

Surgical Resectability of Skull Base Meningiomas

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Abstract

With recent advances in surgical technology such as preoperative imaging, neuro-monitoring, and surgical instruments, the surgical resectability of intracranial meningiomas has increased over the last two decades. This study reviewed clinical articles regarding the surgical treatment of meningiomas to clarify the role of surgical excision, with a focus on skull base meningiomas. We sub-classified clinical articles about skull base meningiomas into two categories (anterior and middle fossa meningiomas; and posterior fossa meningiomas) and reviewed papers in each category. In cases with anterior and middle fossa meningiomas, surgical resectability has reached a sufficient level to maximize functional preservation. In cases of posterior fossa meningioma, however, surgical resectability remains insufficient even with full use of recent surgical modalities. Continuous refining of operative procedures is required to obtain more satisfactory outcomes, especially for posterior fossa meningioma. In addition, recent long-term outcomes of stereotactic radiosurgery (SRS) were acceptable for controlling the skull base meningiomas. Therefore, combination with surgical excision and SRS should be considered in complicated skull base meningiomas.

Key words: meningioma, skull base, surgical resectability

Introduction

With recent advances in surgical technology such as preoperative imaging, neuro-monitoring, and surgical instruments, the surgical resectability of intracranial meningioma has increased markedly over the last two decades. In particular, in the field of skull base meningioma, surgical outcomes have dramatically improved due to these technical contributions. This study reviewed clinical articles regarding the surgical treatment of meningiomas to clarify the role of surgical excision, with a particular focus on skull base meningiomas.

Materials and Methods

We sub-classified clinical articles about skull base meningiomas into two categories and reviewed papers in each category. The first category comprised anterior and middle fossa meningiomas, including meningiomas of the olfactory groove, tuberculum sellae, clinoid, sphenoid wing, and pure cavernous sinus. The second category involved posterior fossa meningiomas, including petrous, petroclival, jugular foramen, and foramen magnum meningiomas. In

addition to reviewing surgical resectability of the meningiomas, we briefly summarized the outcomes of radiosurgery for skull base meningiomas to achieve sufficient outcomes to the patients.

Results

I. Anterior and middle fossa meningiomas

1. Olfactory groove meningiomas

Surgical outcomes of olfactory groove meningiomas have been acceptable since the beginning of the microsurgical era. Initially, a bilateral subfrontal approach was mainly applied for wide exposure of the lesions and surgical safety.¹⁾ Complete removal of the tumor was performed in 84% of patients.¹⁾ Less-invasive approaches such as unilateral subfrontal and frontolateral approaches were subsequently introduced to minimize the sizes of the dural opening and craniotomy.²⁻⁷⁾ Recent articles have revealed that more than 90% of tumors underwent total resection with each approach.^{3,5,7)} Several groups have preferred to select endoscopic approaches to lesions through a frontal key hole window or transnasal corridors to decrease frontal lobe retraction.⁸⁻¹⁰⁾ Surgical resectability of this approach is also acceptable, but endoscopic approaches cannot be applied to tumors more than 40 mm in diameter,

calcification, or absence of a cortical vascular cuff.^{10,11)} The resectability of olfactory groove meningiomas is shown in Table 1. Transcranial approaches are more radical than the endoscopic endonasal approach for olfactory groove meningiomas.

2. Tuberculum sellae meningiomas

Tuberculum sellae meningiomas were resected via various surgical approaches. In the early period of microsurgery, a bilateral subfrontal approach was preferably selected and unilateral subfrontal and frontotemporal craniotomy approaches were applied after good development of microsurgical treatments.^{12–15)} However, visual outcomes remained inadequate until 2005.^{16–19)} In these reports, visual outcomes deteriorated in 20% of patients. For the last 10 years, visual outcomes have improved with better neuromonitoring and additional surgical modifications.^{20–22)} Some groups have used the inter-hemispheric approach to observe the medial and

inferior surfaces of the optic apparatus and have presented sufficient visual outcomes.^{21,22)} Others have applied an endoscopic endonasal approach to minimize optic nerve manipulation.^{23,24)} Endoscopic approaches offer successful visual outcomes, but cannot be applied to all cases. Lateral extension, large tumor volume, calcification, and absence of a cortical vascular cuff seem to be contraindications. Surgical outcomes for tuberculum sellae meningioma are summarized in Table 2.

3. Clinoid and sphenoid wing meningiomas

Clinoid and sphenoidal wing meningiomas were regarded as challenging tumors at the beginning of microsurgery, due to the anatomical proximity to the optic nerve and involvement of the internal carotid artery and its perforating arteries.²⁵⁾ In the report presented by Bonnal et al., successful gross total resection was performed in only 23.5% of patients.²⁵⁾ With advances in skull base techniques, such as clinoidectomy and optic canal unroofing, this type of tumor can be safely and radically resected.^{26,27)} Lee et al. achieved a total resection rate of 86.7% in patients.²⁶⁾ Most recent clinical articles have emphasized the importance of early optic canal unroofing for preservation of optic function.^{28–32)} Table 3 summarizes recent clinical outcomes for clinoid meningiomas.

