Petroclival meningiomas: study on outcomes, complications and recurrence rates

Clinical article

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Object. Petroclival meningiomas are notoriously difficult lesions to manage surgically, given the critical neurovascular structures that are intimately associated with the tumors. In this paper, the authors’ aim was to review their series of patients with petroclival meningiomas who underwent surgical treatment; emphasis was placed on evaluating modes of presentation, postoperative neurological outcome, complications, and recurrence rates.

Methods. Fifty patients underwent surgical treatment for petroclival meningiomas. The majority of the patients were women (72%). The authors retrospectively reviewed the patients’ medical records, imaging studies, and pathology reports to analyze presentation, surgical approach, neurological outcomes, complications, and recurrence rates.

Results. Headache was the most common presentation (58%). The most commonly used approach was the transpetrous approach (in 16 patients), followed by the orbitozygomatic approach (in 13). Gross-total resection was performed in 14 patients (28%), and in the remaining patients there was residual tumor (72%). Eighteen patients with tumor remnants were treated with Gamma Knife surgery. New postoperative cranial neuropathies were noted in 22 patients (44%). The most common cranial nerve (CN) deficit following surgery was CN III dysfunction (in 11 patients) and facial weakness (in 10). In 9 patients, the CN dysfunction was transient (41%), and 7 patients had permanent dysfunction (32%). Eight patients developed hydrocephalus and all required placement of a ventriculoperitoneal shunt. A CSF leak was noted in only 2 patients (4%), and wound dehiscence was noted in 1. The CSF leaks and the wound dehiscence occurred in patients who were undergoing reoperations. Adequate radiographic follow-up (minimum 6 months) was available for 31 patients (62%). The mean follow-up was 22.1 months. In 6 patients, tumor progression or recurrences were noted. The median time to recurrence was 84 months. At the time of discharge from the hospital, 92% of the patients had good outcomes (Glasgow Outcome Scale Scores 4 and 5). Three patients died of causes not directly related to the surgery.

Conclusions. Petroclival meningiomas still pose a formidable challenge to neurosurgeons. In their series, the authors used multiple skull base approaches and careful microneurosurgical technique to achieve a good functional outcome (Glasgow Outcome Scale Score 4 or 5) in 92% of patients, although the extent of gross-total resection was only 28%. The authors’ primary surgical goal was to achieve maximal tumor resection while maintaining or improving neurological function. The authors favor the treatment of residual tumor or recurrent tumor with stereotactic radiosurgery. (DOI: 10.3171/2010.11.JNS10326)

Key Words • petroclival meningioma • surgery • Gamma Knife surgery

When to take great risks; when to withdraw in the face of unexpected difficulties; whether to force an attempted enucleation of a pathologically favorable tumor to its completion with the prospect of an operative fatality, or to abandon the procedure short of completeness with the certainty that after months or years even greater risks may have to be faced at a subsequent session—all these take surgical judgement which is a matter of long experience.

Harvey Cushing

Abbreviations used in this paper: CN = cranial nerve; CPA = cerebellopontine angle; GOS = Glasgow Outcome Scale; GTR = gross-total resection; GSPN = greater superficial petrosal nerve; SRS = stereotactic radiosurgery; STR = subtotal resection; VP = ventriculoperitoneal.

Approximately 20% of all primary intracranial tumors are meningiomas. Of these, only about 2% occur in the petroclival region. Historically, resection of these rare tumors was associated with unacceptably high morbidity and mortality rates. They were even considered by some to be inoperable. Advances in neuroimaging (CT scanning, MR imaging, and so on) and neurosurgical techniques (the use of the operating microscope, microsurgical dissection, and refined cranial base approaches) have generally led to earlier tumor diagnosis, improved extent of resection, and less operative morbidity and mortality.

This article contains some figures that are displayed in color online but in black and white in the print edition.
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Despite these advances and the usually benign histology of the tumor, petroclival meningiomas remain extremely challenging lesions to approach and to resect. The dural base of these lesions is often broad, making wide exposure of the petroclival region a necessity. This may involve transpetrosal approaches that often carry inherent risks, such as hearing loss. The tumors often adhere to or invade the brainstem, usually have an intimate association with some portion of the vertebrobasilar complex, and often have CN fibers splayed over portions of the capsule. Thus, even with improved corridors to access the lesion, the surgical manipulation needed to remove the tumor may result in injury to these eloquent structures, and often GTR is not safely feasible. The results of SRS, either as a primary or adjunctive treatment for these meningiomas, are promising.40,41

In this study, we review our surgical experience in treating 50 patients with petroclival meningiomas. We discuss our management paradigm, selection of surgical approach, neurological outcomes, complications, and recurrence rates.

