Current Management of Petroclival Meningiomas

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Lesions of the petroclival area have long been considered by neurosurgeons as unreachable,[1,2] and until recently, patients afflicted with meningiomas in this region have carried poor prognoses, usually with a lethal outcome.[1,2] Refined approaches and advances in microsurgery techniques, along with the aid of intraoperative monitoring, have encouraged neurosurgeons to reevaluate the efficacy of surgery and to accept the challenge of tackling these formidable lesions. Although the complication rate remains high, developments in microsurgery techniques with magnification, and a better understanding of the anatomic behavior of these tumors have led to a reduced rate.[1,5–12] A variety of approaches have been used to remove these tumors. We prefer the "petrosal approach" because it allows exposure of the tumor from the middle fossa to the region of the foramen magnum and has several other advantages.

HISTORICAL REVIEW

"Clivus" means "slope" in Latin. This term for the clival bone was coined by Blumenbach, a German physician and anthropologist.[15] Clival and petroclival meningiomas are thought to arise in the "spheno-occipital synchondrosis," the vicinity of the articulation between the sphenoid and the occipital bones.[15,16] The earliest report of a clival meningioma was by Hallopeau, who in 1874 described a lower clival meningioma.[15] This was a small tumor that was found at autopsy in a patient who died after presenting with paralysis of the upper extremities followed by paralysis of the lower extremities, with no significant sensory deficits. In 1953, Castellano and Ruggiero divided posterior fossa meningiomas into different categories according to their dural attachments. Their classifications included cerebellar convexity, tentorial, posterior aspect of the petrous bone, clivus, and the region of the foramen magnum. Meningiomas located on the posterior surface of the petrous bone and the clivus accounted for 55% of their cases. They limited the term "clival meningiomas" to only those lesions that were attached to the superior part of the clivus; they excluded the "inferior clival meningiomas," considering them foramen magnum meningiomas.[2] A decade later, Dandy et al., in their definition of clival meningiomas, excluded meningiomas that totally engulfed the basilar artery or infiltrated between the basilar artery and the brain stem, violating the arachnoid spaces; they limited the term to only those lesions that grow along the clivus anterior to the basilar artery.[16] Subsequently, Yasargil et al. further differentiated the basal posterior fossa meningiomas into five subgroups: clival, petroclival, sphenopetroclival, foramen magnum, and cerebellopontine angle meningiomas.[7]

Although the above descriptions include most of the meningiomas in the petroclival region, a subgroup of meningiomas that extend from the petroclival area into Meckel's Cave and involve the cavernous sinus region still remained. These were first described as Gassero petrosal tumors by Cushing, who noted they invariably become partly supratentorial and partly infratentorial.[1] However, Yasargil later identified these tumors as being sphenopetroclival meningiomas.[7]

In this report, we consider the clival (medial origin), petroclival (origin at the petrous tip medial to the V nerve), and sphenopetroclival (origin at Meckel's Cave) meningiomas as one surgical group, which we call "petroclival meningiomas."

CLINICAL PRESENTATION

Petroclival meningiomas follow the pattern of other meningiomas in their 2:1 female-to-male ratio.[2,16] The average age of presentation is the mid-forties.[illegible] Although the tumor has been traced in some patients as far back as 17 years prior to presentation,[illegible] the recent trend has been toward earlier diagnoses, which is most likely due to the recent advances in neuroimaging diagnostic techniques.

The patients present insidiously with an average onset of symptoms of 3 to 5 years duration before diagnosis. The neurologic presentation of patients with petroclival meningiomas varies; the clinical symptoms are due to: increased intracranial pressure (ICP), involvement of the cranial nerves, cerebellar compression, or compression of the brain stem. In a 1977 report by Hakuba et al. on 44 cases of petroclival meningiomas, presentation was due to increased ICP (70%), cerebellar involvement (70%), impairment of the V nerve (68%), hearing loss (64%), facial nerve palsy (57%), and involvement of the corticospinal tract (57%). Other symptoms were related to involvement of other cranial nerves, nystagmus, or sensory deficits.[9] In a series by Mayberg and Symon, the most common presenting symptoms were gait disturbances and headaches.[17]

