered to have had a gross total resection. There were no perioperative mortalities. Two (3%) developed increased weakness from an MCA distribution infarct. There were no cases of cerebrospinal fluid (CSF) leakage, meningitis, abnormal cerebral swelling and edema, hydrocephalus, wound dehiscence, and/or infection.

The median follow-up time after resection was 15.9 (7.1 to 41.3) months. Local recurrence occurred in nine (14%) patients at a median interval of 37.4 (17.3 to 52.2) months. Eight (12%) patients received postoperative radiation therapy. At last follow-up, 14 (22%) patients had decreased visual acuity compared with their preoperative status, five (8%) had improved, and 46 (71%) were stable. Twelve (33%) of the 36 patients who had documented visual deficits preoperatively had progressive loss of visual acuity in the postoperative period. Of the 14 patients with postoperative visual decline, six (43%) experienced perioperative visual decline (<1 month of surgery), and eight (57%) experienced delayed visual decline (>1 month from surgery). The patients with delayed visual decline experienced visual deterioration at a median (IQR) of 17.9 (3.7 to 38.2) months.

Predictors of Postoperative Visual Acuity Preservation

Univariate associations ($p < 0.1$) with postoperative decline of visual acuity included male gender, smoker, preoperative visual decline, proptosis, cavernous sinus involvement, optic nerve encasement, subtotal resection, recurrence, repeat surgery, and postoperative radiation therapy. No other clinical, imaging, operative, or pathologic variables were found to be associated with postoperative visual changes in this dataset.

In the multivariate model, only preoperative visual decline (RR [95% CI]; 13.431 [2.601 to 46.077], $p = 0.006$), subtotal resection (RR [95% CI]; 3.717 [1.204 to 13.889], $p = 0.02$), and repeat surgery (RR [95% CI]; 5.681 [1.278 to 19.802], $p = 0.03$) were found to be associated with decreased visual acuity at last follow-up (►**Table 3**). Tumor recurrence (RR [95% CI]; 2.708 [0.805 to 8.257], $p = 0.09$) and postoperative radiation therapy (RR [9%CI]; 2.859 [0.874 to 8.794], $p = 0.10$) trended toward an

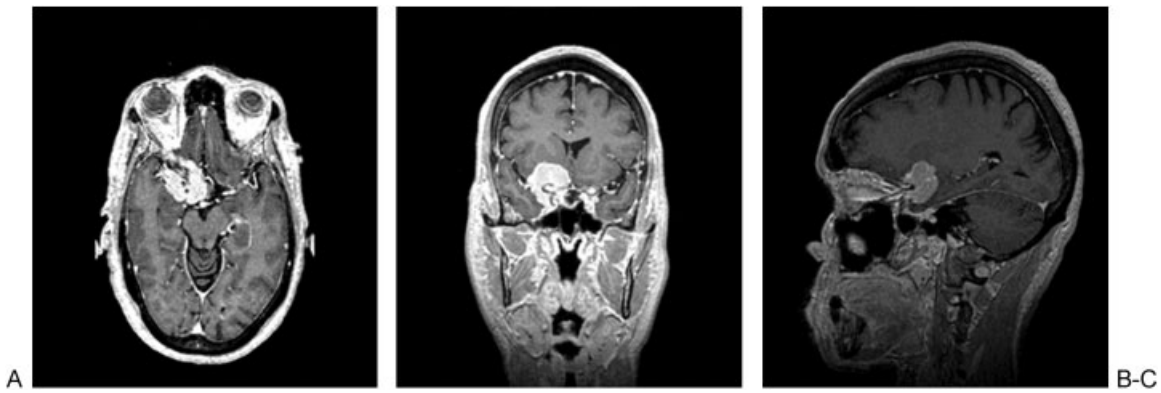

Figure 2 T1-weighed magnetic resonance imaging image with contrast of a patient with a right sphenoid wing meningioma centered about the right anterior clinoid process and enveloping the optic nerve. (A) Axial view. (B) Coronal view. (C) Sagittal view.

Table 2 Summary of Long-Term Operative Outcomes in 65 Patients with Clinoidal Meningiomas

Outcome	No. of Patients (%)
Gross total resection	42 (65%)
Local Recurrence	9 (14%)
Postoperative radiation	8 (12%)
Visual outcome	
Visual deterioration	14 (22%)
Visual improvement	5 (8%)
Visual stabilization	46 (71%)
Visual improvement/stabilization	51 (78%)

Table 3 Statistically Significant Independent Associations between Pre-, Peri-, and Post-Operative Variables with Vision Loss Following Medial Sphenoid Wing Meningioma Resection

	Multivariate Associations	
	Relative Risk (95%CI)	*p* Value
Preoperative variables		
Visual decline	13.431 (2.601–46.077)	0.006
Perioperative variables		
Subtotal resection	3.717 (1.204–13.889)	0.02
Postoperative variables		
Tumor recurrence	2.708 (0.805–8.257)	0.09
Repeat surgery	5.681 (1.278–19.802)	0.03
Radiation therapy	2.859 (0.874–8.794)	0.10

association with visual decline but did not reach statistical significance. In subgroup analysis, there was no significant difference in the extent of resection for patients who presented with and without preoperative visual decline ($p = 0.46$).

