Microsurgery for Potential Radiosurgical Skull Base Lesions: A Retrospective Analysis and Comparison of Results

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ABSTRACT

The outcomes of 26 complex skull base tumors treated with microsurgery were compared with the outcomes of similar tumors treated with radiosurgery as reported in the literature. The University neurosurgery database was searched for patients who underwent microsurgery for the treatment of skull base tumors between 1990 and 2001 at Louisiana State University Health Sciences Center in Shreveport, Louisiana. Twenty-six skull base meningiomas treated by microsurgery by the senior author (AN) were identified retrospectively. On imaging, the tumors were well defined and less than 3 cm in the greatest diameter, making them ideal candidates for a radiosurgical procedure had this modality been available. The follow-up and outcomes of these 26 patients were compared with the published outcomes of similar tumors treated with radiosurgery. Total excision was achieved in 17 (65.3%) patients. Excision was subtotal in 9 (34.6%) patients due to the critical locations of their tumors. The median hospital stay for these patients was 4 days (range, 3 to 12 days). Two patients (7.6%) had transient cerebrospinal fluid leaks from the wound, and 2 (7.6%) had transient facial paresis. Overall, preoperative symptoms improved in 23 (88.4%) patients. The median follow-up was 56 months (range, 3 to 120 months). The overall survival rate for all was $87.2 \pm 3.7\%$ at 50 months. Two patients (7.6%) subsequently underwent repeat surgery for a recurrent or progressive disease. The actuarial 8-year tumor control rate was $86.4 \pm 4.4\%$ using the Kaplan-Meier method. For small skull base tumors with benign histology, microsurgery is as safe and effective a treatment option as stereotactic radiosurgery. The symptomatic improvement in patients is better with microsurgery than with radiosurgery because the volume of the tumor is reduced immediately. A combined approach using both modalities is usually needed for larger tumors when attempts at total resection would jeopardize the neurologic function of the patient.

KEYWORDS: Gamma knife, microsurgery, radiosurgery, skull base tumor

The skull base has always been challenging to access surgically. The critical neurovascular structures involved with lesions of this region, the depth of surgical field required, and the obstruction of operative exposure by important soft-tissue structures contribute to the difficulties in accessing this region. Surgical difficulty is further increased because the dense and irregular bone is structurally important and invests crucial neural and vascular entities. However, contemporary skull base procedures have rendered formerly inaccessible lesions both accessible and resectable.

The morbidity rates associated with the surgical resection of various skull base tumors have decreased significantly with advances in neuroimaging, improved understanding of anatomy, and the introduction of intraoperative neuronavigational techniques. As we move into the third decade of contemporary skull base surgery, the emphasis has shifted from designing new approaches to establishing an approach intended to preserve neural functions.

This retrospective study compared the outcomes of 26 skull base meningiomas treated microsurgically with the published outcomes of similar tumors treated by radiosurgery. These 26 meningiomas also would have been ideal cases for radiosurgical treatment. During this time, however, stereotactic radiosurgery was unavailable at our institution or in the state of Louisiana. The first Leksell Gamma Knife® (Elekta Instruments, Atlanta, GA) was not commissioned at our institution until January 2000.

MATERIAL AND METHODS

A retrospective search of the University Neurosurgery database was conducted to identify patients who underwent microsurgery for treatment of skull base tumors between 1990 and 2001 at our institution, Louisiana State University Health Sciences Center. The diagnostic imaging studies of patients were reviewed, and 26 patients (17 males, 9 females; mean age, 42.2 years; range, 15 to 71 years) were

selected for inclusion in this comparison. Inclusion criteria were as follows: (1) skull base location, (2) < 3 cm in all dimensions (i.e., ideal size for a radiosurgical procedure), and (3) requiring a highly specialized, complex skull base approach for resection.

The presenting symptoms ranged from asymptomatic to multiple cranial nerve deficits (Table 1). The tumors involved various locations and required a variety of surgical approaches (Table 2). The senior author (AN) performed the microsurgical procedures on all 26 patients in the series. Follow-up reports and imaging studies of all 26 patients were carefully scrutinized, and the rates of disease-free survival, complications, mortality, and morbidity as a result of the surgical procedure were calculated. The statistical results were compared with those published by various radiosurgery groups for similar tumors.