In our review of 35 patients, cranial nerve deficits and cerebellar ataxia were the most common physical findings. Cranial nerve deficits were frequent findings in several other series, with the V and VIII nerves being the most commonly involved.[illegible] The ocular motility nerves were infrequently involved at presentation, although in the majority of patients the tumors were intimately related to these nerves anatomically.[5]

PREOPERATIVE EVALUATION

Detailed preoperative radiologic work-up of a patient with a petroclival meningioma is essential. Computerized tomography (CT) scans and magnetic resonance imaging (MRI) with contrast enhancement provide crucial information for the surgical plan (Figs. 1, 2). Information gleaned include: the exact location and extension of the tumor; its relationship to the surrounding neural structures (including the brain stem and cranial nerves); the possible encasement of cerebral vessels; any involvement of the cavernous sinus and the temporal bone; and the presence or absence of associated hydrocephalus. The T2-weighted MRI images are also helpful in predicting the consistency of the tumor: a hyperintense tumor on a noncontrast T2-weighted image indicates a tumor with high water content and may predict a soft "suckable" tumor.

Cerebral angiography with visualization of both the carotid and vertebral circulation is considered an essential component of the preoperative diagnostic work up. We recommend very carefully studying the venous aspect of the circulation, a practice that has provided us with valuable information for planning the surgical approach and preserving important venous drainage. More recently, we have used both MR angiography and venography.

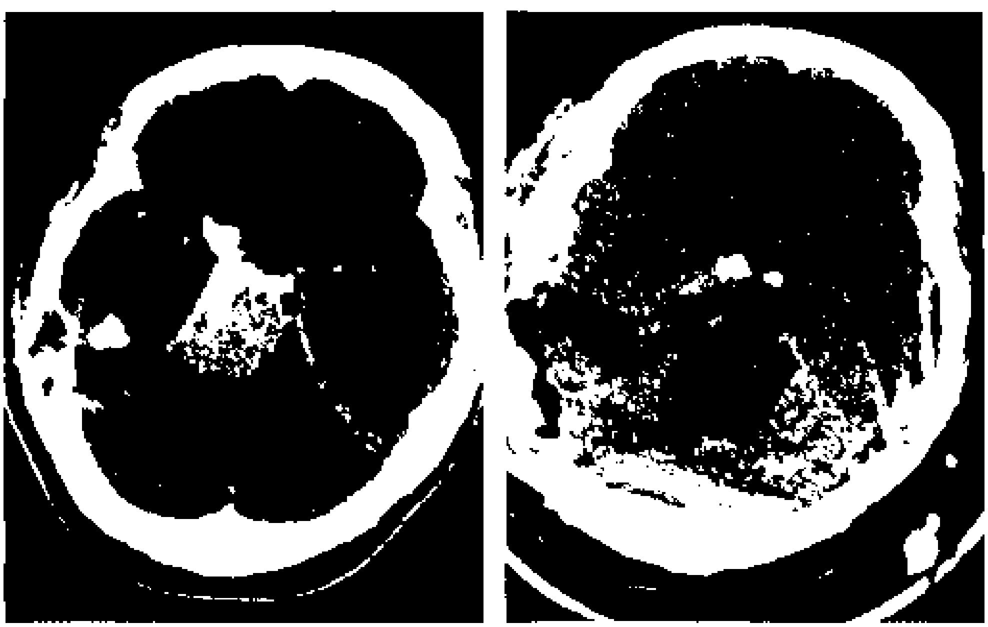
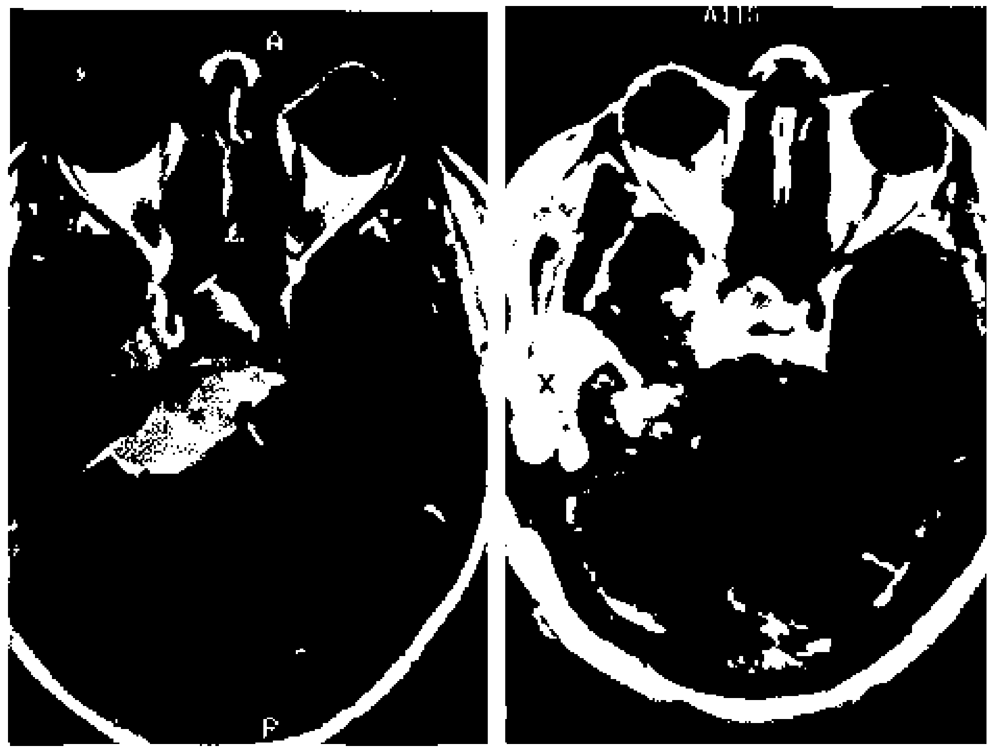