Methods

After obtaining local institutional review board approval and in compliance with Health Information Portability and Accountability Act (HIPAA) regulations, we retrospectively reviewed a prospectively collected database containing the medical records, neuroimaging studies, and pathology reports of 50 patients who underwent resection of petroclival meningiomas during a 15-year period between 1993 and 2008. The primary author (A.N.) performed all the surgical procedures. Meningiomas arising from the dura medial to CNs V–XI were included in this study, comprising petroclival, clival, and sphenopetrolival meningiomas.

All patients underwent preoperative Gd-enhanced MR imaging. One patient underwent preoperative cerebral angiography for tumor embolization. The principal signs and symptoms at presentation were obtained from the medical records. The maximal tumor dimensions, presence of brainstem edema, and spread of tumor outside the petroclival region were ascertained from the preoperative MR image.

All patients underwent contrast-enhanced CT scanning in the immediate postoperative period as well as Gd-enhanced MR imaging to assess the extent of resection. Extent of resection was described as gross total (Simpson Grade I or II), subtotal (> 90% resection), or partial (< 90% resection), as determined by the surgeon’s intraoperative impression and the postoperative MR image. Neurological outcome was graded according to the GOS at most recent follow-up. Intraoperative and perioperative complications were gleaned from the medical records. Follow-up neuroimagines were evaluated to determine recurrence or progression of meningioma.

Statistical analysis was performed using SPSS software (version 13, SPSS, Inc.). Spearman correlation coefficients (r) were calculated when necessary. Probability values < 0.05 indicated statistical significance.

Results

Fifty patients underwent excision of petroclival meningiomas during a 15-year period. There were 36 women and 14 men, and the mean age was 55 years (range 23–90 years). Headache, the most common presenting symptom in the series, was seen in 58% of patients. Other common presenting symptoms included ataxia (12%) and dizziness (12%). Other common neurological signs included facial numbness (in 5 patients), hemiparesis (in 5), and facial weakness (in 2).

The surgical approach was selected by the primary author based on multiple factors including the size, extent of brainstem compression, involvement of vasculature, extension of tumor outside the petroclival area, neurological status (including presence or absence of hearing), and goal of surgery (that is, GTR or STR for brainstem decompression). The most commonly used approach was the transpetrosal approach (in 16 patients), followed by the orbitozygomatic approach (in 13) (Fig. 1). Staged resection was performed in 1 patient (2%). In addition to the petroclival meningioma, 1 patient was also noted to have an associated internal carotid artery aneurysm, which was subsequently surgically clipped.

Extent of Resection

Gross-total resection was defined as Simpson Grade I or II removal confirmed by postoperative Gd-enhanced MR imaging. Gross-total resection was performed in 14 patients (28%); in the remaining cases a tumor remnant was left behind (72%). We tried to analyze the reasons for incomplete resection by reviewing the operative charts and follow-up notes for these patients. In 2 patients, we did not have adequate information to ascertain the reason for incomplete resection. In 12 patients, the surgeon believed that the excision was gross total, but the postoperative images showed residual tumor. In 5 patients, the tumor adhered to the brainstem, and in 4 patients it adhered to major blood vessels. In 6 patients, STR was planned. In 3 patients, a small residual tumor was left behind in the cavernous sinus. In 2 patients, the tumor was extremely vascular, and in 2 other cases, a small remnant attached to the tentorium was left behind.

In 2 patients with residual tumors, tumor progression was noted. Of these 2 patients, one underwent initial SRS followed by excision, and the other underwent direct excision for the growing residual tumor. Eighteen patients with residual tumor underwent SRS. One underwent excision for the residual tumor. The remaining patients with very small residual tumors are undergoing follow-up (Fig. 2).

