Conservative Posterior Petrosectomy

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General Considerations

Posterior petrosectomy is the key component of the posterior petrosal approach. This skull base osteotomy is a combination of 1) temporal craniotomy, 2) posterior petrosectomy, and 3) suboccipital craniotomy.

Posterior petrosectomy involves partial resection of the petrous pyramid to allow access to the petroclival region, anterior cerebellum, and brainstem at the level of cranial nerves (CNs) V-X. In other words, this route facilitates access to the petroclival region bounded by the middle fossa dura superiorly and the jugular bulb inferiorly.

Petroclival lesions above this level are more suited for an anterior petrosectomy. Lesions below the level of the jugular tubercle can be readily reached through an expanded retromastoid exposure.

In essence, posterior petrosectomy is centered over the petrous ridge and is comparable to pterional approach that is based on the sphenoid ridge.

There are several variations of posterior petrosectomy that differ in the quantity of temporal bone resected. Stepwise removal of the temporal bone expands the ventral operative trajectory, but also increases the risk of CN injury, particularly to CNs VII and VIII.

Several expansive modifications of posterior petrosectomy can be defined based on a progressive increase in bone removal to allow a wider and more direct approach to the anterior brainstem along the cerebellopontine angle: retrolabyrinthine, transcrusal, translabyrinthine, transotic, and transcochlear. The transotic and transcochlear approaches sacrifice hearing and are associated with a risk of facial nerve injury (Table 1).

Table 1: Expansive Variations of the Posterior Petrosectomy

Stage	Temporal Bone Structures Removed
Retrolabyrinthine	Mastoidectomy with skeletonization of the lateral petrous bone, semicircular canals are preserved.
Transcrusal (partial labyrinthectomy)	Superior and posterior semicircular canals are removed from the ampullae to the common crus
Translabyrinthine	Horizontal canal and vestibule are removed and the lateral internal auditory canal is opened.
Transotic	Otic capsule is removed, including the cochlea, vestibule, and semicircular canals. Facial nerve is skeletonized, but left covered by bone. The wall of the external auditory canal may be divided, the ear canal sutured, and ear structures reflected forward. Carotid is exposed and the eustachian tube is plugged.
Transcochlear	Same as transotic plus posterior mobilization of the facial nerve by cutting its anterior branches from the geniculate ganglion.

Reproduced with permission from Horgan MA, Delashaw JB, Schwartz MS, Kellogg JX, Spektor S, McMenomey SO. Transcrusal approach to the petroclival region with hearing preservation. Technical note and illustrative cases. *J Neurosurg*. 2001;94:660–666

When combined with the subtemporal approach, posterior petrosectomy expands the exposure as listed in Table 2.

Table 2: The Anatomy Accessible Through the Different Variations of the Posterior Petrosectomy (Including the Subtemporal Approach)

Variations of Posterior Petrosectomy	Anatomic Structures Accessible

Retrolabyrinthine	Middle half of the clivus, middle fossa, cerebellopontine angle, *lateral* aspect of the brainstem
Translabyrinthine	Middle half of the clivus, middle fossa, cerebellopontine angle, *anterolateral* aspect of the brainstem
Transcochlear	Middle half of the clivus, middle fossa, cerebellopontine angle, central clival depression, *anterior* aspect of the brainstem

Reproduced with permission from Horgan MA, Anderson GJ, Kellogg JX, Schwartz MS, Spektor S, McMenomey SO, et al. Classification and quantification of the petrosal approach to the petroclival region. *J Neurosurg.* 2000;93:108–112.
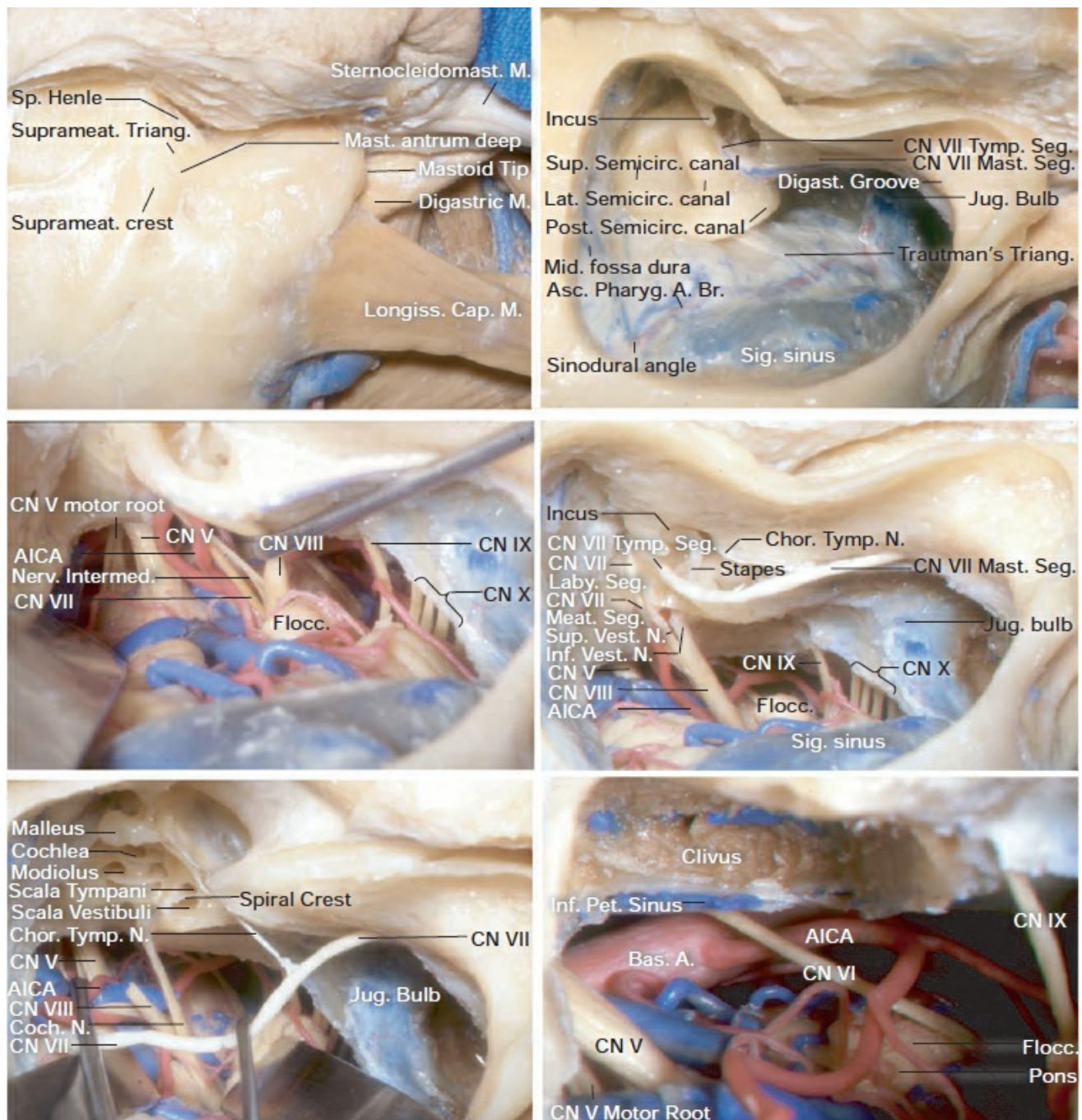
Figure 1: Mastoidectomy, retrolabyrinthine, partial labyrinthine, translabyrinthine, and transcochlear approaches have been demonstrated. The mastoid bone and its superficial anatomy are shown in the left upper photo. The spine of Henle is at the posterosuperior margin of the external meatus and superficial to the deep lateral semicircular canal and junction of the tympanic and mastoid segments of the facial nerve. The supramastoid crest approximates the level of the transverse and sigmoid sinuses. In the right upper photo, mastoidectomy has exposed the middle fossa dura, the sigmoid sinus and the jugular bulb; these structures form the borders of the presigmoid dura where intradural operative trajectory is centered. The sinodural angle is where the sigmoid sinus meets the middle fossa dura.

In the left middle image, the retrolabyrinthine exposure is complete and the dura has been excised to reveal cranial nerves V to X within the cerebellopontine angle. In the right middle image, the translabyrinthine approach allows a more ventral view of the brainstem. Furthermore, the meatal and labyrinthine segments of the facial nerve are apparent. In the left lower image, the facial nerve has been transposed posteriorly for removal of the cochlea in the transcochlear approach. The semicircular canals and vestibule have also been removed. In the right lower image, removal of the cochlea allows resection of the remainder of the petrous apex, facilitating an unhindered view of the anterior brainstem (images courtesy of AL Rhoton, Jr).

Most operative extra-axial lesions displace the brainstem and provide additional working space after their decompression; therefore, the retrolabyrinthine and translabyrinthine approaches are usually adequate to access the anterior lesions crossing the midline.

In this chapter, I attempt to describe a limited posterior petrosectomy involving the retrolabyrinthine approach in combination with subtemporal and suboccipital craniotomies. This modification of posterior petrosectomy is the most conservative osteotomy and carries the lowest risk of hearing loss and facial nerve injury.

The main limitation of this approach is that in most patients, it does not

provide direct access to the region of the clivus known as the *central clival depression*. The central clival depression is the area of the clivus nearest the midline between the intermeatal plane above and the jugular tubercles below. Access to this area decreases via the retrolabyrinthine approach in individuals with more acute petroclival angles.

In my experience, in most cases, intracapsular tumor decompression provides an ample amount of space to reach the anterior brainstem, with no need for more extensive bone removal as described for the other variations of posterior petrosectomy. In patients with a very pronounced central clival depression, the retrosigmoid or transcondylar approaches can, in fact, provide a more desirable operative working angle.

The next chapter of this volume focuses on a more extended posterior petrosectomy that via additional petrous drilling skeletonizes the hearing apparatus to provide a more anterolateral trajectory to the brainstem. The more expanded variations of this skull base approach through a radical petrous pyramid resection are rarely necessary and may lead to avoidable morbidity.

Indications for Posterior Petrosectomy

Partial resection of the petrous pyramid facilitates exposure of the inferior two-thirds of the petroclival region and its associated extra-axial lesions such as meningiomas.

Vascular pathologies such as aneurysms of the middle third of the basilar artery and ventrolateral pontine cavernous malformations can be accessed as well. However, lesions along the lower third of the clivus and foramen magnum are more effectively exposed through the retrosigmoid and/or transcondylar corridors.

The supratentorial ventrolateral brainstem or anterior midbrain may be accessed through this approach via an inferior-to-superior working trajectory. Retrochiasmatic craniopharyngiomas were previously reached through this route. However, the endoscopic transnasal corridor has obviated the use of petrosectomy for this purpose.

Epidermoid tumors can be removed with relative ease through the extended retrosigmoid approach even if they cross the midline and center themselves along the ventral brainstem. These tumors' soft consistency and relative lack of adherence to the surrounding neurovascular structures allow the more limited approaches to perform adequately.

I use posterior petrosectomy and its extended variant for large meningiomas of the middle to lower two-thirds of the clivus. Almost all other lesions can be handled via the extended retrosigmoid craniotomy or the conservative transcondylar osteotomy.