Fig. 1 **(A)** Preoperative contrast enhanced axial CT scan of a right petroclival meningioma. **(B)** Postoperative axial CT scan of the same patient showing complete tumor resection.

A



B

Fig. 2 **(A)** Preoperative contrast enhanced axial T1 weighted MRI showing right petroclival meningioma (*) that also extends in to the cavernous sinus (*). Note the engulfment of the basilar artery (arrow) by the tumor. **(B)** Postoperative contrast enhanced axial T1 weighted MRI showing complete tumor resection. Note the fat graft in the tumor bed (X).

The angiographic relationship of the basilar artery is critical. Frequently the basilar artery is usually pushed posteriorly and to one side (Fig. 2A). No displacement may occur if the basilar artery runs either along the anterior aspect of the tumor or in the tumor bed itself, which has encased the artery. The posterior and superior cerebellar arteries usually are frequently elevated on the same side of the tumor, and they may become separated as the tumor extends through the tentorial incisura. The angiogram also helps delineate the blood supply. Petroclival meningiomas usually recruit branches from the intracavernous portion of the internal carotid artery, as well as the external carotid branches, via the ascending pharyngeal and middle meningeal arteries. The venous phase of the angiogram is helpful in demonstrating the presence and the contribution of the two transverse sigmoid sinuses and in delineating the course and dominance of the vein of Labbé.

MANAGEMENT

We maintain that the best treatment for clival and petroclival meningiomas is radical surgical removal (Figs. 1, 2). Although these tumors remain among the most challenging of all meningiomas to treat surgically, total removal of petroclival meningiomas is feasible and is best achieved during the first operation.[illegible] When a subtotal removal of these tumors must be accepted, a good outcome may still result, particularly in cases of slow-growing tumors, allowing the patient to enjoy a productive, functional survival. Small and asymptomatic meningiomas, particularly in elderly patients, can be observed and followed with neurologic exams and MRIs.

Surgical Approaches

Various approaches have been used to remove these tumors. A few of these are the frontotemporal,[illegible] the occipital transtentorial,[21] the subtemporal transtentorial,[illegible] the suboccipital,[illegible] the combined subtemporal and translabyrinthine,[illegible] the transcochlear,[illegible] the combined suboccipital translabyrinthine,[illegible] the transtemporal,[illegible] the anterior transpetrosal-transtentorial, the retromastoid, the pterional, the subtemporal, the combined retromastoid-subtemporal, and the presigmoid.