RESULTS

Of the 26 patients in our series, total excision was achieved in 17 (65.3%) patients. Excision was subtotal in 9 (34.6%) patients because of the critical locations of their tumors (Figs. 1 and 2). The median hospital stay for these patients was 4 days (range, 3 to 12 days). Two patients (7.6%) had a transient cerebrospinal fluid (CSF) leak from the wound, thus lengthening their hospital stay. Two (7.6%) patients had transient facial paresis (House-Brackman grades II and III), which improved over the next 6 months.

All patients underwent early postoperative examinations to evaluate their neurological status. Clinical improvement was defined as a positive change in their functional status (measured using Karnofsky's score), resolution of neurologic deficit, a reduction in preoperative symptoms, or all three. Neurological symptoms improved in 19 (65.51%) patients within 1 month of surgery. The primary improvements involved the function of the abducens, facial, and trigeminal nerves in 14 patients, followed

Table 1 Clinical Characteristics of 26 Patients with Skull Base Tumors

Age	Sex	Presenting Symptoms	Diagnosis
41	M	Diplopia, facial paresthesia	Meningioma
66	F	Facial numbness	Meningioma
51	M	Diplopia	Meningioma
46	F	Seizures	Meningioma
55	F	Ataxia, diplopia	Meningioma
39	F	Incidental	Meningioma
35	M	Incidental	Meningioma
46	M	Ataxia, ninth cranial nerve paresis	Meningioma
54	M	Vocal cord paresis	Meningioma
63	F	Headaches	Meningioma
43	F	Incidental, after minor HI	Meningioma
53	F	Diplopia, hearing loss	Meningioma
43	F	Headache, facial numbness	Meningioma (atypical)
63	F	Incidental, vascular headache	Meningioma
21	F	Ataxia, diplopia	Meningioma
45	M	Abducens paresis	Meningioma
52	F	Diplopia, deafness	Meningioma
71	F	Seizures	Meningioma (atypical)
15	M	Incidental	Meningioma
42	M	Facial numbness	Meningioma
39	M	Seventh nerve paresis, impaired hearing	Meningioma
42	M	Headaches	Meningioma
67	M	Ataxia, ninth cranial nerve paresis	Meningioma
58	M	Ataxia, diplopia	Meningioma
51	M	Incidental	Meningioma
62	M	Headaches	Meningioma

HI, head injury.

by improvements in balance problems and ataxia in 5 patients. Four other patients reported improved abducens nerve functions 6 to 9 months after surgery. Overall, preoperative symptoms improved in 23 (88.4%) patients.

Long-Term Follow-Up

Follow-up reports were available on all 26 patients. The median follow-up was 56 months (range, 3 to 120 months). At the last documented follow-up examination, 24 (92.3%) patients were alive and 2 (7.6%) had died. Both deaths were caused by unrelated medical ailments (diabetes and heart disease). Two patients subsequently underwent surgery for

recurrent or progressive disease at 15 and 36 months, respectively, after their initial surgery (mean, 25.5 months).

Statistical Analysis

Survival data for all patients was analyzed using the method of Kaplan-Meier. The overall survival rate for the series was $87.2 \pm 3.7\%$ at 50 months. Tumor control was defined as the absence of a demonstrable recurrence or of an increase in the contrast-enhancing area on follow-up magnetic resonance images as compared with the images obtained immediately after surgery. Tumor control was achieved in 24 of 26 (92.3%) patients with microsurgery alone.