Preoperative Considerations

The presence of parenchymal edema in the brainstem is an ominous sign—it signifies a high risk of pial violation if the operator attempts gross total resection. Extension of the tumor to the midline or the contralateral side increases the technical complexity of the procedure. Encasement of the basilar artery is not uncommon, and does not necessarily correlate with the absence of arachnoid planes around the artery.

A computed tomography scan can define the degree of tumor calcification. Highly calcified meningiomas present a daunting challenge, and their encasement of the surrounding vital vessels should warn the surgeon against radical resection. Surgery on these tumors should be limited to conservative debulking and brainstem decompression.

I do not use preoperative embolization for meningiomas, but I do so for [glomus jugulare tumors](#) and [hemangiopericytomas](#) within the posterior fossa. The operator is often unable to devascularize deep-seated posterior fossa tumors early in surgery. They may be out of reach due to the surrounding cranial nerves and limited working space to mobilize the tumor and expose its base without its initial generous enucleation. This feature may encourage one to embolize the tumor preoperatively.

Brainstem auditory evoked responses (BAERs) and somatosensory evoked potentials (SSEPs) monitoring are used during the petrosectomy procedures. Facial nerve electromyography and lower cranial nerves'

monitoring (including endotracheal tubes with electromyographic sensors) may be needed for select patients.

A CT or catheter angiogram is beneficial in localizing displaced vascular anatomy and the location of the anteriorly displaced vein of Labbé that can affect the subtemporal trajectory. In addition, the presence of major veins traversing the tentorium discourages a posterior approach during which the tentorium would need to be sectioned. Alternatively, combined approaches obviating the need for tentorial sectioning are recommended.

Operative Anatomy

The detailed anatomy of the temporal bone is relevant. The surgeon needs to gain extensive experience in the laboratory with temporal bone drilling to effectively perform transtemporal approaches. The participation of our otologist colleagues during the procedure and specifically during the petrosecotmy stage is recommended.
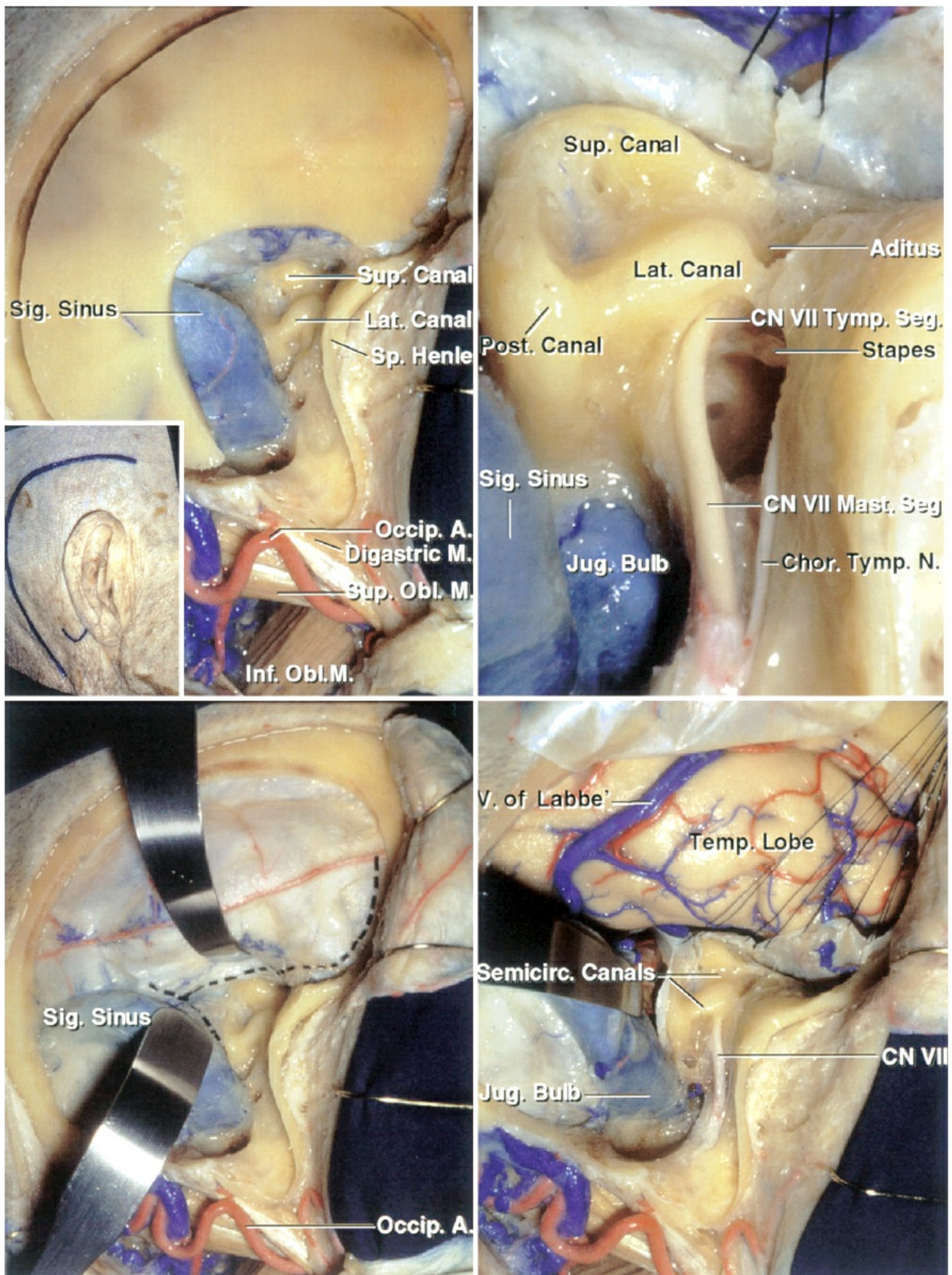
Figure 2: Surgical steps for a right-sided posterior petrosal or presigmoid approach combined with a subtemporal extension are demonstrated. The mastoidectomy will reveal the presigmoid dura, and the extent of drilling of the dense cortical bone housing the semicircular canals determines the difference between the standard (conservative) and extended posterior

petrosal approaches (upper images). The relevant anatomy of the temporal bone is depicted in the right upper image. The tympanic segment of the facial nerve travels inferior to the lateral canal. The initial dural exposure is demonstrated (left lower image). The vein of Labbé is protected during dural incisions (right lower image)(images courtesy of AL Rhoton, Jr). Please note that the demonstrated retrolabyrinthine approach in these photos requires more aggressive bone resection (similar to the one for the extended posterior petrosectomy) than the approach illustrated in the operative sketches below (images courtesy of AL Rhoton, Jr).
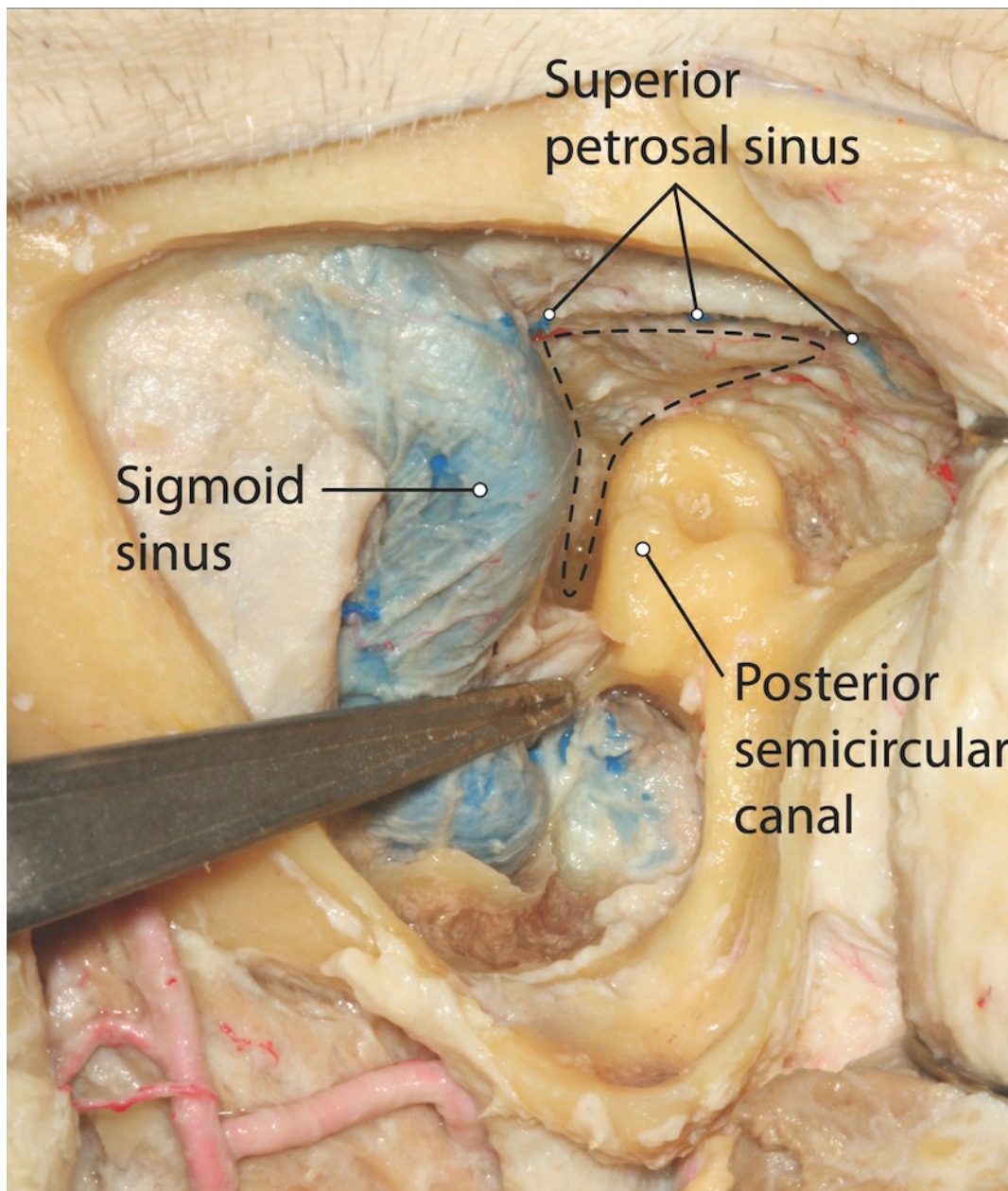
Figure 3: The location of a right-sided Trautmann's triangle (marked by the hashed line) and its relationship to the surrounding structures is shown. Removal of the bone over this triangle is the principle maneuver