Petrosal Approach

We recommend the "petrosal approach." This approach has evolved from modifications of the suboccipital craniectomy combined with the translabyrinthine approach used in 1904 by Fraenkel and Hunt for acoustic tumors.[33] Morrison and King added the subtemporal supratentorial approach with ligation of the sinus and cutting of the tentorium,[25] and Hakuba et al. further modified the approach by preserving the vestibular apparatus.[9] Al-Mefty et al. later introduced the unilateral temporal and suboccipital approaches combined with drilling of the temporal bone through a presigmoid retrolabyrinthine exposure. They reported on 13 cases of surgical removals of petroclival meningiomas with preservation of the sigmoid sinus and the vein of Labbé, as well as the facial nerve, the facial canal, the cochlea, and the labyrinth.[8] More recent reports indicate the popularity of this approach and its frequent use.[illegible]

Operative Advantages

The petrosal approach allows exposure of the tumor from the middle fossa to the region of the foramen magnum. It has several advantages, including the following:

1. Minimal retraction of the cerebellum and the temporal lobes
2. Shortening of the operative distance to the clivus
3. Possible preservation of the neural and autologic structures (cochlea, labyrinth, and facial nerve)
4. Preservation of the transverse and sigmoid sinuses, as well as the vein of Labbé and several basal, temporal, and occipital veins
5. Early interception of the blood supply to the tumor on the posterior petrous bone surface
6. Ability to drill and remove the invaded portion for the petrous bone
7. Availability of a wide field of vision, providing multiple axes of dissection
8. Means for the surgeon to have a direct line of sight to the anterior and lateral aspects of the brain stem.

Positioning the Patient

The patient is placed in a supine position, and the table is flexed 20-30 degrees to allow elevation of the head and proximal trunk. The ipsilateral shoulder is slightly elevated with a shoulder roll. The head is turned away from the surgical side, inclined toward the floor, and tilted toward the opposite side. The position of the neck should be checked carefully to assure that contralateral jugular vein compression has not occurred with this maneuver. The head is then fixed in a three-point Mayfield headholder. After the patient is properly positioned and the side for the incision is decided, the electrodes for the electrophysiological monitoring are attached. We routinely obtain brain stem auditory-evoked potentials and median nerve somatosensory-evoked potentials bilaterally. Facial nerve function is monitored using electromyography (EMG) of several facial muscles on the ipsilateral side. Monitoring of other cranial nerves is performed in the same fashion when indicated.

Skin Incision

A reverse question mark shaped incision is made starting at the zygoma in front of the ear, circling above the ear, and descending two finger breadths medial to the mastoid process (Fig. 3). The skin flap is elevated and then retracted anteriorly and inferiorly. The large triangular pericranial flap with its adequate vascular base is elevated and retracted over the skin flap all the way to the level of the external ear canal. The temporal muscle is elevated and retracted anteriorly and inferiorly, and the sternocleidomastoid insertion is detached from the mastoid process and retracted posteroinferiorly (Fig. 4). This allows adequate exposure of the temporal fossa, the mastoid process, and the lateral posterior fossa regions.

Fig. 3 The skin incision (right side, artistic illustration). Note its relationship to the suture lines and bony landmarks, as well temporalis (TM) and sternocleidomastoid (SM) muscles.

Petrosal Craniotomy

Four burr holes are made for a bone flap, two on each side of the transverse sinus. One hole is made medial and just inferior to the asterion in the posterior fossa and below the transverse sigmoid sinus junction, and another hole is drilled at the squamal and mastoidal junction of the temporal bone and leads to the supratentorial compartment (Fig. 4). These burr holes are good markers of the exact location of the sigmoid sinus that lies between them. The foot attachment of a high-speed craniotome is used to incise a bone flap that includes the temporal bone above the tentorium and a portion of the occipital bone. The burr holes flanking the transverse sigmoid region are then connected using a thin rongeur or a B-1 attachment of the Midas Rex drill. Care is taken to avoid drilling through the outer wall of the sigmoid sinus, which protrudes outward and into a bony impression on the inner surface of the skull. The bone flap is elevated, and the transverse sinus is exposed, with special care being given to its attachment at the junction of the transverse and sigmoid sinuses. This concludes the first part of the exposure and leads to the second stage, drilling of the temporal bone.