Table 2 Approaches Used to Resect Meningiomas in 26 Patients

Tumor Location	Surgical Approach	Complications	Extent of Excision	Symptomatic Improvement
Petrous apex	Mid. fossa, anterior petrosectomy (Kawase approach)	None	Total	Yes
Petroclival	Mid. fossa, anterior petrosectomy, (Kawase approach)	None	Total	Yes
Clival	Extradural petrous apex resection	None	Subtotal	No
Petroclival	Transpetrous approach	CSF leak	Total	Yes
CP angle	Retrosigmoid approach	None	Total	Yes
Meckel's cave	Two excisions (skull base approach)	Facial paresis	Subtotal	Yes
Tuberculum sella	Basal frontal	CSF leak	Total	Yes
Petroclival	Transpetrous approach	None	Subtotal	Yes
Tuberculum sella	Basal frontal	None	Total	No
Petroclival	Retrosigmoid approach	Facial paresis	Total	Yes
Middle cranial fossa	Orbitozygomatic approach	None	Total	Yes
Clival	Extradural petrous apex resection	None	Total	Yes
CP angle	Retrosigmoid approach	None	Total	Yes
Petroclival	Mid. fossa, anterior petrosectomy (Kawase approach)	None	Subtotal	Yes
Petroclival	Mid. fossa, anterior petrosectomy (Kawase approach)	None	Total	Yes
Middle cranial fossa	Orbitozygomatic approach	None	Subtotal	Yes
Meckel's cave	Combined approach	None	Subtotal	Yes
CP angle	Retrosigmoid approach	None	Total	Yes
Clival	Extradural petrous apex resection	None	Total	Yes
Petroclival	Mid. fossa, anterior petrosectomy (Kawase approach)	None	Subtotal	Yes
Petrous apex	Mid. fossa, anterior petrosectomy (Kawase approach)	None	Total	Yes
Petrous apex	Transpetrous approach	None	Total	Yes
CP angle	Retrosigmoid approach	None	Subtotal	Yes
Meckel's cave	Combined approach	None	Total	No
Middle fossa	Combined approach	None	Total	Yes
Petroclival	Mid. fossa, anterior petrosectomy (Kawase approach)	None	Subtotal	Yes

CSF, cerebrospinal fluid; CP, cerebellopontine.

Two documented failures (7.6%) had atypical histological features and subsequently underwent repeat craniotomy. The Kaplan-Meier method was used to estimate the 8-year actuarial survival and tumor control rates. The projected survival in the present study for different benign tumors was $85.4 \pm 3.2\%$ at 96 months. Similarly, the 8-year tumor control rate was $86.4 \pm 4.4\%$ (95% confidence interval).

DISCUSSION

Neurosurgical progress has been described as the "thorny road to success."¹ In the past two decades, major neurosurgical advances have consistently aimed to minimize the invasiveness of neurosurgical intervention while enhancing the safety and effectiveness of surgical objectives. In particular, skull base

mors. Our institution has recently acquired a Leksell Gamma Knife, and radiosurgery can now be offered as a treatment option to patients with skull base tumors. This acquisition will also allow us to compare the outcomes of radiosurgery with those of conventional surgery. In general, surgical resection is considered optimal care for patients with benign

intracranial neoplasms.^{3,4} The success rates associated with the microsurgical excision of benign skull base tumors has varied from 26 to 89%.⁴⁻⁹

The morbidity associated with surgical intervention is well described. Permanent cranial nerve deficits, CSF leakage, and motor deficits have been the most frequent complications of skull base surgery.² In our series, the 65% rate of total tumor excision is comparable to those of most contemporary publications. In their series of 60 patients, Gay and associates¹⁰ achieved a 67% rate of total excision. Their recurrence-free survival rate was 80% at 3 years and 76% at 5 years. Their slightly lower rate may reflect that tumor volume or size was not a selection criterion in their series. In our series immediate surgical complications included CSF leakage (7.6%) and facial neurapraxia (7.6%), both of which were transient and improved without further intervention. These rates are also consistent with most previous series.^{2,10}

