Surgical Approaches to Petroclival Meningiomas Part I: Upper and Midclival Approaches

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Strictly considered, *petroclival* meningiomas represent only a percentage of the 10% of all intracranial meningiomas that reside in the posterior fossa. Although not statistically frequent, with their location in proximity to cranial nerves, the basilar artery and its perforating branches, and the brainstem, these tumors have been considered to represent some of the most formidable challenges in skull base surgery. It is no surprise that the removal of petroclival meningiomas historically has been associated with high morbidity and mortality; in testimony to this fact, before 1970 the reported risk of mortality from resection of petroclival meningiomas was > 50%. Indeed, a successful total removal was reported in only one case prior to 1970, and as recently as 1967 these tumors were deemed by some authorities to be inoperable. However, left unchecked, continued growth of these tumors in this location will result in a natural history of brainstem compression with ultimate progression to fatality.

With the advent of improved radiographic evaluation and microsurgical techniques, removal of these tumors has become increasingly safe, with more recent published series reporting mortality rates <10%. When planning a surgical approach to these lesions, the surgeon must consider the presenting symptoms, precise anatomical location, and size of the lesion when formulating the goals of surgical resection for an individual patient.

This topic will be covered in two lessons. Part I discusses classification, clinical presentation, and upper and midclival surgical approaches. Part II, which will appear in the next lesson, will cover extended surgical approaches, staged resections, results and complications, and adjuvant therapy.

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Classification

As noted by Al-Mefty and Smith, there has been no reported systematic classification of clival and petroclival meningiomas. Previous classifications of posterior fossa meningiomas have been presented by Castellano and Ruggiero, and Yasargil et al. Using postmortem studies, Castellano and Ruggiero classified posterior fossa tumors by site of dural attachment. They described locations as follows: cerebellar convexity (10%), tentorium (30%), posterior petrous (42%), clivus (11%), and foramen magnum (4%). They did note, however, a group of tumors that extended from Meckel's cave into the posterior fossa. Based upon intraoperative observations, Yasargil et al. classified posterior fossa tumors as those with primary attachment to clival, petroclival, sphenopetroclival, foramen magnum, or cerebellopontine angle locations.

From a surgical standpoint, tumors emanating at or medial to cranial nerves in the posterior fossa represent significant challenges and should be strictly classified within the context of *petroclival*. These tumors do remain a significant surgical challenge and some of the more contemporary surgical approaches may facilitate their removal. The one confounding location in classifying these lesions by this method is illustrated by the tumors that not uncommonly emanate directly from the region of Meckel's cave; Cushing ascribed the name *gasserо-petrosal* (equivalent to the sphenopetroclival tumors of Yasargil) to these tumors. With continued growth, such tumors invariably become both supra- and infratentorial, and occupy both medial and lateral positions to the fifth nerve. From a clinical perspective, these tumors are to be

Category: Tumor

Key Words: Meningiomas • Petroclivus • Surgical approach • Upper clivus • Midclivus

- Location of skull base attachment (upper/mid/lower clivus and medial/lateral)
- Extent of basal attachment (eg., supra and/or infratentorial)
- Preoperative cranial neuropathies (especially status of hearing)
- Goals of resection

Table 1. Considerations when choosing a surgical approach

Retromastoid	60 (53%)
Combined petrosal (with retrolabyrinthine, translabyrinthine, transcochlear)	22 (19%)
Subtemporal	12 (11%)
Transtemporal	11 (10%)
Frontotemporal transcavernous	8 (7%)

Table 2. Surgical approaches chosen for petroclival tumors in our series of 109 patients (four cases required staged procedures).

considered with those originating medial to Meckel's cave (either apical petroclival or pure clival), as strategies for their surgical management will be similar. As such, they are considered by most authorities to be included in the petroclival classification. The upper and middle clival region includes the posterior clinoid processes, the dorsum sellae, and the clivus down to the jugular foramina. We agree with other authors in considering tumors located on the lower third of the clivus as being primarily foramen magnum lesions and as such will not be discussed in either part of this lesson (Fig. 1 and 2).