Drilling the Temporal Bone

Drilling of the temporal bone requires a thorough knowledge of the anatomy of the petrous bone and the surrounding structures. This part of the procedure is performed using the microscope. The first step is to perform a mastoidectomy using a high-speed air drill. The diamond bit is used when

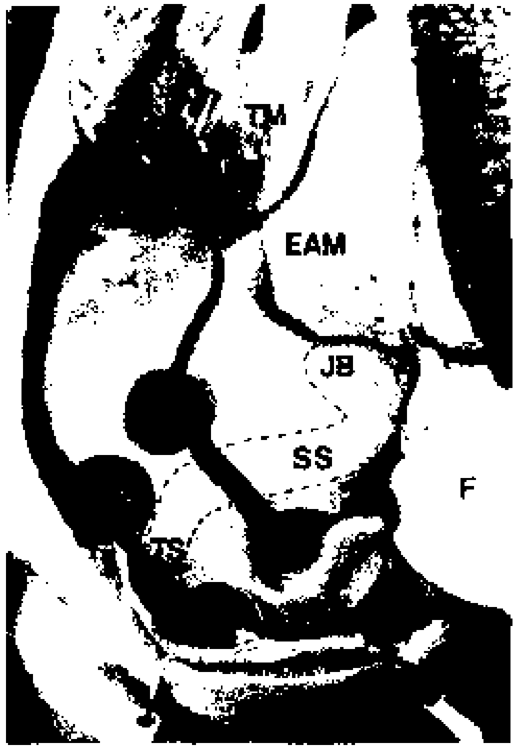


Fig. 4 The petrosal craniotomy (right side, anatomic specimen). The temporal and sternocleidomastoid fascia (F) is reflected inferiorly, whereas the temporalis muscle (TM) is reflected anteriorly. The craniotomy is performed with burr holes located above and below the transverse (TS) and the sigmoid sinuses (SS). The course of the sigmoid sinus is delineated, as is the expected level of the jugular bulb (JB). Note also the position of the external acoustic meatus (EAM).

drilling near vital anatomical structures. The sigmoid sinus is exposed and skeletonized distally to the region of the jugular bulb. The sinodural angle (Citelli's angle), which identifies the location of the superior petrosal sinus, is also drilled. Drilling of the mastoid begins behind the posterior wall of the external ear canal and continues more deeply until the facial canal and the lateral and posterior semicircular canals are reached. (The depth of the drilling can easily be guided by the level of the antrum of the mastoid.) Once the sigmoid sinus has been skeletonized, the retrolabyrinthine portion of the temporal bone is removed, thereby exposing the posterior fossa dura in the presigmoid region (Fig. 5). Drilling is continued along the petrous pyramid toward the petrous apex region. Extra precaution should be exercised to preserve the facial canal, as well as the middle and inner ear structures. Opened air cells are obliterated with bone wax.

Opening the Dura

The posterior fossa dura is opened anterior to the sigmoid sinus. The incision extends from the level of the jugular bulb upward to meet the supratentorial dural opening along the floor of the temporal fossa (Fig. 5). The temporal lobe is gently retracted superiorly, anterior to the junction of the vein of Labbé and the transverse sigmoid region. Extra precaution is taken to prevent any kinking or compression of the vein of Labbé. The superior petrosal sinus is then coagulated and cut. The incision is carried medially along the tentorium and parallel to the petrous pyramid to the medial edge of the tentorial incisura. This step is performed with extra precaution to locate and preserve the trochlear nerve along its course medial to the incisura and as it pierces the inferior aspect of the tentorium. The tentorium is cut to allow exposure of the upper portion of the tumor and the anterior and lateral aspects of the brain stem. The trigeminal nerve rootlets frequently are seen under the tentorial surface, stretched and separated by the tumor mass. The dura of the posterior fossa is opened anterior to the skeletonized sigmoid sinus, and its opening is continued inferiorly as far as the jugular bulb. The cerebellar hemispheres then can be retracted posteriorly, allowing exposure of the more lateral portion of the petroclival region inferiorly and of the more