Although introduced by Lars Leksell in 1951,¹¹ radiosurgery has gained popularity as a treatment option for benign skull base tumors mostly during the past few years. Many series have described both the early and long-term results of radiosurgery for the treatment of various benign intracranial neoplasms.¹²⁻¹⁵ In such series, tumor control rates at various follow-up intervals have been excellent. Radiosurgery has come to be considered as the primary treatment modality for many benign skull base neoplasms that are less than 3 cm in their maximal dimension.^{2,12,15,16} In their series of petroclival meningiomas treated with radiosurgery, Subach et al¹⁵ found a reduction in tumor size in 23% of patients. The overall control rate was $86.7 \pm 8.7\%$ at 96 months. Transient abducens nerve paresis was noted in 3% of patients, while 5% of patients developed new cranial nerve deficits involving other nerves that had not resolved at the time of last follow-up. They documented uncontrolled tumor progression in 5 of 39 patients (12.82%). In the subgroup of 22 patients who received radiosurgery as their primary treatment, 1 patient (4.5%) showed neurologic deterioration. None, however, demonstrated evidence

of tumor growth on imaging. The calculated tumor control rate also excluded two patients with tumors associated with aggressive histology (i.e., malignant meningioma). Aichholzer et al¹² have published their results of using gamma knife radiosurgery to treat skull base meningiomas. A subgroup of patients received radiosurgery as their primary treatment option. For this group, their overall rate of tumor control was 93.3% at a median follow-up of 48 months. In this group, 47% percent demonstrated an improved neurologic status. The authors did not state the number of patients in this group with a radiologically documented decrease in tumor volumes.

The outcomes of our patients who have undergone microsurgery alone for small skull base tumors are comparable to the published series in terms of overall survival rates. The tumor control rates associated with radiosurgery are better than those for surgery. Radiosurgery, however, stabilizes a tumor but less frequently reduces its volume.^{2,12-15} Similarly in radiosurgical series, control is achieved if a patient's symptomatology remains unchanged compared with preoperative levels and does not worsen. In contrast, microsurgery always reduces the volume of a tumor. A greater percentage of patients improve symptomatically because relieving the pressure of the tumor on adjacent brain tissue and cranial nerves could ameliorate symptoms.

CONCLUSION

Comparing the 26 cases presented here with the outcomes of published series is complex because the field of skull base surgery is progressing rapidly. It is difficult to decide retrospectively whether one treatment option would really have been better than the other. Microsurgery alone, without the need for adjuvant therapy, appears to be safe and effective as a treatment option for small skull base meningiomas with typical histology. However, as long-term outcomes of contemporary skull base surgery and ra-

diosurgery series become available, it appears prudent to follow a cooperative treatment strategy: careful preoperative planning aimed at microsurgical debulking of difficult skull base lesions while preserving neural functions followed by radiosurgical treatment of residual lesion. Such a planned, cooperative management strategy may improve the long-term functional status of many patients with complex skull base lesions.

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Commentary

The authors retrospectively reviewed 26 patients who underwent microsurgical resection of skull base meningiomas over an 11-year period. All tumors were less than 3 cm. Gross total resection was achieved in 65% of patients and subtotal resection was achieved in 35%. The rate of tumor control was excellent (92%). Two patients (7.6%) had transient cerebrospinal fluid leaks and two had mild facial nerve palsies. The latter improved over a 6-month period but their final House-Brackmann grade is unclear. One month after surgery, symptoms improved in 65% of patients. The clinical results, however, cannot be duplicated in radiosurgical patients. Overall, symptoms improved in 88% of patients. During a 56-month follow-up, 92% remained alive. Two patients died from unrelated causes.

Open surgical resection or gamma knife radiosurgery should be considered for patients with skull base meningiomas. Our institution offers surgical resection to patients with accessible tumors that appear to be compressing the brain stem significantly or causing mass effect, and to patients whose tumors can be resected totally with minimal complications. Gross total resection provides patients a 90 to 96% chance of disease-free progression in the near future. Radiosurgery offered as an adjunct or alternative to surgical resection is a viable option for subtotally resected lesions, for patients who are poor surgical candidates, and for patients who do not desire open surgical resection. This contemporary neurosurgical series serves as one

of many studies to set the standard for excellent neurosurgical outcomes. Although the complication rate will always be higher in patients who undergo open surgery, patients who undergo radiosurgery for skull

base meningiomas will never have magnetic resonance images that are free of tumor.

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