Clinical Presentation

Remarkably, these lesions may attain strikingly large size with relatively minimal symptoms. The usual presentation of a petroclival tumor is in a patient in midlife with a long history of rather insidious symptoms (up to several years). Symptoms may relate to cranial nerve impairment, cerebellar or brainstem compression, or increased intracranial pressure. Our experience is consistent with that of Mayberg and Symon, in that the most common symptoms in our series were gait disturbance or headache, while cranial nerve palsies represented the most common presenting signs. Headache may be secondary to hydrocephalus from compression of the aqueduct with raised intracranial pressure. Symptoms from brainstem or cerebellar compromise, such as motor deficit or gait disturbance, are often very slowly progressive and in many cases the diagnosis is delayed. Cranial neuropathies may include any within the posterior or middle fossa, with unilateral hearing loss or facial sensory disturbances being the most frequently encountered.

Surgical Approaches

In approaching tumors adjacent to midline neurovascular structures, the goal is to minimize cerebellar or brainstem retraction. In many instances, bone removal may be necessary to facilitate medial exposure and minimize retraction on neural structures. In choosing an approach to a particular tumor, several factors must be considered (Table 1). The most important consideration in planning an approach is the location and extent of the skull base attachment. Careful examination of the preoperative gadolinium-enhanced MRI provides the surgeon with the most valuable information regarding skull base attachment and/or involvement by the tumor. In particular, using high-field, thin-section MRI, many cranial nerves may be visualized in their intradural course, and any deviations or loss of continuity within the tumor mass should be carefully noted. In general, sizable lesions with the entire mass within the posterior fossa will necessitate some suboccipital and/or transtemporal bony removal. Extension beyond the tentorial hiatus will require additional supratentorial exposure if total removal is to be attempted; this may be accomplished either by direct supratentorial transsylvian or subtemporal exposure, or opening the tentorium via the posterior fossa. Midline tumors, such as those entirely related to the clivus and medial to the cranial nerve foramina in the skull base, will require a more lateral approach to visualize the attachment. While it would appear that some of the midline approaches (e.g., transsphenoidal/ transoral/ transmaxillary) may offer a more direct route to the tumor (and have appeared as

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reports for meningioma removal in the literature), because such tumors in this location will invariably possess a significant intradural component, these midline approaches through contaminated fields are generally not our primary choice, unless there is an associated mass extending anteriorly which may not be accessible from a more lateral approach. Thus, a general rule for tumors in this location is that the more medial the attachment, the more lateral the bone removal necessary for exposure. Ideally, an approach is chosen to expose and enable immediate interruption of the tumor blood supply at the base of the skull; this may be accomplished intradurally or extradurally, depending upon the location of the attachment.

Another major consideration in determining the approach is the status of the patient's hearing. Inasmuch as the eighth cranial nerve is prone to early injury from tumor growth, often the hearing is diminished and this may be an advantage to the surgeon should a medial exposure be necessary. Preoperative hearing assessment is mandatory in any tumor in the vicinity of the VII-VIII cranial nerve complex. If functional hearing is significantly impaired (> 50 dB hearing loss or < 80% speech discrimination), a translabyrinthine or transcochlear exposure that sacrifices residual hearing may facilitate a more medial exposure to the tumor attachment while providing early interruption of the tumor blood supply through removal of the temporal bone.

In our institution, all patients are administered intravenous high-dose corticosteroids, usually 1 to 2 days preoperatively. Regardless of the surgical approach chosen, cranial nerve monitoring (brainstem auditory evoked response), evoked potentials, and EEG monitoring are utilized in all cases. Facial nerve activity is measured by EMG electrodes, as may be the activity of the III and VI nerves as indicated by percutaneous needle electrodes. The most common approaches utilized in our series of petroclival meningiomas are listed in Table 2.

Upper Clival Approaches

Frontotemporal Transsylvian (Pterional) or Subtemporal

Through a standard frontotemporal craniotomy, wide splitting of the Sylvian fissure will offer access to the dorsum sellae and posterior clinoid region. This approach has the advantage of early exposure and control of the intradural portion of the internal carotid artery, should the tumor extend to involve this artery. The major disadvantage to this approach is the limited basal exposure and potential injury to perforating vasculature emanating from the circle of Willis and the M1 segment of the middle cerebral artery (Fig. 3A). In addition, the intradural course of the third and fourth cranial nerves may impede access to the tumor attachment. Depending upon the superior extent of the tumor above the dorsum sellae, an orbitozygomatic osteotomy or zygomatic osteotomy may be performed to allow the temporalis muscle to be reflected inferiorly, ultimately to enable a lower visual trajectory to facilitate exposure for tumors projecting superiorly.