4. Cavernous sinus meningiomas

In the 1990s, when skull base approaches flourished, many experts tried total resection of cavernous sinus meningioma through several cavernous triangles. Surgical results were not satisfactory for functional preservation of cranial nerves passing through the cavernous sinus.^{33–35)} Subtotal resection with stereotactic radiotherapy has since been regarded as acceptable treatment to preserve cranial nerve functions.^{36–38)}

Table 1 Surgical resectability of olfactory groove meningiomas

Author	No. of patients	Surgical approach	Gross total resection (%)
Bassiouni et al. ³⁾	56	Transcranial	100
Bitter et al. ⁵⁾	61	Transcranial	98
Romani et al. ⁷⁾	66	Transcranial	91
Banu et al. ⁹⁾	6	Endoscopic endonasal	50
	7	Endoscopic supraorbital eyebrow	100
Koutourousiou et al. ¹¹⁾	50	Endoscopic endonasal	66.7

Table 2 Surgical outcome of tuberculum sellae meningiomas

Author	No. of patients	Surgical approach	GTR (%)	Visual deterioration (%)
Arai et al. ¹⁴⁾	21	Interhemispheric	100	10
Fahlbusch et al. ¹⁶⁾	47	Pterional	98	20
Goel et al. ¹⁷⁾	70	Unilateral subfrontal	84.3	10
Park et al. ¹⁸⁾	30	Frontolateral	76.7	30
Nakamura et al. ¹⁹⁾	72	Pterional	91.7	12.5
Mathiesen et al. ²⁰⁾	29	Pterional	85.1	0
Chokyu et al. ²¹⁾	34	Bifrontal interhemispheric	79.4	0
Curey et al. ²²⁾	20	Interhemispheric	95	9
Koutourousiou et al. ²³⁾	75	Endoscopic endonasal	76	3.6

GTR: gross total resection.

Table 3 Surgical outcome of clinoid and sphenoid wing meningiomas

Author	No. of patients	GTR (%)	Visual deterioration (%)
Lee et al. ²⁶⁾	15	86.7	0
Bassiouni et al. ²⁷⁾	106	59	14
Romani et al. ²⁹⁾	73	78	10
Mariniello et al. ³⁰⁾	46	84.8	3.3
Nakamura et al. ³²⁾	108	92.3	4

GTR: gross total resection.

Table 4 Surgical outcome of posterior petrous meningiomas

Author	No. of patients	GTR (%)	Facial palsy (%)	Hearing loss (%)
Schaller et al. ³⁹⁾	17	88	29	22.5
Roberti et al. ⁴⁰⁾	9	100	NR	NR
Selesnick et al. ⁴¹⁾	6	99	0	NR
Bassiouni et al. ⁴²⁾	19	100	5	0
Batra et al. ⁴³⁾	10	NR	0	11
Nakamura et al. ⁴⁴⁾	44	91	7	23
Wu et al. ⁴⁵⁾	28	100	7.1	NR
Devèze et al. ⁴⁶⁾	9	78	11	25
Sanna et al. ⁴⁷⁾	7	100	14	0
Peyre et al. ⁴⁸⁾	17	94	0	18

GTR: gross total resection.

II. Posterior fossa meningiomas

1. Petrous meningiomas

Petrous meningiomas originating from the posterior surface of petrous bone can be sufficiently resected via a lateral suboccipital approach. Neuro-monitoring of cranial nerves and the microsurgical anatomy of the posterior fossa have greatly contributed to the advancement of surgical results. In most recent articles, petrous meningiomas behind the internal auditory canal have been successfully excised via a lateral suboccipital approach.^{39–48)} Previous studies have already emphasized the less important morbidity regarding auditory and facial function in this group compared with petroclival meningiomas.⁴⁸⁾ The surgical results published in the literature are presented in Table 4. Rates of facial function preservation have been good (mean, 94%; range, 71–100%), but the rate of serviceable hearing preservation is more variable (mean, 85%; range, 75–100%).

Table 5 Surgical outcome of petroclival meningiomas in early period

Author	No. of patients	GTR (%)	Mortality and morbidity (%)
Hakuba et al. ⁴⁹⁾	6	100	67
Samii et al. ⁵¹⁾	24	71	63
Al-Mefty et al. ⁵²⁾	13	85	49
Mayberg et al. ⁵⁵⁾	35	26	54

GTR: gross total resection.