executed during the petrosal approach.
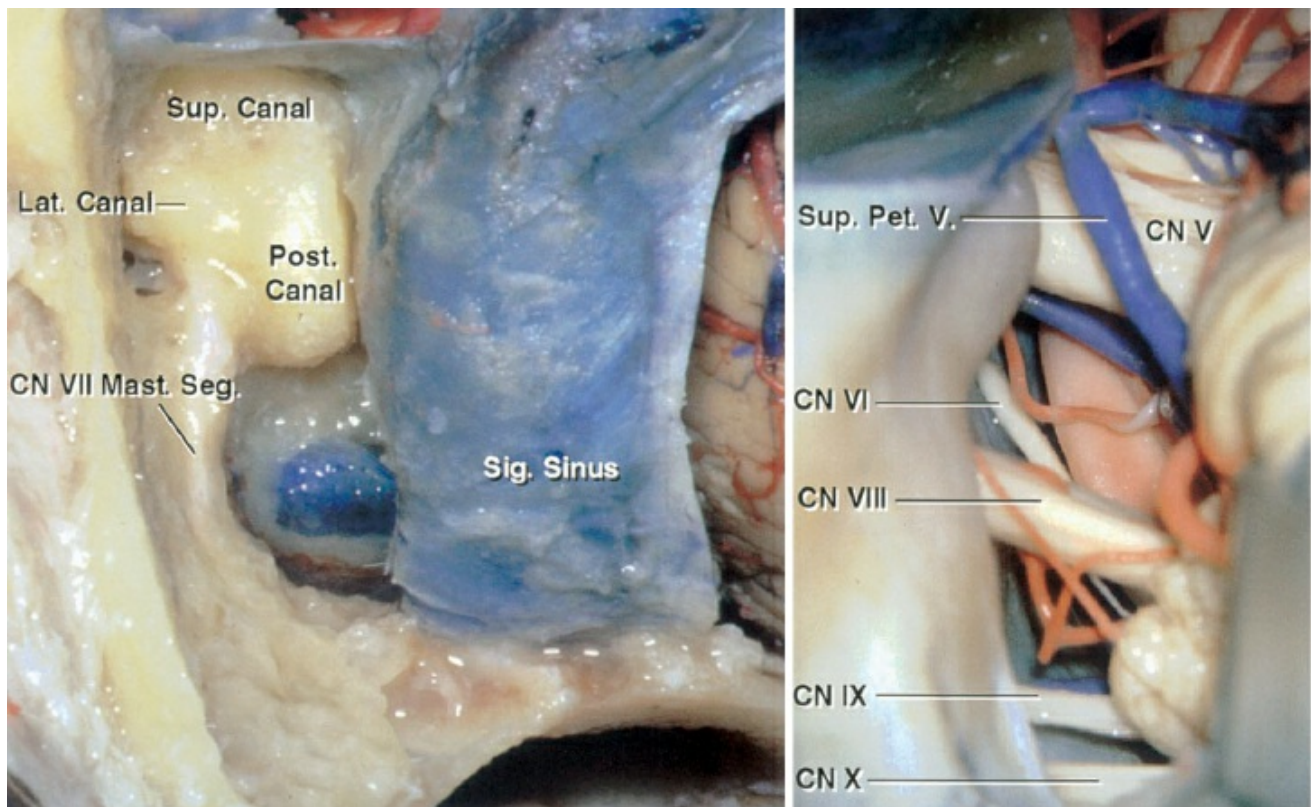
Figure 4: Extradural (left image) and intradural (right image) exposures through a left-sided posterior petrosectomy or presigmoid osteotomy are shown (images courtesy of AL Rhoton, Jr).

CONSERVATIVE POSTERIOR PETROSECTOMY

The operative corridor through the posterior transpetrosal approach is narrow, requiring extradural retraction of the temporal lobe and cerebellum during bone work before reaching the cerebellopontine angle cisterns to drain cerebrospinal fluid (CSF). Consequently, intraoperative implantation of a lumbar drain before skin incision should be strongly considered.

I have not experienced any complication such as herniation syndromes related to the use of a lumbar drain, regardless of the large size of the tumor and the associated mass effect. Gradual CSF drainage is used during burr hole placement and elevation of the bone flap. This decrease

in intracranial tension facilitates mobilization of the dura and its associated venous sinuses away from the inner skull surface and protects them during bone work.

I drain 20cc of CSF upon completion of the skin incision and then drain up to 40 cc more (in 10-cc aliquots) as necessary to achieve adequate dural relaxation during bone work and manipulation of the dura along the middle and posterior fossae. This maneuver obviates the need for fixed retractors and diuretics, including mannitol.

The patient is positioned supine on the operating room table. The thorax should be slightly elevated to promote venous drainage. A shoulder roll is placed under the patient's contralateral shoulder and the patient's head is rotated until the sagittal suture is nearly parallel with the floor.

If the patient has a supple neck, up to 70 degrees of rotation may be applied. If the patient has limited neck mobility, the size of the shoulder roll can be increased to compensate for the limited neck rotation.
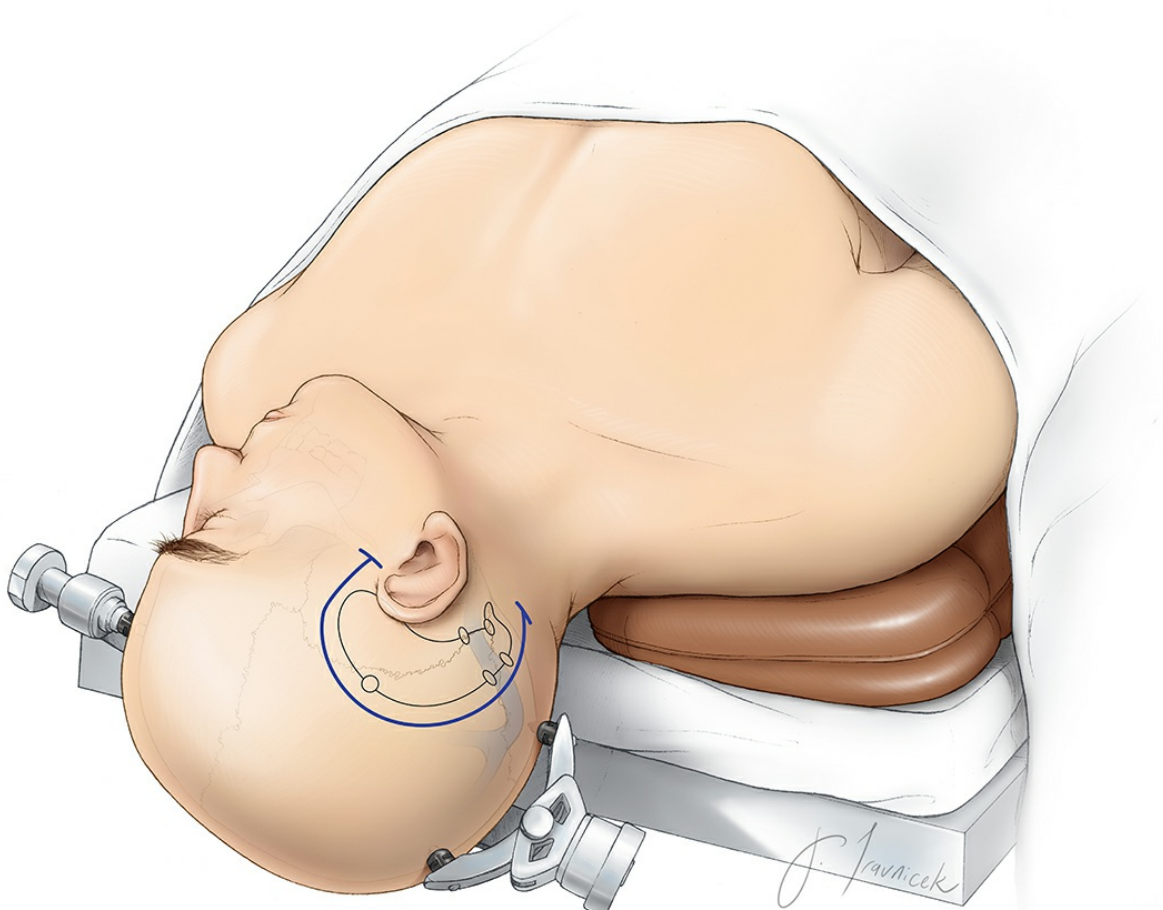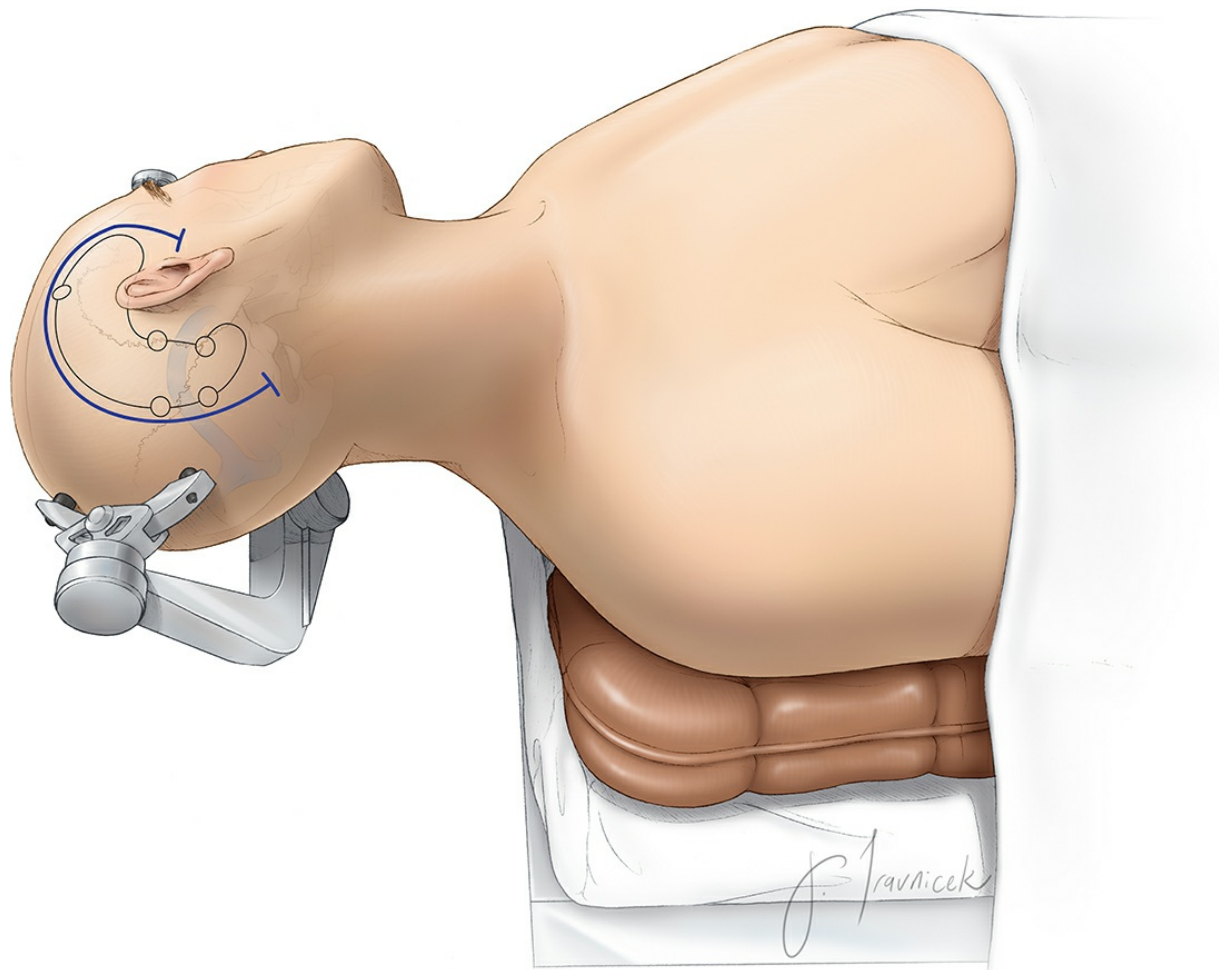
Figure 5: Patient position, skull clamp fixation, and skin incision are illustrated. The locations of the burr holes and craniotomy in relation to the dural venous sinuses are evident. The vertex of the head is tilted slightly toward the floor until the zygoma is the highest point on the operative field. The skull clamp pins are positioned so the pins stay away from the outlines of the incision. I place the single pin anteriorly over the frontal area and the two-pin rocker arm low on the occipital bone and parallel to the sagittal plane.