If necessary, the standard pterional approach may be

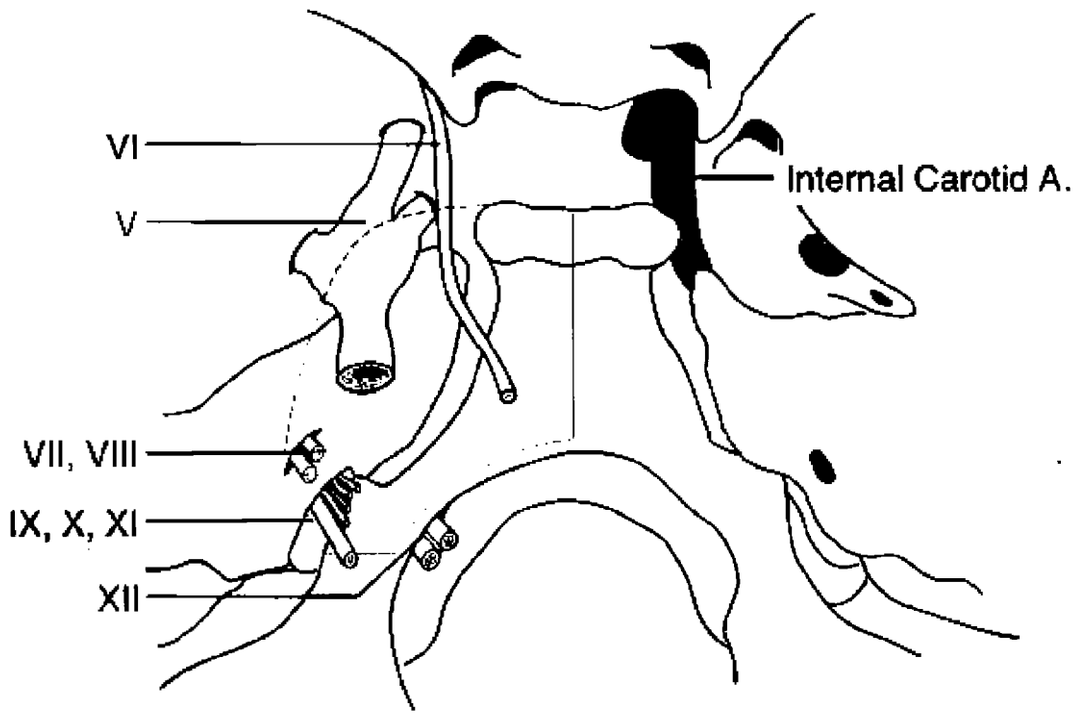


Figure 1. Present definition of petroclival meningiomas: Tumors defined as petroclival are those with basal attachments at or medial to the skull base foramina of cranial nerves V-IX,X,XI.

combined with a transcavernous exposure if tumor resection in this region is indicated.

Posterior Transcavernous (with Removal of the Petrous Apex)

Following a standard frontotemporal craniotomy, either an intradural or extradural subtemporal dissection is performed with removal of the medial petrous bone from the apex to the cochlea, a dissection that provides exposure of the upper and midclival region (Fig. 3B). This bony removal allows visualization to the level of the midclivus and is well suited for those tumors with limited tumor mass within the upper posterior fossa. With bony removal in this location, the trigeminal root may be mobilized, and tumor involving the posterior cavernous sinus and Meckel's cave may be removed. The disadvantage of the approach is the requirement for some temporal lobe retraction, potential injury to the cranial nerves within the cavernous sinus, and limited mid- and lower clival exposure. The use of this approach should be restricted to those cases of petroclival involvement in which removal of the posterior cavernous component is a fundamental goal.

Extended Basal Subfrontal Approach

Extending a standard subfrontal approach posteriorly, with resection of the posterior ethmoids and sphenoid between the orbits and optic nerves allows exposure of the entire sphenoid sinus, sella, and upper clivus (Fig. 3C). However, this approach has the disadvantage of potential contamination through the nasal sinuses, and difficulty in achieving a watertight dural closure following tumor resection. In addition, lateral exposure is limited by the optic nerves and cavernous sinus. This approach may be appropriate for anteriorly-projecting midline tumors extending from the clivus to involve the sphenoid sinus and anterior skull base. Although the entire clivus is accessible, lesions involving the upper clivus are more amenable for application of this approach.

