ORIGINAL ARTICLE

Surgery for Petroclival Meningiomas: A Comprehensive Review of Outcomes in the Skull Base Surgery Era

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ABSTRACT

Skull base surgery has evolved to a point that its focus is now shifting to outcome analysis. To do so for petroclival meningiomas is difficult. The rarity of the tumor, different treatment philosophies, and variations in reporting complicate the outcome analysis. With this limitation in mind, we analyzed the literature on this disease and report the combined outcomes in a unified fashion in hopes that it will serve as a starting point for further prospective analysis. Data was extracted from all available reports on MEDLINE/PubMed published in English. All studies were retrospective and uncontrolled. The majority of studies represent the experience of a single surgeon at a single institution. Of the 19 studies with detailed demographic and outcome data, no data met criteria for meta-analysis. A total of 1000 patients were reported. The mean age of the patients was 50 years. The male to female ratio is 1:3. GTR (gross total resection) was reported in 49% of patients. Thirty-four percent of patients experienced some neurological deficit in the early postoperative period (<3 months). The most common morbidities reported were cranial nerve deficits (34.4% [range: 20 to 79%]) with facial nerve injury accounting for 19%, followed by motor deficits (14%), infection rates (1.6%), CSF leaks (5%), hemorrhage (1.2%), and hydrocephalus (1%). Death within 1 year of surgery was reported for 1.4% of patients. Once considered untreatable, petroclival meningiomas can now be approached relatively safely. There, however, still remains an ~34% morbidity with the most common being cranial nerve. Despite this, >75% of patients return to independence at 1 year, many of which will resume employment. The nature of this study limits the conclusions that can be drawn; however, it provides some generalizations that may help guide patient questions regarding treatment outcomes.

KEYWORDS: Meningioma, petrous, clivus, sphenopetroclival, petroclival

Meningiomas account for 20 to 25% of all intracranial tumors and 10% are seen in the posterior fossa. Of posterior fossa meningiomas, those arising from the petroclival region account for 5 to 11% of meningiomas and thus 0.15% of all intracranial tumors.[1–3] Petroclival meningiomas, though typically benign and slow-growing, can become quite large before any clinical sequelae are evident. The majority of patients

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present with headache, cerebellar signs, or cranial nerve deficits.[4–9]

The natural history of these lesions suggests progressive growth with progressive neurological deterioration and inevitable death.[1,10] Early in the history of neurosurgery, these lesions were considered unresectable. Over the last three decades, with modern neurosurgical techniques and approaches, many patients have undergone surgery.[11] Generally speaking, total resection provides the only chance of cure.

Meningiomas arising from the apical petrous bone and/or clivus with extension to the sphenoid bones or cavernous sinus are challenging tumors surgically: proximity and adhesion to cranial nerves, major blood vessels, and the brainstem can make postoperative morbidity and mortality high. Complex surgical approaches are oftentimes needed. Furthermore, many argue that peri- and postoperative care places unnecessary burden on the patients and caregivers. Much of this opinion was based on early surgical series, which demonstrated high complication rates after surgery.[3,12,13] Due to the fact that untreated lesions will ultimately result in patient death, many elect for resection of their lesions and modern outcomes have been generally acceptable (>75% return to independent functional status or return to work at 1 year).[7,14–17]

The current literature is vast with respect to individual or institutional case series; however, a comprehensive summary does not exist. Given the relative rarity of these tumors, it can be difficult to counsel patients regarding surgical outcomes. We sought to summarize the current literature specifically focusing on reported outcomes. The goal of this systematic review is to provide insight for surgeons and patients alike with regards to perioperative risks from surgical resection of petroclival meningiomas. There is no doubt that a study such as this has some important limitations. There is some variation in what is classified as a petroclival meningioma. Furthermore, this study groups different treatment philosophies and techniques. Nevertheless, we feel that this study provides an important overview of the range of expected outcomes and may serve as a basis for future prospective multicenter studies evaluating outcome.

MATERIALS AND METHODS

We performed a MEDLINE/PubMed search of all papers written in the English language using the key words meningioma, petrous, clivus, petroclival, sphenopetroclival, and/or surgery in various combinations with the terms outcome, natural history, survival, and/or morbidity. The bibliographies of all identified studies were searched for additional references. This method was repeated until no further studies could be identified. Data was extracted from all case reports and case series. The papers were included in the review if outcomes were presented.