The usual incision for posterior petrosectomy starts at the level of the zygoma, approximately 1 cm anterior to the tragus. It circles 3-4 cm above the ear, and descends 4 cm behind the mastoid process, exposing the suboccipital bone. The extent of temporal bone work can be tailored based on the extension of the tumor into the middle fossa.
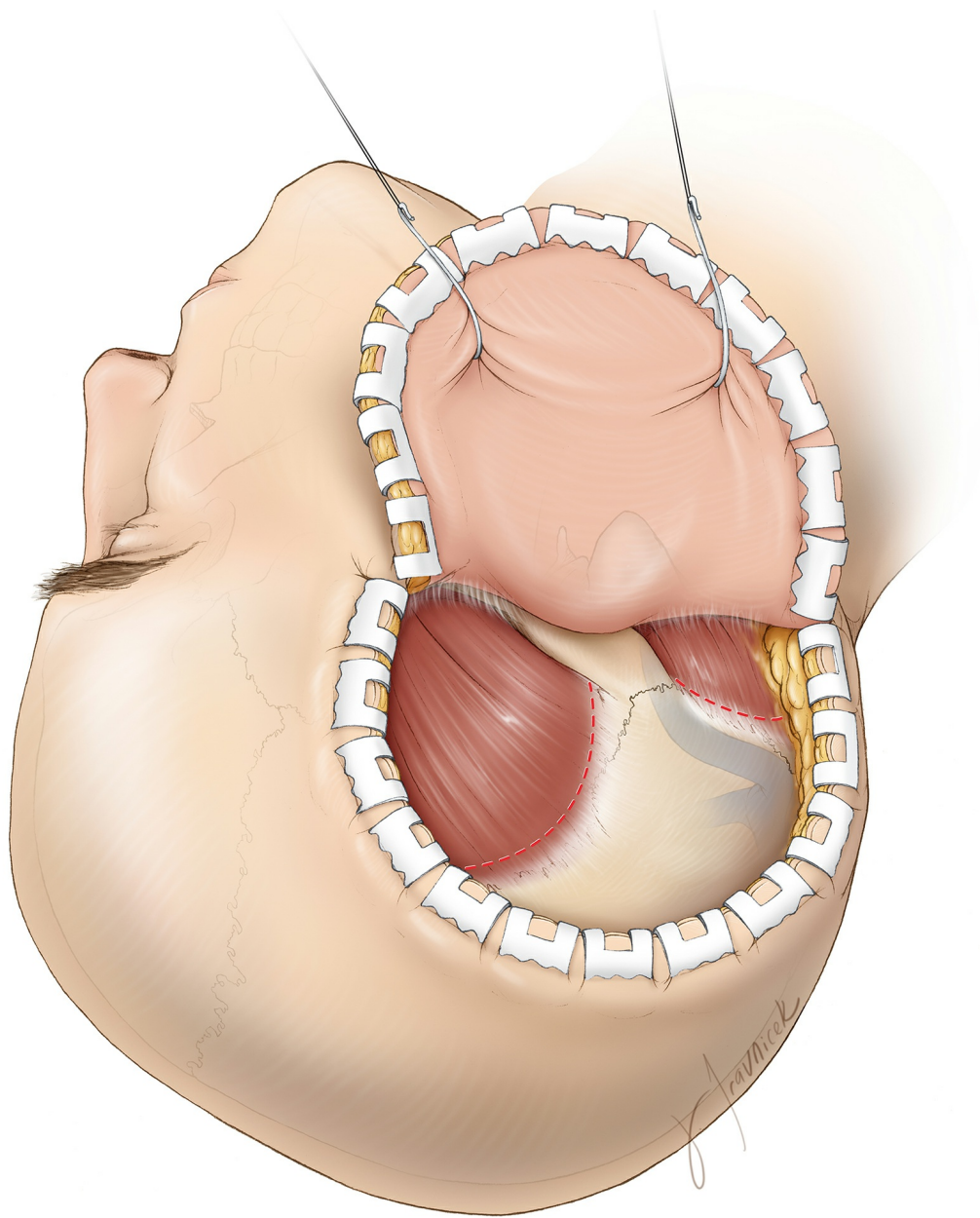
Figure 6: The scalp flap is reflected anteroinferiorly and the natural plane between the temporalis fascia and galea is developed. The pericranium and temporal fascia is incised along the edges of the incision and separated from the muscle. This pericranial flap is further dissected beyond the superior nuchal line in continuity with the sternocleidomastoid muscle, which is released from its insertion on the mastoid bone. This technique provides a large, vascularized fascial/pericranial flap that can be used for skull base reconstruction at the end of the operation.

The temporal muscle is then detached from the bone and also reflected anteroinferiorly. Other muscle attachments on the mastoid and superior nuchal line are also released to gain exposure for the suboccipital craniotomy.
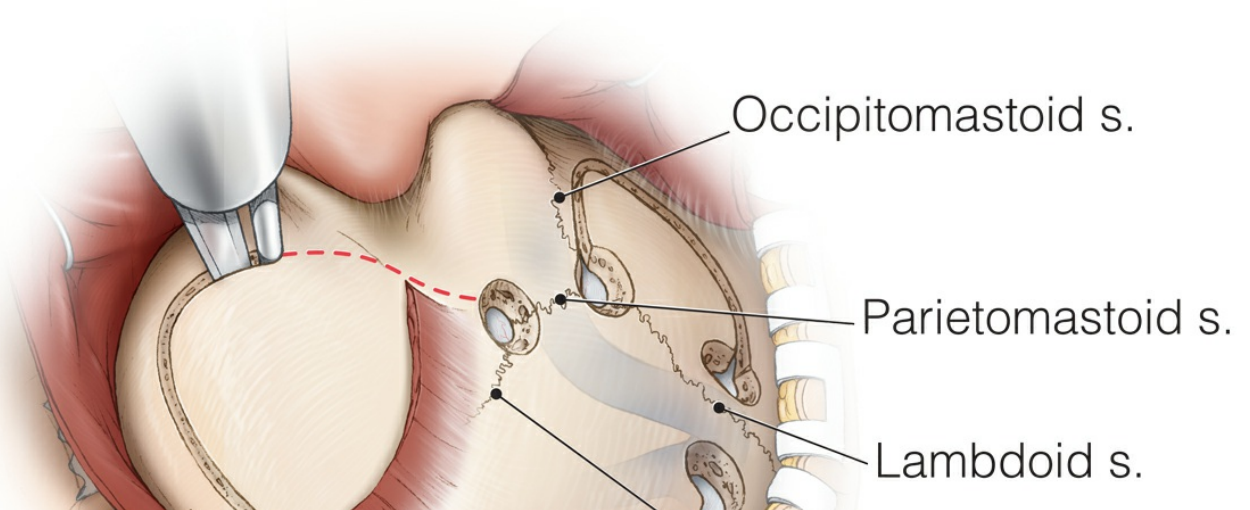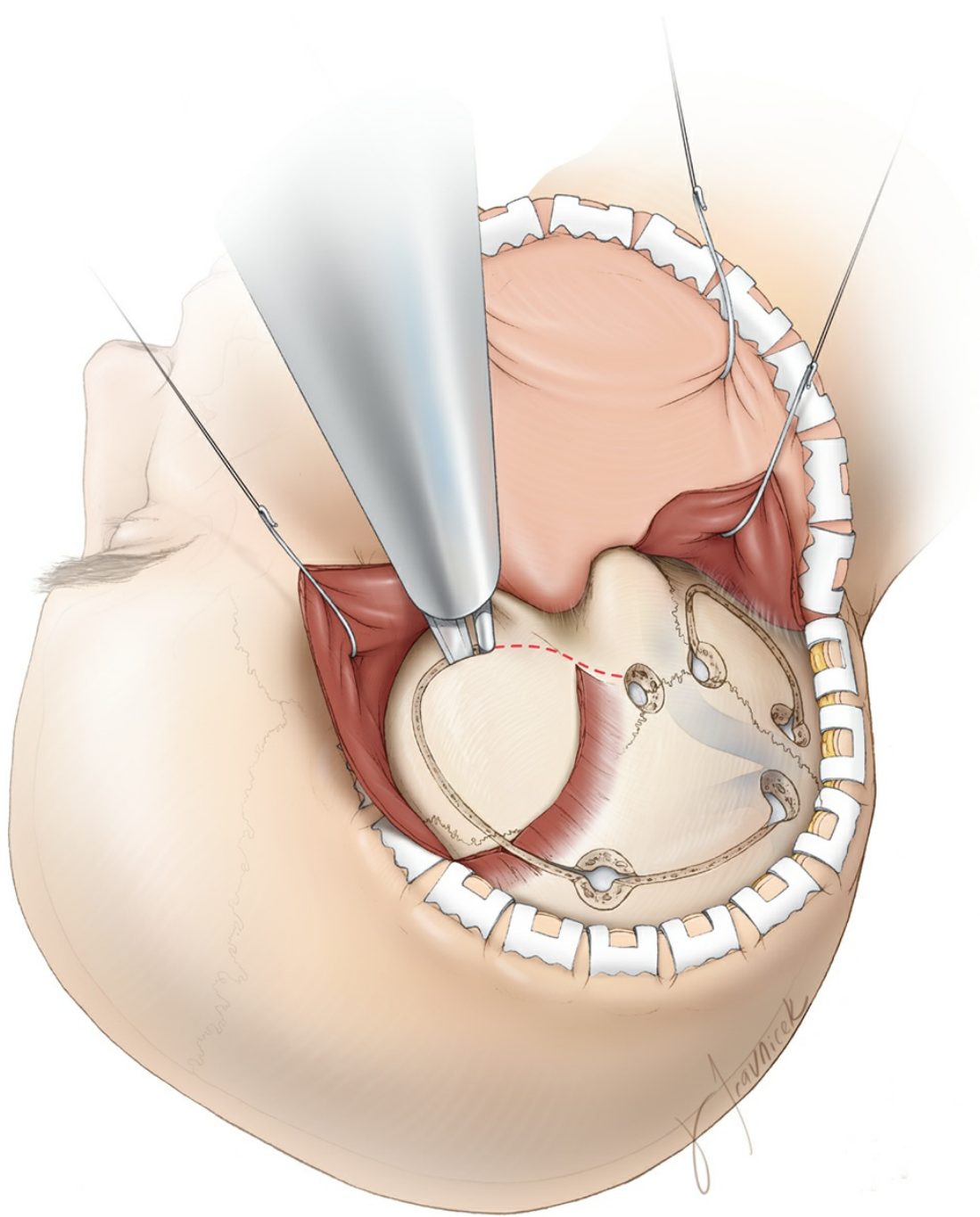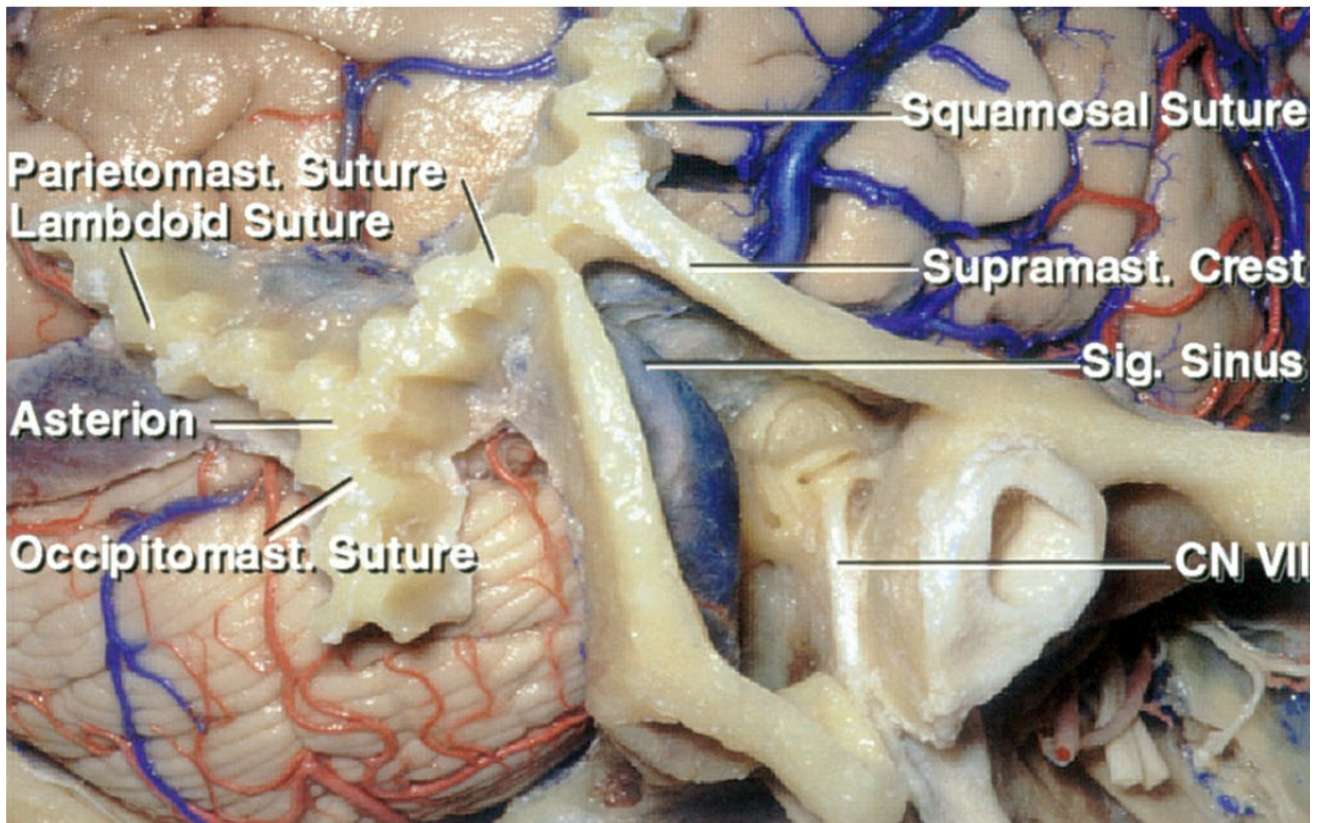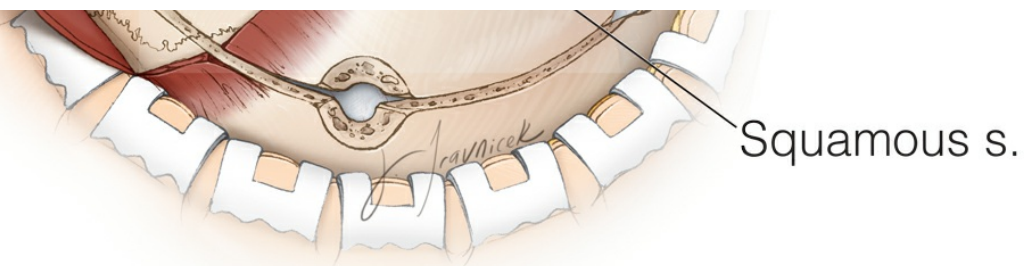
Occipitomastoid s.