Midclivus Approaches

Retrosigmoid

In reviewing the combined preferences of four surgeons at our institution, it was noteworthy that the most popular approach chosen was that of the simple retromastoid craniotomy. Tumors that are more laterally situated with a limited area of dural attachment are well suited to this approach. Simple and rapid to perform, it offers access primarily to the midclival region, although tumors soft in consistency with a more extended attachment may be resected through this approach. By definition, this approach is entirely intradural, and in order to provide more medial access (e.g., pure clival lesions), significant cerebellar retraction is necessary. In addition, while this relatively simple approach is suitable for lesions with attachments limited to the posterior fossa, those tumors in which the base of attachment is over a larger area may require an extended or additional approach for their removal.

Transtemporal Approaches

We define transtemporal approaches to include presigmoid or transsigmoid retrolabyrinthine, translabyrinthine, and transcochlear. They have the advantage of providing more medial access than the standard retromastoid approach. In addition, should the attachment of the tumor be centered in the vicinity of the cerebellopontine angle, these primary extradural approaches facilitate extradural devascularization of the tumor with the bony removal. One obvious disadvan-

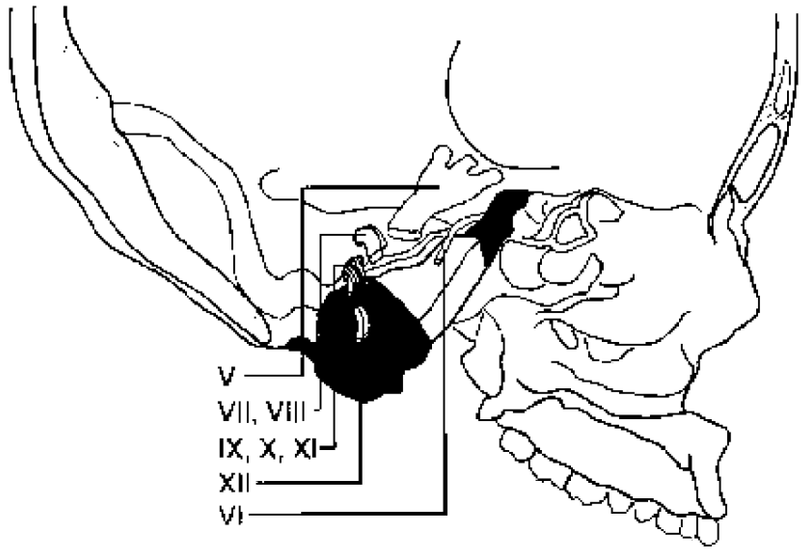
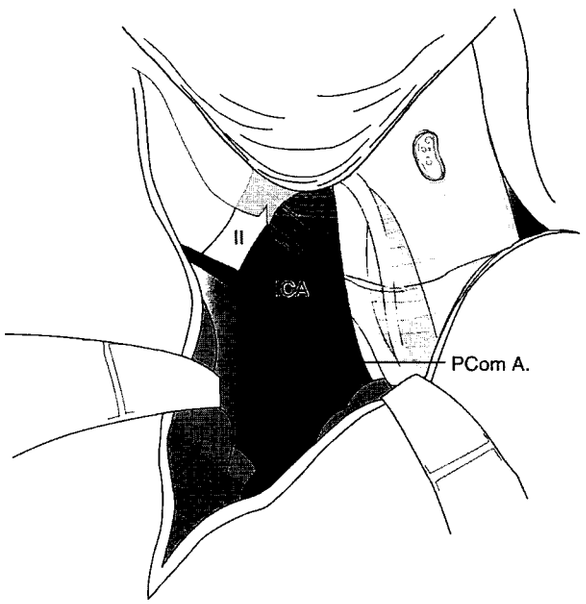


Figure 2. Present definition of petroclival meningiomas: Lesions of the lower third of the clivus (shaded region) are best considered as foramen magnum in location when planning surgical strategies.

tage relates to hearing loss following the drilling of the labyrinth or cochlea; in addition, the dural opening may be limited; but these approaches may be combined with a standard retromastoid craniotomy if the sigmoid sinus is sacrificed. This requires angiographic evidence of patency of the contralateral sinus. It has become our practice to test occlude the sinus prior to definitive section. This may be performed by temporary occlusion with an aneurysm clip while simultaneously testing the proximal venous pressure by manometer and observing for any increase in venous congestion with either cerebral or cerebellar swelling. An increase > 10 mm Hg has been suggested previously as a limit for any increase of venous pressure during temporary occlusion. A further disadvantage to any transtemporal approach is the difficulty in obtaining a primary dural closure, which necessitates packing of the defect with fat and fascia prior to closure, and placement of a mastoid dressing postoperatively.