Fig. 5 The dural exposure (right side, anatomic specimen). Drilling of the mastoid process and the presigmoidretrolabyrintine portion of the petrous bone is completed. The interrupted line delineates the dural incision. Also note the preserved semicircular canals, superior (SSC), lateral (LSC), and posterior (PSC); the external acoustic meatus (EAM); the sigmoid sinus (SS); the superior petrosal sinus (SPS); the vein of Labbé (Labbé); the emissary vein (EV); and the jugular bulb (JB). Note also the posterior fossa dura (PFD).

medial portions superiorly. This exposure precludes the need to cut the sigmoid sinus and achieves the same advantage by alternating the position of the microscope from supratentorial to infratentorial angles (Figs. 6A,B).

Resecting the Tumor

After the dura has been opened, further relaxation of the brain is obtained by draining cerebral spinal fluid (CSF) from the arachnoid cisterns. Interrupting the blood supply to the tumor, which is preferentially addressed first, is performed by coagulating its dural attachment to the posterior aspect of the petrous pyramid. The arachnoid over a chosen area of the tumor is then opened, and the resection of the tumor is begun. The tumor is debulked using a suction, a Cavitron Ultrasonic Surgical Aspirator, the bipolar coagulation, and, occasionally, the laser, with care being taken to avoid injury to the cranial nerves, which are usually splayed around the tumor. The VII and VIII cranial nerves are more easily seen around smaller tumors. In tumors that are very large often the nerves are significantly thinned and flattened; they may also be engulfed by the tumor. The posterior and anterior inferior cerebellar arteries also may be embedded in the tumor. An angiogram may be helpful in providing information related to these facts.

Once the tumor has been debulked, the surrounding capsule becomes more mobile, and the arachnoidal planes can be dissected more easily. Preservation of these arachnoid planes is crucial in order to preserve the adjacent neurovascular structures, including the brain stem, the cranial nerves, and the basilar artery and its branches. Dissection of the lower cranial nerves off the inferior pole of the tumor is performed very gently to avoid hypotension and bradycardia from vagal stimulation that can result from aggressive handling. The VI nerve, which is usually stretched anteriorly and inferiorly, is also dissected free from the tumor and followed distally. The tumor capsule is then dissected off the brain stem, which is best done by preserving the arachnoidal plane in which all the surface vessels are located. In some cases, the basilar artery may be embedded in the tumor, in which event, extra precaution is needed to preserve the small branches arising from the basilar trunk. Although in the majority of cases preservation of these vessels is possible with complete removal of the tumor, it is far better to leave some tumor than to sacrifice these important perforating vessels. Drilling the internal auditory meatus may be necessary if the tumor extends into it, and, likewise, the jugular foramen may require widening if the tumor extends into it. Hyperostotic bony segments of the petrous bone are drilled with a high speed air drill using a diamond bit.

Closing the Wound

We routinely prepare the thigh as a donor site for a piece of fascia lata. We also harvest subcutaneous fat from the thigh or from a separate abdominal

Fig. 6 **(A)** The inferior intradural portion of the exposure (right side, anatomic specimen). It allows visualization of the pons (P) the lower cranial nerve complex (IX-X) and the trigeminal nerve superiorly (V). Note also the reflected dura (D), the cut edge of the tentorium (T), and the anterior inferior cerebellar artery (AICA). **(B)** The superior intradural portion of the exposure (right side, anatomic specimen). The visualized space extends from the level of the oculomotor nerve (III) to the level of the cranial nerves VII-VIII. Note also the posterior cerebral artery (P_2), superior cerebellar artery (SCA), pons (P), mesencephalic vein (V), IV nerve and the lateral (LSC), posterior (PSC) and superior (SSC) semicircular canals.