Parietomastoid s.

Lambdoid s.

Squamous s.

Figure 7: The craniotomy for posterior petrosal approach includes both a temporal and a suboccipital component. I make four burr holes, two sets on each side of the transverse sinus. The first burr hole is placed immediately medial and inferior to the asterion. This burr hole gives access to the infratentorial compartment.

The second burr hole is made at the junction of the squamous and parietomastoid sutures (upper and middle images). This burr hole provides access to the supratentorial compartment. The space between these two burr holes contains the transverse-sigmoid junction. A second set of burr holes is placed more medially above and below the superior

nuchal line, flanking the transverse sinus.

A high-speed drill with a foot attachment is used to elevate subtemporal and suboccipital-retromastoid craniotomies. I avoid the use of the footplate attachment over the dural sinuses since these sinuses are often embedded in the inner surface of the skull bone and tenaciously adherent. The anatomy of the sutures in the region is further depicted in the lower image (images courtesy of AL Rhoton, Jr).
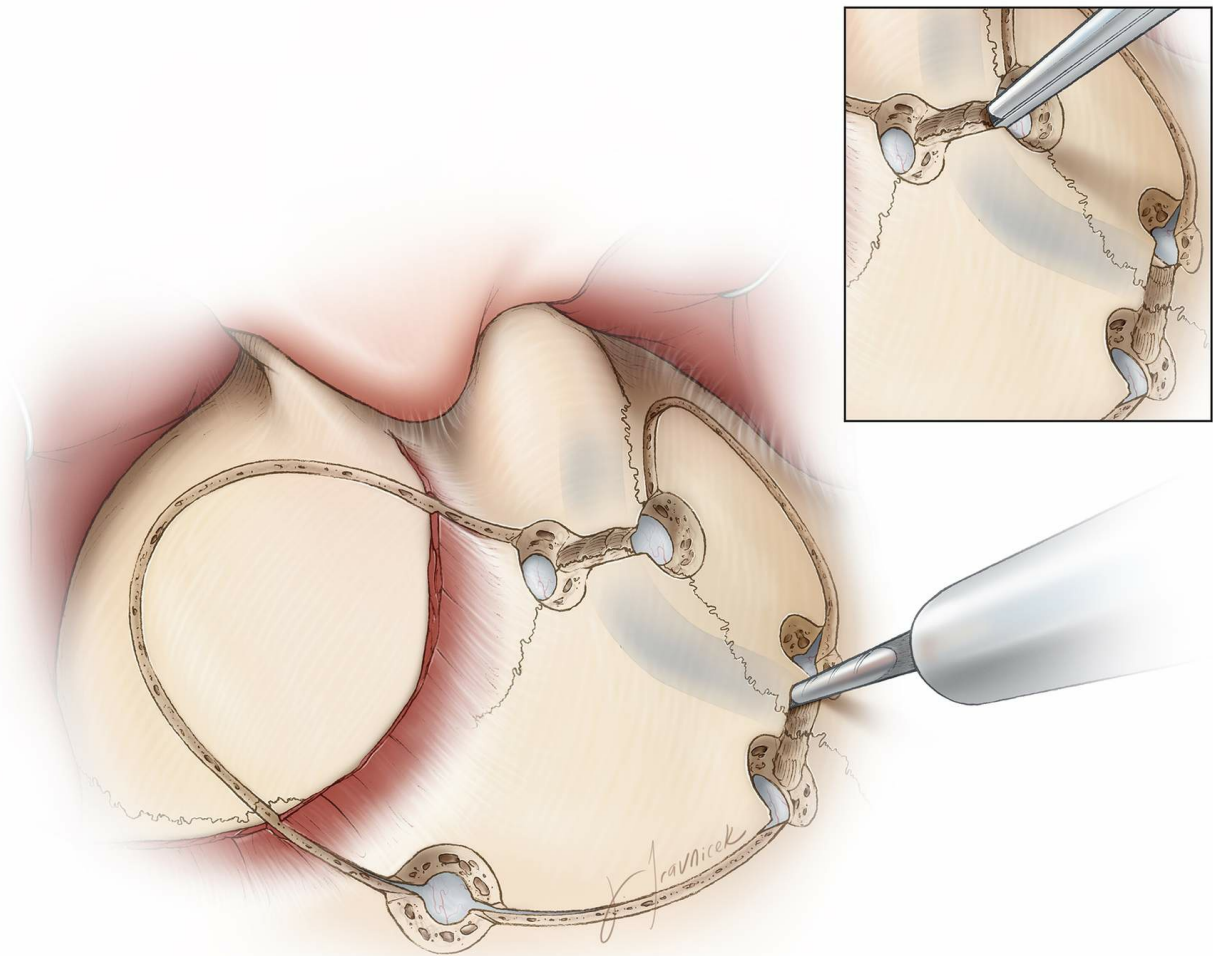
Figure 8: I "eggshell" the bone between the burr holes and overlying the venous sinuses using a side-cutting burr (B1 without a footplate). I then slowly detach the sinus wall from the inner skull table and remove the remaining bone over the sinuses using a Kerrison rongeur (inset).

The bone flap is then carefully elevated. Minor injuries to the venous sinus can usually be covered and not aggressively packed with hemostatic material (Surgicel Fibrillar, Ethicon, Somerville, NJ). Larger tears require primary repair using a local dural flap. Again, the lumen of

the sinus should not be packed to avoid its thrombosis. The osteotomy over the mastoid bone can be less straightforward, requiring the use of a round side-cutting burr.