2. Petroclival meningiomas

Petroclival meningioma remains a most challenging tumor due to the proximity to critical neurovascular structures. Until the mid-1980s, this tumor was regarded as unresectable. However, after pioneering efforts in the skull base field, surgical resectability of these tumors started to increase in the 1990s.^{49–55)} Several variations of transpetrosal approaches have been introduced, mainly in this period.^{49–55)} At that time, surgical morbidity was the main problem to be improved, despite the high resectability of the tumors.^{48–55)} New neurological deficits appeared in more than 50% of patients in most clinical articles.^{48–55)} Surgical results from that time are presented in Table 5. Some recent groups have recommended surgical excision via a lateral suboccipital approach to simplify the procedures and decrease venous complications around the temporal lobe.^{56–59)} In this procedure, subtotal resection followed by radiosurgery is preferable to minimize complications. In the article presented by Seifert, the frequency of postoperative cranial nerve deficits decreased to 22%.⁵⁸⁾ Those results are acceptable. On the other hand, other groups have recommended the more sophisticated petrosal approach to minimize surgical complications and achieve satisfactory surgical outcomes.^{60–65)} One reason for this controversy regarding surgical approaches is the definition of petroclival meningioma. The narrow definition is a meningioma originating from the medial side of the trigeminal nerve and compressing cranial nerves and the brainstem backward. Under such a narrow definition, a petrosal approach is an essential procedure for safe radical resection.^{62,63)} The broader definition is meningioma arising from the petrous apex and tentorium and extending to the petroclival junction. Such tumors compress cranial nerves downward and the brainstem medially. Under this situation, a lateral suboccipital approach is reasonable and efficient.^{56–58)}

3. Jugular foramen meningiomas

Jugular foramen meningioma is a very rare entity and few clinical articles have presented outcomes.^{66–68)} In those articles, jugular foramen meningiomas

Table 6 Surgical outcome of jugular foramen meningiomas

Author	No. of patients	GTR (%)	New deficit of lower cranial nerves (%)
Bakar ⁶⁶⁾	96	85.7	30.6
Sanna et al. ⁶⁷⁾	13	84.6	61.5
Ramina et al. ⁶⁸⁾	10	50	50

GTR: gross total resection.

usually invade the dura mater, cranial nerves, and surrounding bone. Radical surgical excision of the tumor usually leads to severe lower cranial nerve paresis.^{66–68)} In the few articles published, 30–60% of patients suffered lower cranial nerve palsy after tumor excision. The extent of tumor removal should thus be decided with care, considering preoperative lower cranial nerve function. Clinical outcomes are shown in Table 6.

4. Foramen magnum meningiomas

The surgical difficulty of treating foramen magnum meningioma mainly depends on the site of attachment. The definition covers meningiomas arising from the lower-third of the clivus to the axis. Most articles have reported foramen magnum meningiomas attaching to the lower-third of the clivus as the most challenging tumor for the preservation of lower cranial nerve functions. On the other hand, meningiomas at the level of the foramen magnum, atlas, and axis have been successfully resected in all recent clinical papers.^{69–75)} Precise radiological evaluation is recommended to estimate surgical resectability.^{69–75)}

III. Radiosurgery for skull base meningiomas

Particularly with the advent of computed tomography and magnetic resonance imaging, which have facilitated improved targeting and early detection, stereotactic radiosurgery (SRS) has been used with increasing frequency to treat patients with skull base meningiomas. In the series presented by Starke et al., follow-up imaging demonstrated tumor control in 86% of patients at a median follow-up of 6.5 years and radiological progression-free survival showed 99% at 3 years, 96% at 5 years, and 79% at 10 years.⁷⁶⁾ Similar results were presented by SRS reports.^{77–79)} And these results were acceptable for the patients with skull base meningiomas. When we surgically treat a skull base meningioma, benefits of SRS should be considered in all cases. In cases with severe involvement of critical neurovascular structures, maximum tumor reduction combined SRS should be an ideal procedure for the patients.

The combination of microsurgery and SRS appears to attain higher long-term tumor control rates of above 80% and even above 90% in most series.^{80–82)}

Conclusion

Most cases with anterior and middle fossa meningiomas but not cavernous sinus meningiomas can be removed radically and can be controlled by surgery alone using current skull base techniques. However, the cavernous part of the tumor or some residue around the perforating arteries tends to be treated by SRS to minimize surgical complications. On the other hand, the resectability of posterior fossa meningiomas is insufficient compared with that of meningiomas in the anterior or middle fossa, even with the development of surgical instruments, neuroimaging, and neuro-monitoring. Maximum tumor reduction with functional preservation offers reasonable treatment for posterior fossa meningiomas. However, we should not overlook the fact that radical excision of the tumor leads to good long-term tumor control.⁷⁶⁾ Continued efforts to refine operative procedures are thus required to obtain further satisfactory outcomes.

Conflicts of Interest Disclosure

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

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