incision if necessary. The fascia lata is used as part of the dural closure, and it is usually fitted into the presigmoid region and held in place with stay sutures. The remainder of the dura is closed in a watertight fashion, and a subcutaneous fat graft is applied into the mastoid region above the grafted fascia lata. The pericranium is then turned over the petrous bone and sutured in place, followed by rotating the temporalis muscle over the defect and suturing it to the edges of the sternocleidomastoid muscle. The soft tissues are closed in multiple layers. Occasionally, we use fibrin glue to further reinforce the watertight closure, and as an extra precaution. In our experience meticulous closure has dramatically decreased the incidence of CSF leaks during the postoperative period.

SURGICAL OUTCOME

Hakuba et al. in 1977 reviewed the literature of reported petroclival meningioma cases and found 44 cases, of which 31 had been treated surgically: total removal was achieved in only three patients, 17 died within the first month of the postoperative period, and another two became worse after surgery. Of their own six cases of total removal, only one patient died.[8] Their results were considered a major improvement in the surgical management of these formidable lesions, and as a consequence, became a turning-point in the use of surgery. In 1980, Yasargil et al. reported even better results in their experience with 20 clival cases, of which 13 were subtotal removals (intrathecal radical, but with tumor left in the dural, epidural, and osseous areas) and seven were total. Of the 13 subtotal resections, the outcomes were good (fully employable) in six cases, fair in three cases, and poor in two cases, with two mortalities. The remaining seven patients had total resections, and the outcomes were good (self supporting and working) in five and fair in two; there were no mortalities.[7]

More recent series also have reported zero mortality rates.[illegible] The improvement in the mortality rate occurred with increased extent of tumor resection. The reported rate of total removal has increased from a low 25% up to 86%.[illegible] Symon et al. followed 36 patients for up to twelve months postoperatively; 26 patients had subtotal resections, and 9 had total resections. Four patients died from problems related to recurrence that appeared between 9 and 32 months postoperatively.[15] Their results seem to favor subtotal removal, but the follow up period was not long enough to be conclusive, and further progression of the subtotally removed tumors is possible.

In 1991, Kawase et al. reported on a series of 10 patients with sphenopetroclival meningiomas on whom they used the anterior transpetrosal-transtentorial approach; they achieved total tumor resection in seven patients (70%), with no resultant mortality.[16] That same year, Javed and Sekhar reported their results using a variety of skull base approaches between 1983 and 1990 on 52 patients with petroclival meningiomas.[illegible] They achieved total tumor resection in 38 cases (73%), subtotal resection in 11 (21%), and partial resection in 3 (6%); two postoperative deaths occurred, one from pneumonia and the other from infectious complications. In 1992, Samii and Tatagiba reported successful total removal in 27 (75%) of the 36 patients with petroclival meningiomas on whom they operated between 1978 and 1990. They had no postoperative deaths and, in 83%, no severe morbidity.[illegible]

In our experience, total removal can be achieved in up to 86% of patients with zero mortality. We previously have reported on 33 patients with meningiomas (n=21), schwannomas (n=7), and epidermoid tumors (n=5) who were treated between 1983 and 1989; total removal was achieved in all but 3, all of whom harbored meningiomas.[3]

COMPLICATIONS

Complications related to surgical management of petroclival meningiomas remains as high as 50% and usually are related to cranial nerve deficits that are transient in the majority of cases.[illegible] The most serious complications are related to brain stem injury, which can be devastating and is usually due to compromise of the blood supply to the brain stem.[illegible] In the more recent series, these complications have decreased due to the use of microsurgical techniques with magnification and a better understanding of the anatomic behavior of these tumors, especially the knowledge that the preservation of the arachnoid planes helps in recognizing the blood vessels in the vicinity of the tumor and avoiding their injury.