Mastoidectomy

I collaborate with my otology colleagues for matoidectomy.
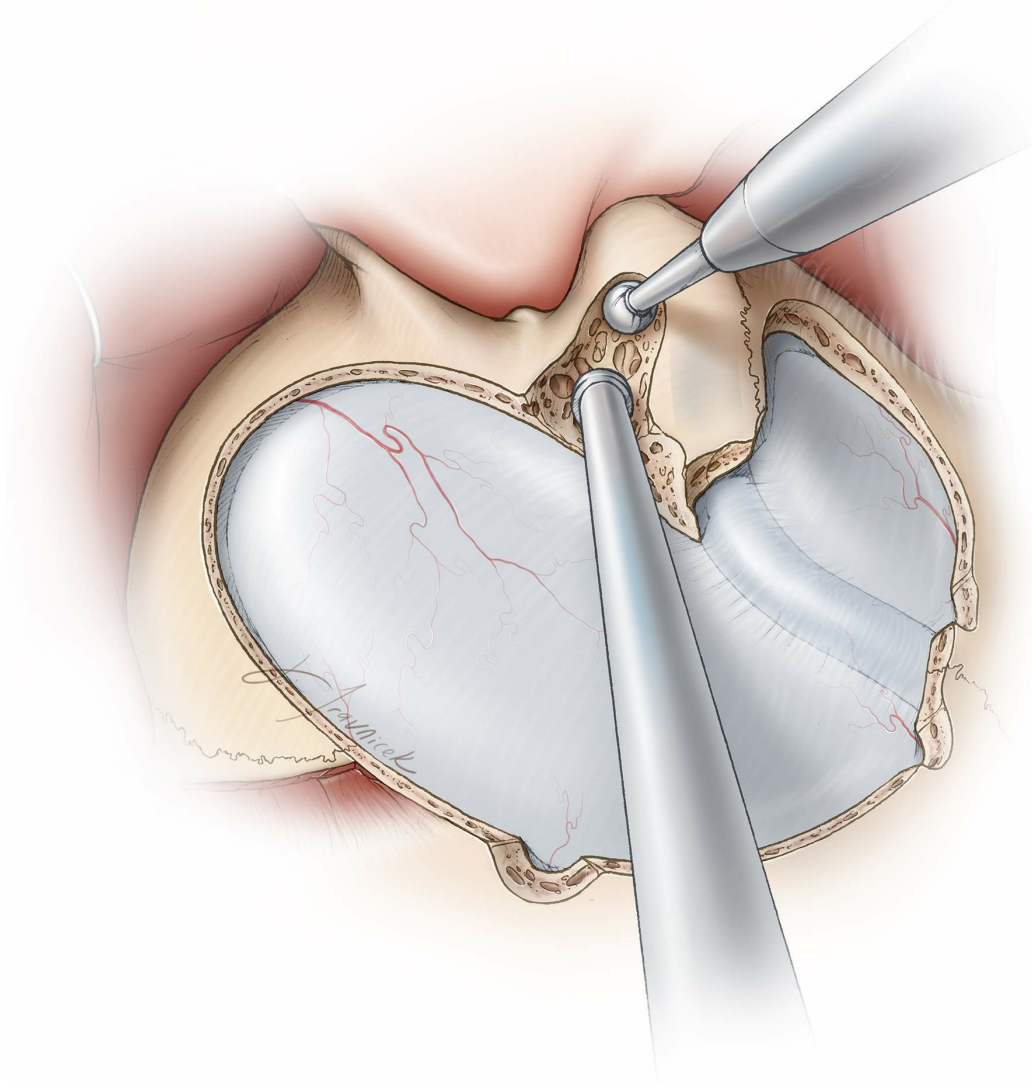
Figure 9: The second component of this approach is an almost complete mastoidectomy. The first step is decortication of the mastoid surface using a high-speed cutting burr and continuous suction irrigation. Troughs are created to outline the superior and anterior limits of the mastoidectomy. The superior trough extends from the zygomatic root to the asterion, just inferior to the infratemporal line.

The anterior trough extends from the posterior rim of the external auditory meatus down to the mastoid tip. The mastoid air cells are removed within these limits. Drilling should take place at an even depth

throughout the process of drilling. The cortical bone over the sigmoid sinus is identified as the air cells are removed. My neuro-otologist usually performs this part of the procedure.
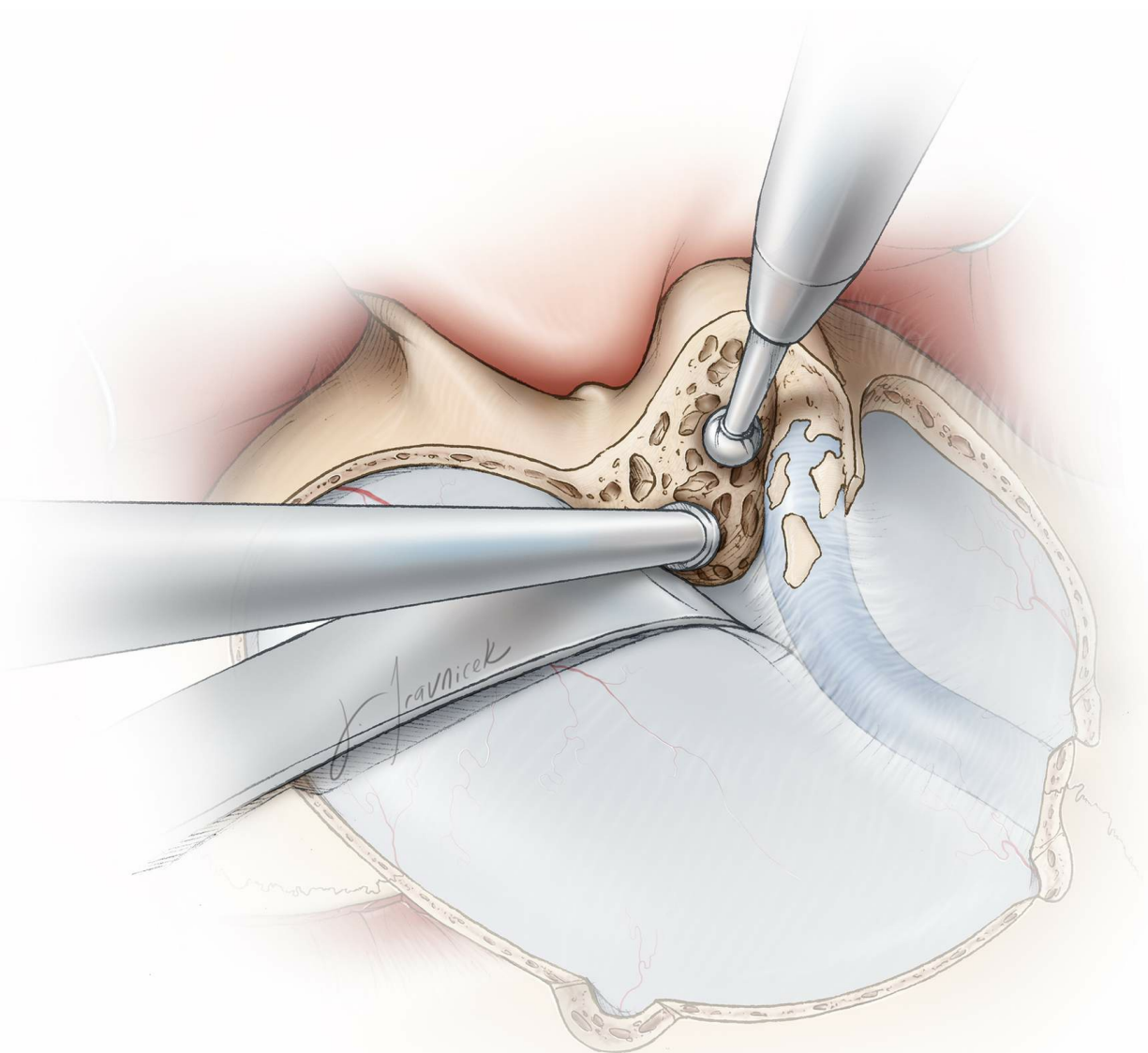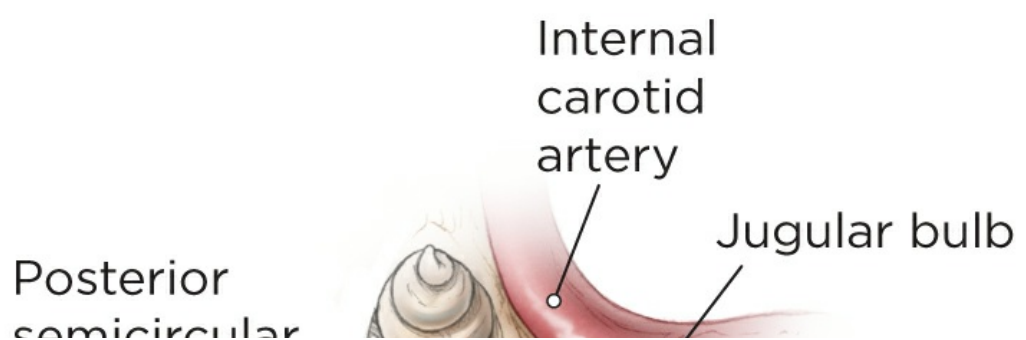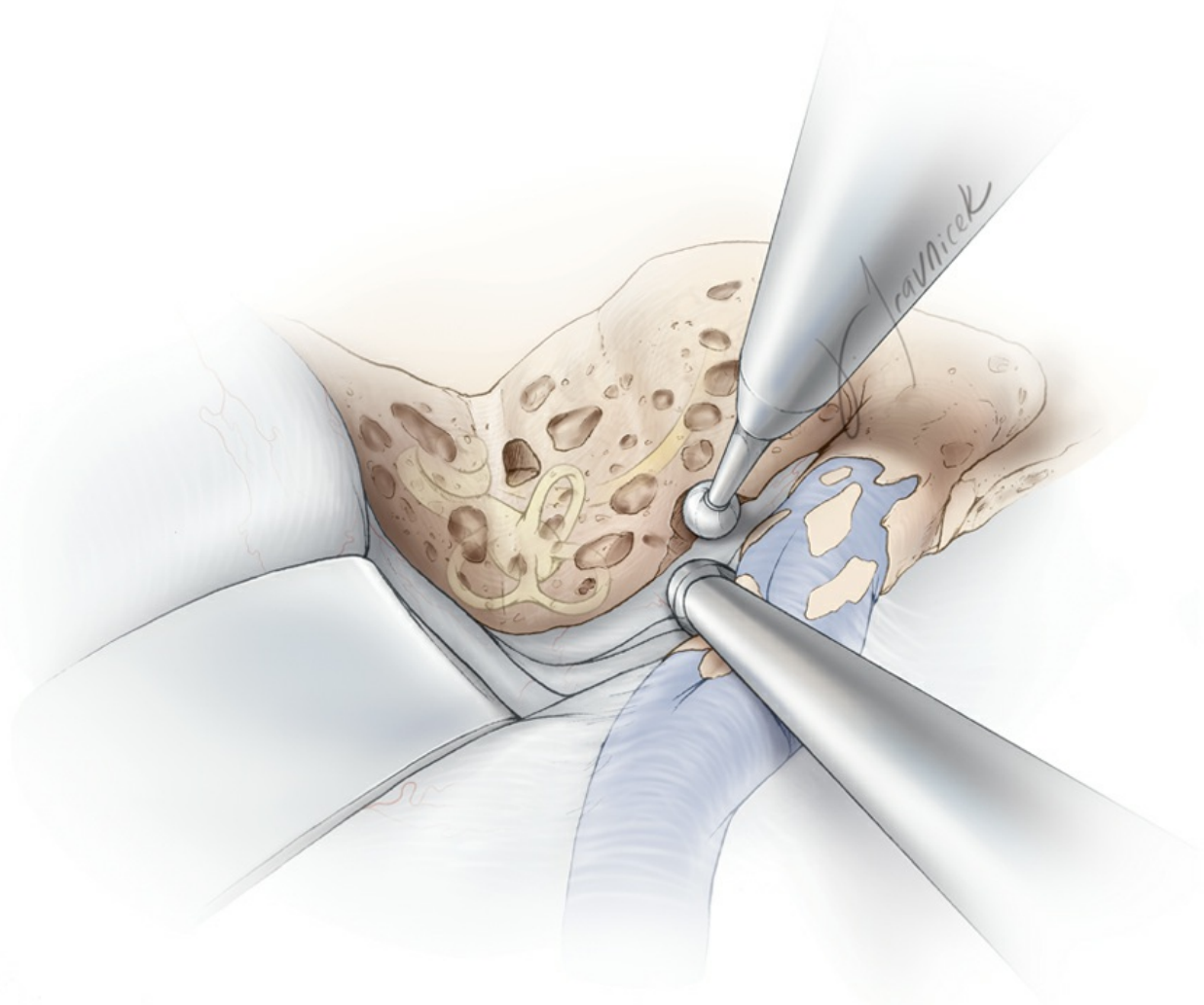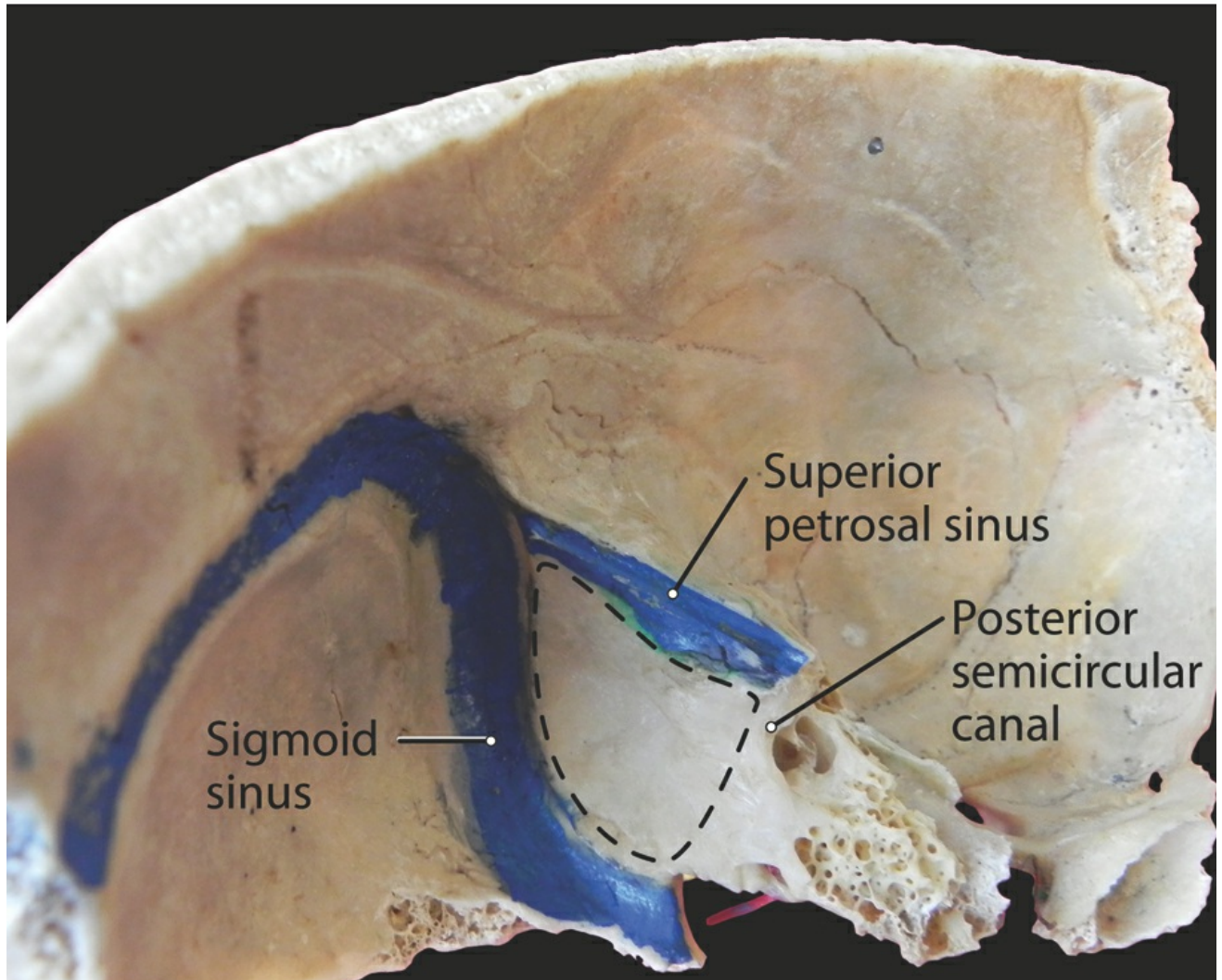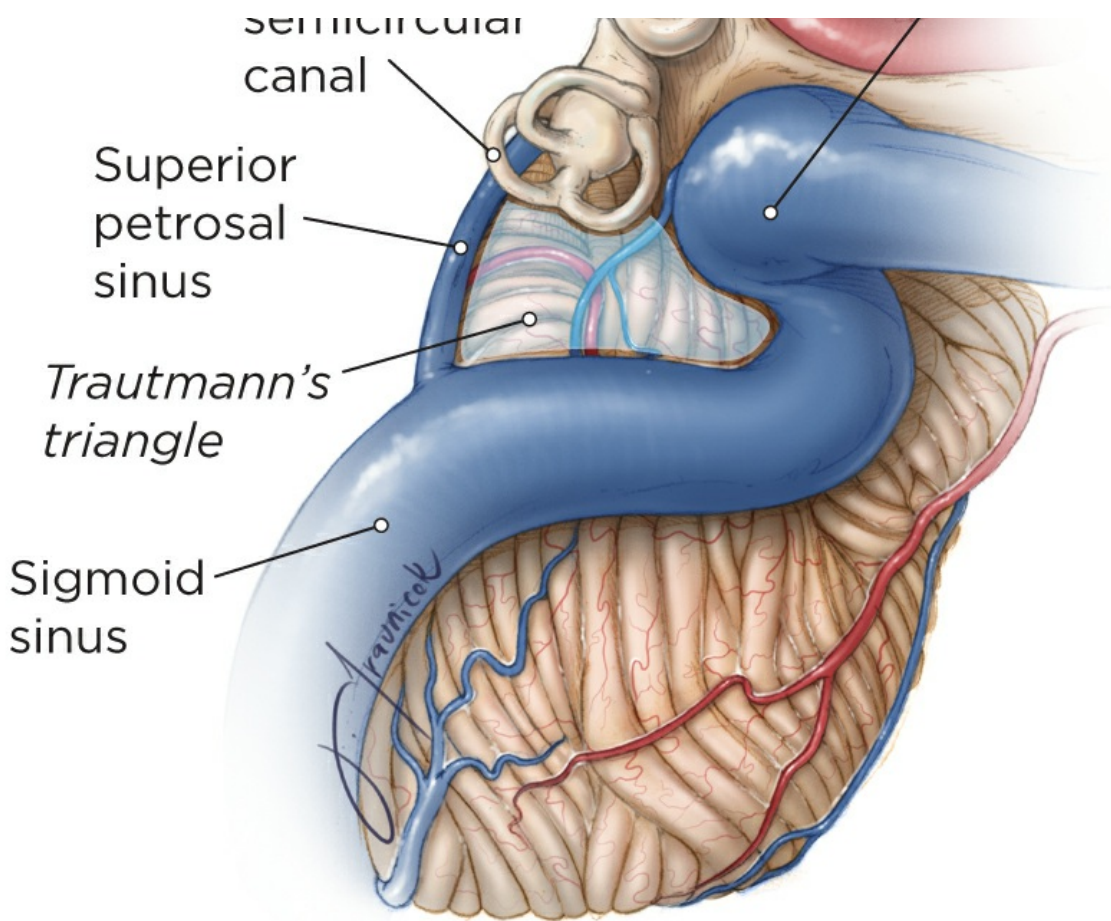