This lesson will be continued in Part II, which will cover extended approaches (petrosal, infratemporal fossa, and facial translocation) as well as staged resections, surgical goals, results, complications, and adjuvant therapy.



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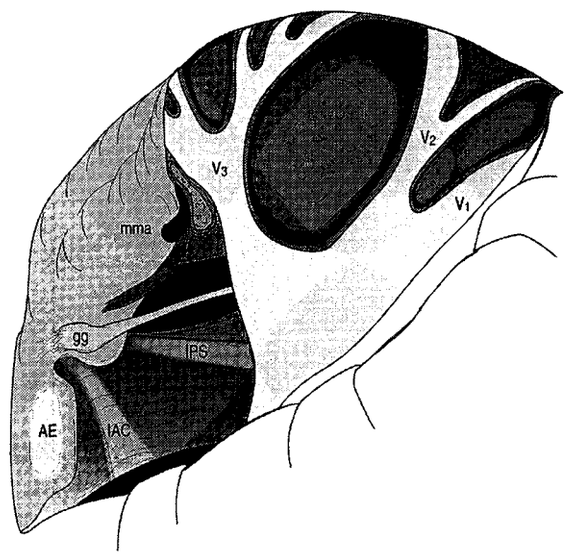

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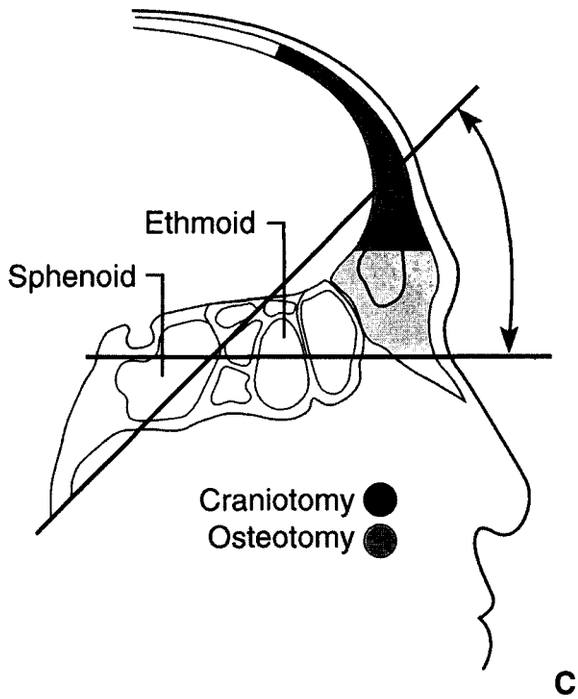

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Figure 3. Surgical approaches to the upper clivus. (*A*) Frontotemporal transsylvian approach offers limited skull base access to the upper clivus region. Caution must be taken to avoid manipulation of perforating vasculature from the proximal circle of Willis. (*B*) Posterior transcavernous approach. An intra- or extradural subtemporal approach may be utilized for exposure of the upper region of the clivus. It is well suited for resection of tumors involving the petrous apex and region of Meckel's cave with limited tumor mass within the posterior fossa. Bone removal enables exposure of the clivus; care must be taken to avoid injury of the cochlea (in the petrous bone below the gasserian ganglion, gg), and the petrous carotid artery (ICA). Depending on the tumor mass within the cavernous sinus, exposure may be increased, e.g., in this diagram the region of Meckel's cave and the entire trigeminal root and its branches may be exposed by reflecting the lateral wall of the cavernous sinus ($V_1V_2V_3$). mma= Middle meningeal artery; IAC= Internal auditory canal; IPS; inferior petrosal sinus. (*C*) Extended basal subfrontal approach with resection of the ethmoid sinus and sphenoid enables exposure of the clivus. By varying the angle of exposure, visualization along the clivus may be possible (*arrow*). This approach is limited by the difficulty in visualization laterally without mobilization of the orbits; also, and similar to other midline surgical approaches, the operative corridor traverses contaminated spaces, and meticulous dural closure is crucial.

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