RESULTS

Of the 19 studies with detailed demographic and outcome data, no data met criteria for meta-analysis. A total

Table 1 Patient/Case Characteristics

Authors	Year	No. of Patients	Mean Age	Male	Female	Mean Follow-up (mo)	GTR	New Deficit*	Recurrence†
Natarajan et al[24]	2007	150	51	29	121	101.6	48		5%
Bambakidis et al[25]	2007	46	55	6	40	42	9	14	15%
Mathiesen et al[16]	2007	29		7	22	66			
Erkmen et al[22]	2005	97	50	19	78			7	
Little et al[27]	2004	137	53	38	99	8.3	55	36	17.60%
Seifert et al[8]	2003	19					12		29%
Cho and Al-Mefty[21]	2002	7	42.5	1	6		5		
Aziz et al[20]	2000	35		6	29		13	11	
Carvalho et al[14]	2000	70	49	21	49	48			
Jung et al[15]	2000	67	47.5	10	57	48	26		
Zentner et al[32]	1997	19	56	2	17		13	5	0
Sekhar et al[9]	1996	75	52	21	54				
Couldwell et al[6]	1996	109	51	40	69	72	75	35	13%
Samii et al[7]	1992	36	47	11	25		27		
Bricolo et al[5]	1992	33	52	12	21		26	33	
Kawase et al[30]	1991	10	55	2	8		7	8	20%
Samii et al[17]	1989	24	45	7	17			11	
Nishimura et al[3]	1989	24	47	7	17		17	20	20%
Al-Mefty et al[4]	1988	13	46	2	11		11	5	

*Any postoperative deficit noted.
†Based on follow-up as noted in manuscript. Percentages shown (%).

of 1000 patients were reported. The mean age of the patients was 50 years. The male to female ratio was 1:3. Gross total resection (GTR) was reported in 49% of patients. Thirty-four percent of patients experienced some neurological deficit in the early postoperative period (<3 months). The most common morbidities reported were cranial nerve deficits (34.4% [range: 20 to 79%]) with facial nerve injury accounting for 19%, followed by motor deficits (14%), infection rates (1.6%), CSF leaks (5%), hemorrhage (1.2%), and hydrocephalus (1%). Death within 1 year of surgery was reported for 1.4% of patients. Review and statistics are summarized in Tables 1 and 2.

DISCUSSION

This study highlights some important limitations in combining the available literature. Specifically, variations in what is reported as a petroclival meningioma, differences in treatment philosophies, and the rarity of the tumor can all limit conclusions that can be drawn from such a study. However, given the rarity of the tumor and the need to counsel patients regarding treatment outcomes, this study can help guide patients in terms of expected outcomes. It can also serve as a potential guide for future prospective multicenter studies evaluating outcomes.

In 1953, Castellano and Ruggiero reported that 42% of meningiomas are seen on the posterior surface of the petrous bone and 11% seemingly arise from the clivus in post-mortem studies.[1] Yasargil originally defined the location and differentiated between clival, petroclival, and sphenopetroclival meningiomas,[18] yet this distinction is rarely made within the literature. Instead, the majority of meningiomas (and lesions in general) are classified as petroclival with or without extension into the sphenoid bone or cavernous sinus. In general, the term petroclival meningioma describes a tumor of the apical petrous bone and upper two-thirds of the clivus. The difficulty in formulating a consensus description of these lesions is due to their large size upon presentation. The larger lesions extend across multiple anatomical landmarks and cranial bases. Hence, petroclival meningiomas may be called sphenopetroclival, tentorial petroclival, petrous apex, or clival. Extension can be seen into the cavernous sinus or the sphenoid sinus, giving hint to their region of origin and vector of spread.

Natural History

Initial descriptions of these tumors described them as universally progressive in growth and patient detriment resulting in patient death.[1,19] More indirect evidence about growth rates of these tumors was seen in studies examining the growth and recurrence of residual tumor after surgery.[5,6,15] van Havenbergh et al[10] reported the only modern series of conservatively treated petroclival meningiomas. After a minimum of 4 years of follow-up, 76% of the lesions demonstrated growth of which 63% had neurological deterioration. Half of the asymptomatic patients developed symptoms. The reported growth rates were 0.81 mm/yr (diameter) and 0.81 cm^3/yr (volume). When only growing tumors were considered, the mean growth rates were 1.16 mm/yr (diameter) and 1.10 cm^3/yr (volume). These numbers are different than those reported for residual tumor growth and it is speculated that untreated tumors may grow at a different rate than resected tumors.[15] One interesting observation made is that a change in the growth rate preceded neurological decline.[10]

Surgical Approaches

The use of various surgical approaches to these lesions is frequently dictated by tumor-specific characteristics, presence or absence of ipsilateral hearing, and surgeon experience and preference.[20,21] Much of these decisions are guided by preoperative imaging, and in the modern era, all patients typically undergo CT to examine the bony architecture and relationships between the skull base and tumor, MRI to evaluate presence of edema in the brainstem and soft-tissue relationships between the CNS and the tumor, and angiography to evaluate the arterial supply and relationship to major vessels.[22] Indeed, many report the use of invasive or noninvasive angiography in 60 to 100% of patients preoperatively.[3,5,23,24]

At different points in history, various surgical approaches were championed.[25] It is important to note that no study to date has looked at morbidity or mortality compared across all approaches and perhaps such an analysis would not be feasible. The approaches used in the literature reviewed include the combined petrosal approach (with or without labyrinthectomy), frontotemporal transcavernous approach, anterior transpetrosal (Kawase) approach, frontotemporal craniotomy with orbitozygomatic osteotomy, transmastoid translabyrinthine approach, postauricular translabyrinthine, transotic, transcochlear total petrosectomy, the retromastoid, and the retrosigmoid approach. Again, patient demographics and complications are presented across all approaches and surgeon expertise; thus much of the data, as presented, is not generalizable.