Figure 10: Once the sigmoid sinus is fully skeletonized, additional air cells anterior to the sigmoid sinus are removed to expose the dura of the middle and posterior fossae. **Small islands of thin adherent cortical bone are left on the sinus to minimize injury to this important venous structure.** Bone removal is continued until the middle fossa dura is exposed. Smaller cutting burrs are employed as mastoidectomy proceeds and the deeper structures are reached.

The sigmoid sinus is followed inferiorly to near the jugular bulb, exposing the inferior segment of the sigmoid sinus and digastric ridge. The facial nerve courses along the inferior edge of the lateral semicircular canal into the stylomastoid foramen located just anterior to the digastric ridge. The

facial nerve is embedded in the cortical bone of the fallopian canal. There is no need to skeletonize the facial nerve unless exposure of the jugular foramen is desired. The sigmoid sinus is now unroofed from its confluence with the superior petrosal sinus superiorly all the way to the level of the jugular bulb inferiorly. Patients with a "high-riding" jugular bulb will provide a limited presigmoid working window and alternative operative corridors besides the posterior petrosal route should be considered.

Internal carotid artery

Jugular bulb

Posterior semicircular

semicircular canal

Superior petrosal sinus

Trautmann's triangle

Sigmoid sinus

Superior petrosal sinus

Posterior semicircular canal

Sigmoid sinus

Figure 11: Removal of the bone over the Trautmann's triangle is shown. The bone covering the presigmoid dura at the sinodural angle is removed (upper image), exposing the Trautmann's triangle. This triangle is an area of the posterior fossa dura bounded inferiorly by the jugular bulb, superiorly by the superior petrosal sinus, anteriorly by the bony labyrinth, and posteriorly by the sigmoid sinus (hashed area in the middle and inferior images).

Bone resection anterior to the sigmoid sinus can progress forward until the cortical bone over the posterior semicircular canals is encountered. Aggressive drilling around the jugular bulb is unnecessary and can lead to injury of the jugular bulb or facial nerve. Once I have achieved exposure of the Trautmann's triangle, the conservative retrolabyrinthine petrosectomy is considered complete.

In this form of nonextended retrolabyrinthine approach, hearing preservation is an important goal, and aggressive skeletonization of the bony labyrinth is not attempted. If an accidental disruption of the bony labyrinth occurs but the membranous labyrinth is intact, a piece of fascia may be used to cover the defect to preserve vestibular function.

However, if both the bony and membranous components of the labyrinth are transected, a small piece of wax must be inserted in the defect. In this situation, postoperative vertigo and/or hearing loss can be expected. For an extended retrolabyrinthine approach that includes skeletonization of the labyrinth, refer to the chapter on Extended Posterior Petrosectomy.