Neurological Outcome

We used the GOS score, as determined by the primary author, to evaluate neurological outcome following surgery (Fig. 3). A GOS score of 5 was noted in 38 patients (76%), and 8 other patients (16%) had a GOS score of 4. Thus, 92% of patients who underwent resection of petroclival meningiomas in our series had a good outcome (GOS Score 4 or 5). Thirty-one patients underwent follow-up for longer than 6 months, and all maintained the same outcome score.
There was no operative mortality in our series; however, there were 3 deaths in the series that were not related directly to surgery (6%). One patient died 8 weeks after surgery of complications from pulmonary infarction. Another patient developed acute renal failure after surgery and died. This patient had been suffering from chronic renal failure prior to excision. The remaining patient died of sepsis. All deaths occurred more than 30 days after surgery.

New postoperative cranial neuropathies were noted in 22 patients (44%). Thirteen patients developed a single CN dysfunction, and the remaining 9 patients had multiple CN dysfunctions. The CN dysfunctions noticed after surgery were as follows: facial numbness (in 5 patients), facial weakness (in 10), abducent nerve palsy (in 3), oculomotor nerve palsy (in 11), dysphagia (in 3), and respiratory failure (in 2 patients). All cranial neuropathies following surgery were new deficits. In 9 patients (41%), CN dysfunction was transient. Seven patients (32%) had permanent dysfunction, and in the remaining 6 patients, there was no adequate follow-up to determine the nature of disability. Both patients with respiratory failure required a tracheostomy. One patient with swallowing difficulty (lost gag reflex) developed aspiration pneumonitis and required tracheostomy, and the other patient with swallowing difficulty required temporary placement of a nasogastric tube.

Eight patients (16%) developed hydrocephalus; all 8 required placement of a VP shunt. One patient underwent shunt revision. Postoperative hemorrhage in the tumor bed was noted in 3 patients. Of these patients, 1 required reexploration. One patient had a postoperative subdural hematoma that required evacuation. Another patient had loss of vision after resection of a purely posterior fossa tumor. This patient had a large petroclival meningioma for which embolization was performed preoperatively. Postoperatively, he developed hemiparesis and dysfunction of
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CNs VI and VII along with visual loss in the right eye. The origin of this nonintuitive deficit remains unclear, as no pertinent hematoma or ischemic changes were seen on postoperative imaging.

Leakage of CSF from the surgical wound with an associated pseudomeningocele was seen in 1 patient who underwent resection via presigmoid mastoidectomy approach; this patient developed Klebsiella meningitis and was treated with lumbar drainage and antibiotics. After sterility of the CSF was achieved, a VP shunt was placed. Cerebrospinal fluid otorrhea was seen in another patient after resection via a transmastoid approach; this resolved spontaneously without intervention.

One patient suffered a wound dehiscence after petrosectomy and mastoidectomy. This was a reoperation performed 1.2 years after the first operation for recurrence. Both CSF leaks and the wound dehiscence occurred in patients who were undergoing reoperations; this correlation was statistically significant (p < 0.01).

Tumor Recurrence

Adequate radiographic follow-up (minimum 6 months) was available for 31 patients (62%), and thus recurrence rates were calculated using this subset of patients. The mean follow-up was 22.1 months (6–156 months). In 6 (19%) of 31 patients who underwent follow-up for longer than 6 months, tumor progression or recurrences were noted. In 2 patients, resection was subtotal and in the remaining 4, the resection was gross total. In 1 patient who had undergone STR, the remnant was initially treated with SRS, and surgery was performed because the tumor was progressing. The other patient who had undergone STR underwent excision for the growing residual tumor. In 2 patients, the recurrences were small (3 and 5 mm) and did not warrant any further intervention. One patient with recurrence underwent staged SRS, and the other patient underwent excision. The median time to recurrence was 84 months (Kaplan-Meier survival analysis; Fig. 4). Figures 5–8 elucidate representative cases of petroclival meningiomas in our series.

Fig. 4. Kaplan-Meier survival analysis showing the overall recurrence-free survival plot. Only 31 patients with follow-up longer than 6 months were included.

Fig. 5. A and B: Preoperative CT scans showing gross calcification of the tumor. C–F: Preoperative MR images showing a large petroclival meningioma with obstructive hydrocephalus in a 70-year-old patient with hypertension, diabetes, and dyslipidemia. The patient underwent VP shunt placement only, and the tumor is undergoing follow-up. Over the past 3 years, the tumor has remained stable. Conservative management is a good option for asymptomatic tumors, especially in elderly patients and in those with risk factors for surgery.