Discussion

In this study of 65 patients who underwent surgical resection of a medial SWM, 46 (71%) maintained their preoperative visual acuity, five (8%) had improved vision, and 14 (22%) had worsened vision at last follow-up. In stepwise multivariate analysis, male gender, preoperative visual decline, subtotal resection, and need for repeat surgery were all independently associated with postoperative visual decline. Additionally, tumor recurrence and postoperative radiation therapy trended toward an association with visual decline but did achieve statistical significance. The findings of this study support early surgery for patients with medial SWM before visual decline occurs and also argues for aggressive surgery to minimize the need for repeat surgery, tumor recurrence, and radiation therapy. An understanding of these features may help guide surgical and medical management aimed at maximizing visual outcomes for patients harboring medial SWMs.

Given the close proximity of the sphenoid wing to critical neurological and vascular structures, as well as the tendency of SWMs to invade these critical structures, surgical resection is often associated with significant morbidity and mortality (►**Fig. 1**).[4,11,19–21] One of the major complications is vision loss, which has been reported to occur in 20 to 35% of cases in some series.[22–26,30,31] Most of the studies on vision and meningiomas have been limited to suprasellar meningiomas.[22,30,31] Andrews and Wilson, in a study of 38 patients with suprasellar meningiomas, documented that tumors involving the optic canal and medial sphenoid wing were most commonly associated with postoperative visual deterioration.[22] Wang et al found that tumor recurrence, cerebral edema, and preoperative visual decline were associated with visual outcome in 45 patients with suprasellar meningiomas.[30] Nakamura et al, on the other hand, reported that cavernous sinus involvement was associated with poor outcomes after reviewing 55 patients with medial SWMs.[24] These and other prior studies investigating visual outcome, however, did not perform multivariate analyses, included various types of SWMs, have been limited to suprasellar meningiomas, and/or were limited by small patient numbers.[22–26,32] It remains unclear which patients are at highest risk for developing visual loss following medial SWM resection. Medial SWMs are distinctly different than suprasellar meningiomas.[4,11,19–21]

Preoperative visual decline was found to be independently associated with altered postoperative visual acuity, where

patients with preoperative vision loss were unlikely to have preserved vision. This trend has been described in other studies as well. Al-Mefty et al documented that 24 of 28 patients with clinoidal meningiomas presented with visual disturbances, and only six (25%) improved after surgery.[28] Likewise, Risi et al found that only 32% of 20 patients with preoperative visual decline had maintained/improved vision following surgical resection.[25] The analysis in this study confirms these findings statistically and suggests that early surgical intervention may benefit patients before visual decline starts. This is especially important, as more meningiomas are being discovered incidentally with the widespread availability of neuroimaging.[33]

Extent of resection in this study was also associated with postoperative visual function. If a tumor was subtotally resected, there was nearly a fourfold increased risk of visual decline at last follow-up. Likewise, need for repeat resection was also independently associated with visual decline at last follow-up. Repeat surgery was associated with a near sixfold increased risk of visual decline. Repeat surgery makes it more difficult to achieve safe resection because of increased scarring, loss of arachnoid planes, and a more fibrous tumor.[34,35] These features emphasize the importance of radical resection at the time of the first surgery to minimize the chance of residual tumor, which has an increased propensity to recur.[34–36] This recurrence is inherently more difficult to resect.[34–36] This difficulty may play a role in predisposing patients to visual decline. Interestingly, an association between tumor recurrence and postoperative radiation with decreased visual acuity trended toward significance. These findings further support the importance of radical resection at the first time of surgery to minimize residual tumor, propensity for recurrence, and need for repeat surgery or radiation therapy.

Strength and Limitations

We believe this study provides several useful insights. First, studies ascertaining factors associated with visual outcome for patients with medial SWMs are few and limited. The majority of prior studies have included meningiomas from diffuse locations (lateral sphenoid wing, suprasellar, planum, etc.), which makes it difficult to assess outcomes for patients with medial SWMs. Second, this study not only confirms the importance of preoperative visual function, but also adds the importance of extent of resection, repeat surgery, and possibly tumor recurrence and radiation therapy to postoperative visual function. Lastly, the findings of this study may provide useful information that may help guide treatment strategies aimed at preserving and possibly improving vision for patients with medial SWMs.

This study, however, has some limitations. One of these limitations is its retrospective design, and, as a result, no direct causal relationships can be inferred from these data. Additionally, although our study is the largest of its kind, a study with a larger patient population may be able to more definitively identify factors associated with visual outcome. Moreover, it is hard to discern the true reasons behind tumors that were subtotally resected. It seems intuitive that tumors were subtotally resected when they could not be separated from eloquent structures. These tumors might behave more aggressively by invading and infiltrating surrounding tissue, but this was not examined in this study. Lastly, the surgical approach was not uniform in all cases. The majority of patients did not undergo optic canal unroofing, clinoidectomy, and/or optic strut removal. The efficacies of these maneuvers on visual outcome were not assessed. To attempt to limit these limitations, we strictly defined vision loss, only included patients with medial SWMs and neuro-ophthalmology data, and controlled for each variable found to show a statistical association or known to have a strong clinical relationship with our dependent variable using multivariate analyses. Given these inclusion criteria and statistical control with a relatively precise outcome measure, we believe our findings offer useful insights into the management and clinical history of patients with medial SWM. Nonetheless, prospective studies will provide better data to guide clinical decision-making.

Conclusion

This study is the largest clinical study of medial SWMs evaluating independent factors of postoperative visual function. In this study of 65 patients with medial SWMs, preoperative visual decline, subtotal resection, and repeat surgery were found to be independent predictors of visual decline at last follow-up. These findings suggest early surgical intervention before the onset of visual decline, as well as radical resection to minimize residual tumor and possible need for repeat surgery to maximize the likelihood of postoperative visual preservation at last follow-up. These findings may help guide surgical and medical management of patients with medial SWMs, where the incidence is expected to increase with the widespread availability of neuroimaging.

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