Patient and Tumor Characteristics

Some studies attempt, through retrospective analysis, to determine which variables, if any, can predict better or worse outcome for patients with petroclival meningiomas across all approaches. Certainly, some biases exist with respect to patient selection and surgeon

Table 2 Reported Complications

Authors	Year	Deaths*	Paresis†	Cerebellar‡	CN§	III, IV, VI	VII	VIII	IX–XII	Infection¶	Hydrocephalus	Hemorrhage	CSF Leak	Aspiration Pna
Natrajan et al[24]	2007	2	6	1	31	13	2	5	4	1	3	2	3	
Mathiesen et al[16]	2007	0				3	7	9	5					
Bambakidis et al[25]	2007	0	2			6	7	5	2		2		1	
Erkmen et al[22]	2005	0					4	5		2			10	
Little et al[27]	2004	1	10	6	31	20	8	3	12		2	2	10	4
Seifert et al[8]	2003	1												
Cho and Al-Mefty[21]	2002	0												
Aziz et al[20]	2000	0	4			19	6	1	5				1	
Zentner et al[32]	1997	1	1		4	2	2	2				2	5	
Sekhar et al[9]	1996									4			4	5
Couldwell et al[6]	1996	4	16	7	36	18	5	5				4		
Samii et al[7]	1992	0	5			7	15	13	4				5	
Bricolo et al[5]	1992	3	4		26									
Kawase et al[30]	1991	0	5		5	5	1				1		1	
Samii et al[17]	1989	0	3			6	10	10	4				3	
Nishimura et al[3]	1989	2	10	13	20		18	19		8	2	2		9
Al-Mefty et al[4]	1988	0	1		4		2			1				

*Within first year.
†Includes mono-, hemi-, and tetraparesis.
‡Includes all cerebellar deficits.
§All patients with cranial nerve deficits included.
¶Epidural and intraparenchymal abcesses, shunt infections, wound infections, and meningitis included.
CN, cranial nerve; CSF, cerebrospinal fluid; Pna, pneumonia.

preference/training; however, some consistency is seen with the results. The presence of any cranial nerve deficit prior to resection may be predictive of new or worse postoperative cranial nerve injury.[26,27] Fixed cranial nerve deficit is greatest in series where aggressive CS meningioma resection was performed[9,28] with up to 58% of patients having a permanent deficit.

Despite the best of surgical efforts and experience, GTR is only reported in an average of 49% of patients. Many high-volume surgical centers have abandoned GTR for NTR (near total resection) or STR (subtotal resection) later in their experience.[27] Most report that STR/NTR does not have an increased risk or recurrence compared with GTR in most series.[7,27,29–32] The reason for this is unclear; however, one possibility is that tumor devascularization that may occur with the surgery contributes to this observation. Series reported using either initial or adjuvant (post-surgical) stereotactic radiosurgery for residual tumor, in particular, residual in the cavernous sinus show low CN deficits ranging from 1 to 8% and high (<90%) control rates at 5 to 10 years.[6,16,24,27,33–37] Thus, with such high control rates with low morbidity, patients with residual tumor should be presented with the option of stereotactic radiosurgery. The timing of this is debatable. Interestingly, patient preferences about radiosurgery seem to vary with some reports demonstrating that patients only elect for radiosurgery 45% of the time.[24] This would be an interesting finding to investigate further. Of note, patients who survive at 1 year, >75% of patients return to work or are able to independently perform activities of daily living.[7,14–17,24]

There are several limitations to our systematic review. All of the data extracted was from uncontrolled, unrandomized, retrospective data from single or few institutions; formal meta-analysis could not be performed or applied to extracted data. Our combined numbers do not control for data heterogeneity, for example, surgeon preference or experience or surgical approach. All of the studies reviewed lack uniformity of approach, follow-up, preclinical assessment, and postoperative functional status monitoring and assessment. Our review does not account for a publication bias selecting for patients with favorable outcomes. Nonetheless, our review provides some useful insight, in particular with pre- and postoperative patient counseling.

CONCLUSION

Cranial nerve morbidity and motor deficits are the common postoperative neurological complications after resection of petroclival meningiomas. Despite the high morbidity, >75% of patients return to independence at 1 year, many of which will resume employment.

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