Discussion

In this retrospective review of our series of petroclival meningiomas, we elucidate our surgical outcomes, complications, and recurrence rates. Petroclival meningiomas, first described by Cushing and Eisenhardt,12 account for about 10% of posterior fossa meningiomas and 1%–2% of all intracranial meningiomas.23 Cushing and Eisenhardt12 considered these lesions to be difficult to treat surgically, especially those that extended into the Meckel cave and cavernous sinus, which they described as Gassero-petrosal tumors. These tumors typically arise from the upper two-thirds of the clivus along the petroclival synchondrosis and originate from the dura mater medial to the skull base foramina of CNs V–XI.

Historically, petroclival meningiomas were considered to be inoperable, progressively enlarging, and inevitably fatal.9,12,23 These tumors pose a technical challenge because of their deep location, difficult accessibility, intimate as-
Evolution in neuroimaging has made it possible to diagnose all brain tumors, including petroclival meningiomas, more often, and often when they are smaller. Improvement in microneurosurgical techniques and the more frequent use of skull base approaches have significantly improved the surgical results for these lesions when compared with early experiences. Proper selection of a surgical approach, meticulous microsurgical technique, and experience of the operating surgeon are the key factors. More medial tumors extending inferiorly and into the cavernous sinus are more difficult to resect.

Despite these surgical advances, however, the practice of even the most experienced cranial base surgeons has evolved to become less aggressive in resecting these complex tumors; residual tumor adhering to the brainstem or CNs, or located in the cavernous sinus is often treated with adjuvant SRS. Likewise, radiotherapy techniques, especially SRS, have evolved, significantly making this a necessary consideration as primary treatment of all small meningiomas and adjuvant treatment of residual meningiomas after resection.

Natural History

Given the rarity of the occurrence of petroclival meningiomas, it is difficult to outline a standard management algorithm. In such a case, the natural history of the disease becomes crucial. In the largest available series evaluating the natural history of petroclival meningiomas, Van Havenbergh et al. found that 76% of 21 untreated petroclival meningiomas demonstrated radiographic growth over a mean follow-up period of 82 months. More worrisome than this finding, however, was that 63% of patients whose tumors grew demonstrated significant functional decline and that 50% of patients who initially had normal CN function developed cranial neuropathy. As one would expect, they also confirmed that, in cases in which the majority of tumor growth was infratentorial, the functional decline was more significant. Although their study had a relatively small patient population, it intimates that aggressive treatment of petroclival meningioma, either with surgery if the patient can tolerate it or radiation therapy, is supported. We agree with this concept and favor resection, especially for large tumors with brainstem compression in the nonelderly population.

Surgical Approaches

Various surgical approaches have been described in the literature. The choice of approach depends on the size and location of the tumor; extension of the tumor (into the middle fossa, posterior fossa, cavernous sinus, sella, sphenoid sinus, and so on); the patient’s age, neurological status, and hearing status; and surgeon preference. Nowhere has the skull base tenet of “remove bone, not brain” been more useful than in accessing the petroclival area. Various approaches have been adopted, including the frontotemporal orbitozygomatic, subtemporal, anterior petrosal, posterior petrosal, partial labyrinthectomy, petrous apicectomy, translabyrinthine, transcochlear, transtotic, total petrosal, retrosigmoid, and far-lateral transcondylar approaches.

In 1975, Bochenek et al. described the extended middle fossa approach to the internal auditory meatus and the CPA. Kawase et al. described the anterior transpetrosal-transtentorial approach to aneurysms of the lower basilar...
artery; this approach was later used to remove petroclival tumors as well. In 1988, Hakuba et al. described the combined retroauricular and preauricular transpetrosal-transtentorial approach to clival meningiomas.

Various authors have successfully used a standard retrosigmoid approach for petroclival meningiomas. Goel and Muzumdar thought that the retrosigmoid approach was indicated in patients who have functional hearing and inferiorly situated meningiomas. However, others have maintained that this approach does not provide an adequate corridor to the clivus ventral to the brainstem and requires significant cerebellar retraction.

Transpetrosal approaches to the petroclival region often provide the most direct view while requiring the least amount of brain retraction; however, these approaches increase the operative time, often cause either sensorineural and/or conductive hearing loss, and have a higher frequency of CSF leakage.