Hemorrhagic venous infarction of the temporal lobe is another complication that can be devastating, especially if it occurs in the dominant hemisphere. This is usually due to injury to or coagulation of the vein of Labbé or the basal temporal veins.[illegible] To avoid such injury, a thorough evaluation of the preoperative venous phase of the angiogram is essential and helps in delineating the major draining veins around the posterior temporal lobe region. Occasionally, the vein of Labbé is not dominant, and a more anterior and inferior vein plays the prominent role in the drainage of the temporal lobe. Saving these veins is a necessity, as is minimizing their trauma during surgery because, even though the veins may be anatomically saved, an extended period of compression with the subtemporal retractors may cause them to thrombose, leading to a dismal outcome.[illegible]

Posterior fossa hematomas are potential complications after surgery of petroclival meningiomas. Using the retrolabyrinthine presigmoid approach should minimize the extent of retraction of the cerebellum, thereby decreasing the trauma to it and the possibility of postoperative cerebellar hematoma or swelling. Elevating the head during surgery may enhance venous drainage and mask potential venous bleeders. For this reason, a Valsalva maneuver and jugular compression should be performed to confirm meticulous hemostasis before closure.

Depending on the size of the petroclival meningioma, any of the cranial nerves is at risk of injury during surgery. The trochlear nerve can be injured because of its flimsiness and softness, especially in its subarachnoid course in the ambient cistern. To avoid its injury, we recommend isolating the nerve and using the suction device with a control gauge. By decreasing the strength of the suction and covering the nerve with a cottonoid, the chances of sucking the nerve, which causes permanent injury, are decreased. Morbidity from trochlear nerve injury is minimal, but can be troublesome. Complete injury to the trigeminal nerve is less frequent due to its large size, but a trigeminal nerve paresis is a frequent occurrence. This is a potentially serious complication due to the corneal anesthesia that may cause keratitis, a possibility that becomes more likely when there is an associated facial nerve paralysis. In these cases, we recommend immediate postoperative tarsorrhaphy to protect the involved eye until the facial nerve functions are restored. Surgical manipulation of the trigeminal nerve may also result in postoperative facial pain, anesthesia dolorosa, and/or a trigeminal neuralgia-type of picture.[7] The facial nerve is usually displaced posteriorly by the tumor. The chance of its injury is increased in proportion to the increase in the size of the tumor. When injury occurs, intraoperative end-to end anastomosis or graft repair is recommended. Recovery has occurred in 40–80% of reported cases in acoustic tumor series.[13]

Loss of hearing is common with patients with petroclival meningiomas. If the hearing is normal, we recommend several steps to preserve a functioning nerve. It is important to spare the cochlear blood supply and to apply cerebellar retraction in a caudal-to-rostral direction, which minimizes the chances of traction injury of the nerve. In addition, extra precaution is needed during the bone drilling phase to preserve the inner ear compartments. In the postoperative period, injury to the vagus or glossopharyngeal nerves leads to significant compromise in the cough and/or gag reflex, and, as a result, serious pulmonary complications and pneumonia. These nerves should be handled very gently, and if their injury is documented, we recommend an early tracheostomy and tube feeding as preventive measures to avoid a prolonged and morbid postoperative course from pulmonary complications.

CSF leakage is a potentially serious complication of the petrosal approach. It is best avoided with a watertight closure that is supported with a fascia lata flap and subcutaneous fat. The rotation of a vascularized temporalis muscle flap helps seal the potential pathways of a CSF leak. Should a CSF leak occur, we recommend elevating the head and inserting a continuous spinal drainage system as the initial management. If the leak persists after a few days of drainage, the leakage site should be verified with a CT cisternogram and reexploration of the wound and a watertight closure with a fascia lata graft should be performed. Occasionally, an underlying hydrocephalus may be the precipitating cause and should be treated with a shunt.

CONCLUSION

Although surgical management of petroclival meningiomas remains a challenge to neurosurgeons, the advances in diagnostic imaging and microsurgical techniques, along with those of intraoperative monitoring devices, render these lesions considerably more manageable than in the past. The reports of successful surgical extirpation of these meningiomas, along with our own experience, demonstrate that a radical surgery is indicated. The complications can be disastrous, but most are less serious and transient, and microsurgical techniques with magnification in conjunction with a better understanding of the anatomic behavior of these tumors have greatly decreased both the incidence and the severity of complications.

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