The translabyrinthine approach is useful in patients with unilateral hearing loss and tumors confined mainly to the CPA. This approach minimizes the working distance, allows early identification of the facial nerve, and requires only minimal, if any, brain retraction. For large tumors crossing the midline along the clivus, the translabyrinthine approach can be extended to the transcochlear approach with total petrosectomy to allow a more favorable working angle ventral to the brainstem. Obviously, hearing loss is inevitable with these approaches, and thus we do not recommend their use in patients with preoperative functional hearing.

The total petrosectomy approach gives the widest view with the shortest working distance, but it sacrifices hearing and requires rerouting of the facial nerve. Facial nerve rerouting inevitably causes a facial palsy immediately after surgery; this palsy often does not improve past House-Brackman Grade III, even in the long term.

The far-lateral transcondylar approach increases exposure ventral to the pons and medulla and has been used in tumors that extended significantly inferiorly. The orbitozygomatic approach is useful for tumors that extend
above the tentorial notch. This approach also gained popularity for lesions located at the upper clivus and petrous apex. In our series, the majority of cases were treated via a transpetrosal approach (posterior transpetrosal). Other commonly used approaches included the frontotemporal orbitozygomatic (in 13 patients) and far-lateral transcoccygeal (in 3) approaches.

Extent of Resection

Total resection is the optimal goal in meningioma surgery. However, the proximity of multiple CNs, the brainstem, and the vertebrobasilar system to petroclival meningiomas often leads to significant morbidity with aggressive resection. In our series, 28% of patients underwent a GTR as verified on MR imaging. This is comparable to the findings in most reported petroclival meningioma series (Table 1). Sometimes patients request STR as they do not want any CN deficits. In such cases, we comply with the patient’s request. We believe that size also plays a role in determining the extent of resection. In the literature, the extent of GTR varies between 20% and 85%.2,5,9,29,39 In their series of 33 patients, Bricolo et al.5 reported that total removal was achieved in 26 cases (79%), but in nearly all cases in their series, the patients were in worse clinical and neurological condition after surgery than before. In the largest series of surgically treated petroclival meningiomas thus far,23 GTR was achieved in 32% of cases. Park et al.26 reported a GTR rate of 20% with a morbidity rate of 29%. The factors that most often prevent GTR are cavernous sinus invasion, brainstem pial invasion, vascular encasement, tumor extension into multiple compartments, and medical comorbidities.9 With improvements in SRS and fractionated radiotherapy techniques, we advocate aggressive, but safe, resection with adjuvant radiotherapy for residual meningioma. We believe that this optimizes the chance for a good functional outcome.

Morbidity and Mortality

In the present series, there were no operative deaths and 3 deaths that were not related to surgery, due to pulmonary infarction 8 weeks after surgery, acute renal failure, and sepsis. Again, these results are comparable to other reports in the literature.2,33,39

In the literature, the incidence of CN deficits varied between 28% and 76%.2,5,9,29,33,39 In the present series, 22 patients developed CN deficits after surgery (44%). All cranial neuropathies after surgery were new deficits. In 9 patients, CN dysfunction was transient (41%). Seven patients had permanent dysfunction and in the remaining 6 patients, there was no adequate follow-up to determine the nature of the disability.

We found no correlation between extent of resection and the incidence of complications. Sekhar et al.49 reported that male sex, diminished Karnofsky Performance Scale score, tumor size greater than 2.5 cm, brainstem edema, vascular encasement, and tumor blood supply from the basilar artery were each negative prognostic indicators. Park et al.26 noted that favorable prognosis of preexisting cranial neuropathies and overall favorable functional outcome were associated with STR. We advocate intense postoperative motor, swallowing, and speech rehabilitation to allow a faster return to baseline in those with minimal or no postoperative deficits and to allow the development of coping mechanisms in those with deficits.

Complications and Their Avoidance

Cerebrospinal Fluid Leakage. Leakage of CSF from the surgical wound with an associated pseudomeningocele was seen in 1 patient who underwent resection via a presigmoid mastoidectomy approach. This patient developed Klebsiella meningitis and was treated using lumbar drainage and antibiotics. After sterility of the CSF was achieved, a VP shunt was placed. Cerebrospinal fluid otorrhea was seen in another patient after resection via a transmastoid approach. This condition resolved spontaneously without intervention.

Cerebrospinal fluid leakage through the wound is a known complication of posterior fossa surgery. The incidence of CSF leakage varies between 4% and 17%.2,25,43 Cerebrospinal fluid leakage though an improperly closed dura can drain through mastoid air cells (not properly waxed) to the middle ear cavity and through the eustachian tube and present as CSF rhinorrhea. This is known as paradoxical CSF rhinorrhea. Steps to prevent CSF leakage should start from exposure itself. While performing the craniotomy or craniectomy through a retrosigmoid approach, the mastoid air cells are invariably injured. Adequate care should be taken to plug the open mastoid air cells with bone wax. We advocate water-tight dural closure after posterior fossa surgeries. If the dural edges cannot be approximated, autographs such as fascia lata, pericranium, muscle, and fat can be used to repair dural tube defects. Fibrin glue can be used to reinforce the dural closure. In one study, the incidence of CSF leakage was low when dural closure was augmented with fibrin glue.34 The other synthetic agent that can be used to augment the dural closure is poly(ethylene glycol) hydrogel dural sealant (DuraSeal). In a study by Than et al.,49 the incidence of CSF leakage through the incision was significantly less when dural closure was augmented with DuraSeal than with fibrin glue–augmented dural closure (p = 0.03). Level I evidence is most likely needed to recommend these agents routinely for posterior fossa surgery.

Another problem with CSF leakage is pseudomeningocele. The incidence of pseudomeningocele after poste-
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rior fossa surgery varies between 15% and 28%. Cerebrospinal fluid leaking through the defect in the dura because of improper closure may collect under the skin and tissue planes with resulting fluctuating cystic swelling. If the incision breaks, it will result in a CSF fistula. An enlarging pseudomeningocele may be an indication of progression of hydrocephalus and warrants VP shunt placement. It is logical to assume that proper dural closure may prevent the chance of developing a pseudomeningocele, but in a recent retrospective review, the use of tissue glue, dural grafts, and external ventricular drainage was not associated with a reduced rate of clinically or radiologically diagnosed pseudomeningocele formation or postoperative CSF leakage. Various treatment strategies such as repeated lumbar punctures or a CSF diversion procedure might help in reducing the size of the pseudomeningocele. In 1 study, the authors observed that posterior fossa craniectomy rather than craniotomy was associated with an increased incidence of pseudomeningocele formation.

Injury to the endolymphatic sac, which expands under the dura on the posterior face of the petrous temporal bone inferolateral to the posterior meatal lip, should be avoided; it may be entered while removing the dura from the posterior meatal lip. Injury to the vestibular aqueduct, situated inferolateral to the posterior meatal lip, should also be avoided. Encountering mastoid air cells is common while drilling this region, and these cells must be obliterated meticulously to prevent CSF leakage.

Cranial Nerve Injury. The facial nerve may be injured while performing the transposition of the nerve during a transcochlear approach. Unless the facial nerve is transposed, it is prudent to preserve a thin shell of bone over the facial nerve, thereby preserving the peristeum. While drilling the bone overlying the mastoid segment of the facial nerve (translabyrinthine petrossectomy), the nerve is at risk. Care must be taken while exposing the GSPN (in the middle fossa approach), because in most cases there is no bony roof and the dural fibers are intermingled with the nerve. The nerve must be searched for, and the dura mater is gently separated (often with sharp dissection) from the nerve. It is important to remember that if the GSPN is avulsed while separating the dura mater, the major brunt will be borne by the facial nerve, not the GSPN, which will be cut in any case.

One needs to be careful about using bipolar coagulation close to the facial nerve. Electrophysiological monitoring involves monitoring of facial electromyography during surgery, and this greatly helps the surgeon. Any trauma to the facial nerve during surgery will result in electromyography activity that can be heard over a speaker. Electrical stimulation can be used to locate the nerve even when it is out of direct view, and the threshold for stimulation provides a measure of facial nerve integrity. Unlike a vestibular schwannoma, displacement of the facial nerve by a meningioma varies. Premedical CPA meningiomas have been reported to be associated with poorer postoperative facial nerve function than retrocral tumors. This difference in facial nerve outcome may be due to the fact that in premeatal tumors, the facial nerve is displaced posteriorly toward the surgeon.

Recurrence of Tumor Progression. In our series, recurrence or tumor progression was noted in 6 of the 31 patients with a mean follow-up time of 22.1 months. Only 2 patients with residual tumor have demonstrated tumor progression. We found no statistical correlation between extent of resection and tumor recurrence or progression. Obviously, longer follow-up is necessary to strengthen our recurrence data. Various studies have been undertaken to examine the factors influencing the recurrence in skull base meningiomas. Lefkowitz et al. found that recurrence of skull base meningiomas is dependent on their location of origin and on their propensity to invade muscle, bone, nerve, and major blood vessels. Using multivariate analysis, Tao et al. found 4 factors that predicted a higher recurrence rate: higher histopathological grade, lower extent of resection, irregular tumor shape, and presence of contrast enhancement. Jung et al. found that 42% of residual tumors showed imaging evidence of growth, and the residual tumors had a growth rate of up to 3.7 mm/year. This is far higher than the growth rate found by Van Havenbergh et al. in their natural history study of untreated petroclival meningiomas.

Small Petroclival Meningiomas: a Management Dilemma

In patients with large tumors and brainstem compression or displacement, we consider resection as the treatment of choice followed by adjuvant radiosurgery for the residual tumor, if any, infiltrating a vital structure (for example, blood vessel, CN, the brainstem, or the cavernous sinus). Treatment of small petroclival meningiomas (<3 cm), however, is controversial. When a small petroclival meningioma is diagnosed, the following questions arise: Is the tumor causing any symptoms? Could the symptoms improve if the tumor is treated? Should the lesion be treated if the patient is asymptomatic? If yes, then when? Is the wait-and-see strategy appropriate for minimally symptomatic or asymptomatic tumors, and for how long? Does procrastination render the tumor possibly inoperable? Which treatment provides the best chance of a “safe” cure of these lesions?

Radiosurgery is a frequently used treatment for small benign lesions at the cranial base; its objective is to obtain control of tumor growth and improve the clinical symptoms. The role of SRS for primary treatment of petroclival meningiomas is gaining favor. It is being considered a good first-line treatment for patients with small tumors (<3 cm) or for elderly patients who may not tolerate surgery because of medical comorbidities. Subach et al. reported a 92% tumor control rate and a 5% complication rate over a mean follow-up of 37 months. Roche et al. reported a 100% tumor control rate with a 6.3% complication rate over a mean follow-up period of 56 months. These results are promising, but longer follow-up studies are needed. The problem with comparing the results of radiosurgery with those of surgical series is that the indications for the two treatment methods are different. Radiosurgery is the preferred modality for small lesions, and excision is indicated for medium and large tumors and those with mass effect.

Rare reports of the development of secondary malignancy or malignant transformation of the treated tumor after SRS do exist, however, a more recent study
consisting of 5000 patients who underwent SRS for various pathologies and had 30,000 years of total follow-up found no increased risk of malignancy after SRS. However, putative complications of radiosurgery such as CN deficits and ischemic lesions of the brainstem may appear later (12–18 months) after treatment. All patients treated with this method have residual tumor, and in about 8% of patients, the tumor will grow.

The comparison between radiosurgical and surgical series contains much bias because in the latter group, the majority of the patients have larger tumors. Ramina et al. presented their series of patients with small petroclival meningiomas (diameter ≤ 2.8 cm) treated with radical surgical removal. Total resection (Simpson Grade I) was possible with minimal morbidity and no mortality. Although the present study does not deal solely with small petroclival meningiomas, we believe that the best and perhaps only chance to treat a patient with a petroclival meningioma, while preserving neurological function, is radical removal when the tumor is still small.

Conclusions

Harvey Cushing’s advice and judgment are still seminal pearls regarding petroclival meningiomas. When to be aggressive, when to back off, and when to be conservative is a matter of surgical gestalt that develops from personal experience.

Petroclival meningiomas still pose a formidable challenge to neurosurgeons. In our series, we used multiple skull base approaches and careful microneurosurgical technique to achieve a good functional outcome (GOS Score 4 or 5) in 92% of patients, although we attained a GTR in only 28% of patients. Our primary surgical goal was to achieve maximal tumor resection while maintaining or improving neurological function. We consider SRS the treatment modality of choice for residual or recurrent tumor.

Disclosure

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

Author contributions to the study and manuscript preparation include the following. Conception and design: all authors. Acquisition of data: Javalkar. Analysis and interpretation of data: Javalkar. Drafting the article: all authors. Critically revising the article: all authors. Reviewed final version of the manuscript and approved it for submission: Nanda.

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