INTRADURAL PROCEDURE

Dural opening involves the transection of the tentorium.
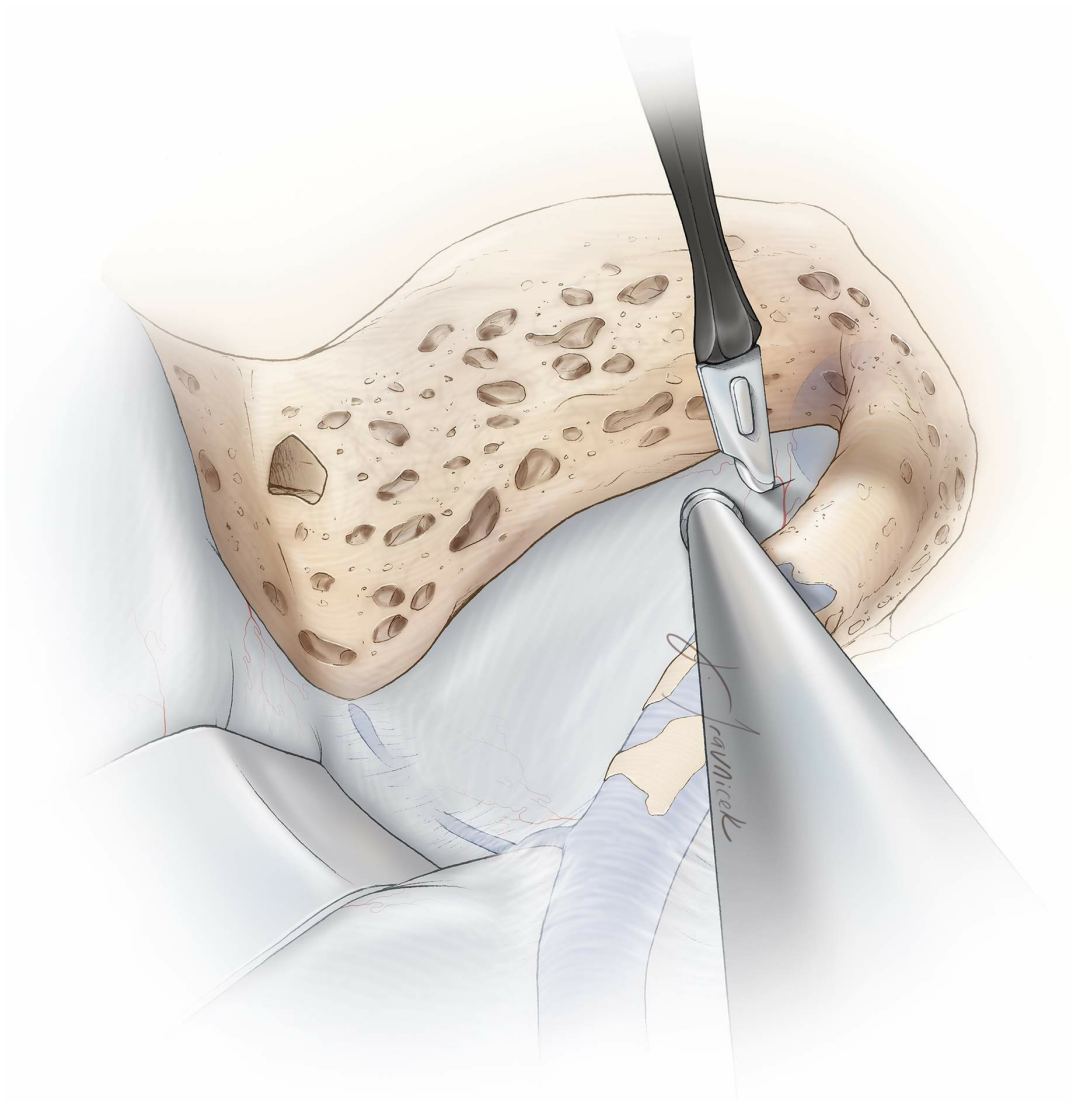
Figure 12: Next, the posterior fossa dura is incised, anterior and parallel to the sigmoid sinus, extending from the jugular bulb to the superior petrosal sinus. The endolymphatic sac will be visible inferior to the posterior semicircular canal as a white, thick area of the dura. This structure is usually the anterior limit of the dural exposure and should be preserved to avoid hearing loss. If the dural incision violates the endolymphatic sac, the patient's hearing may still remain intact if the endolymphatic duct is spared.
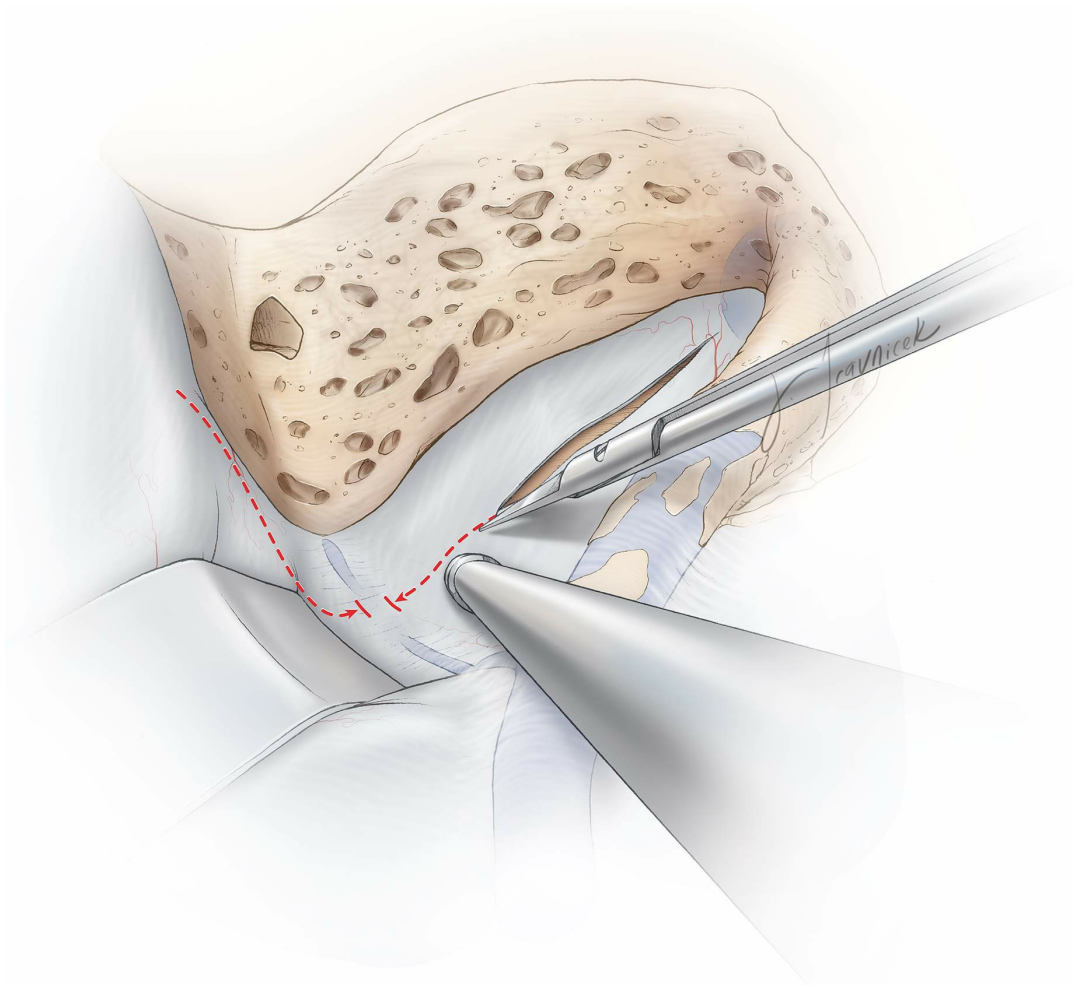
Figure 13: The second segment of the dural incision follows the floor of the temporal fossa and is continued posteriorly to the level of the superior petrosal sinus. To prevent injury to the vein of Labbé, I cut the dura in small increments and inspect the subdural space for the entry point of the vein into the transverse or superior petrosal sinuses.
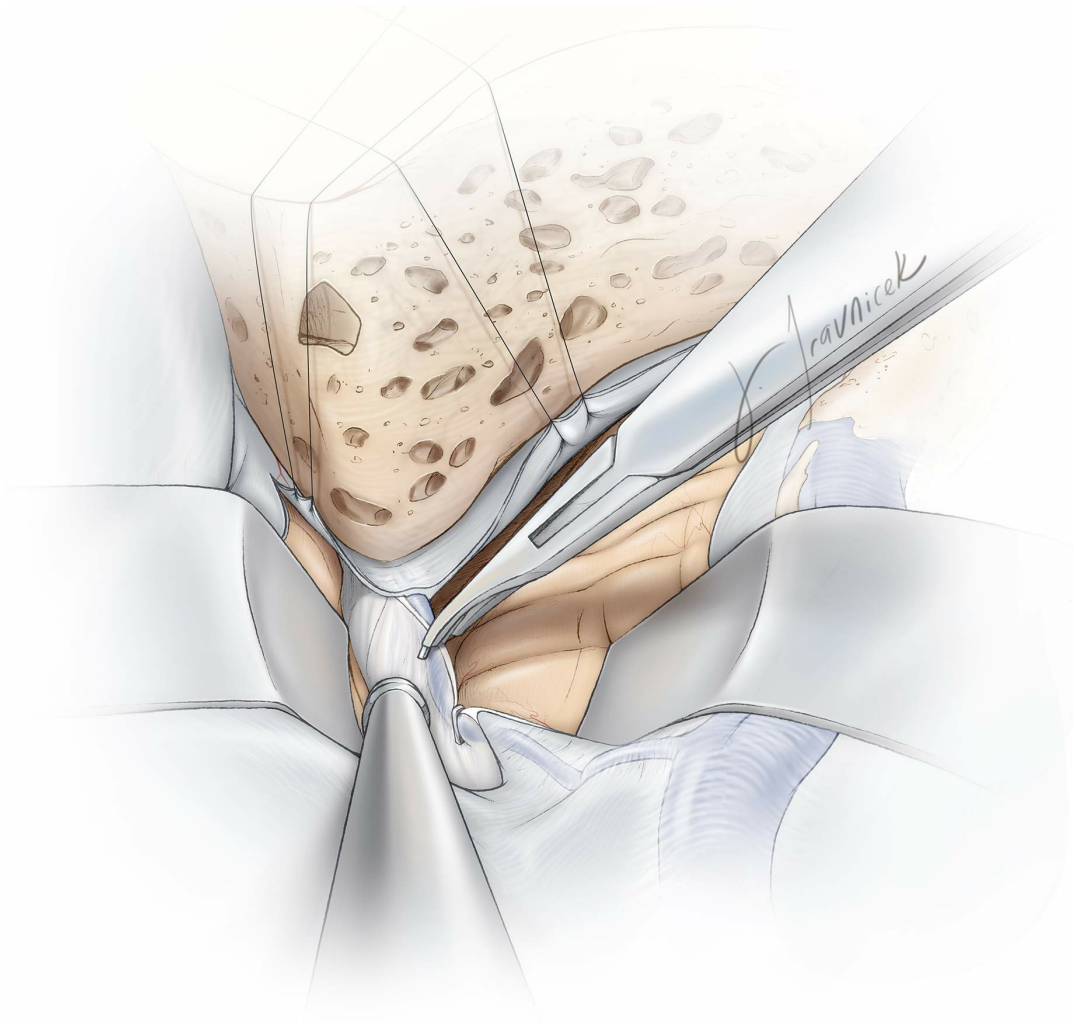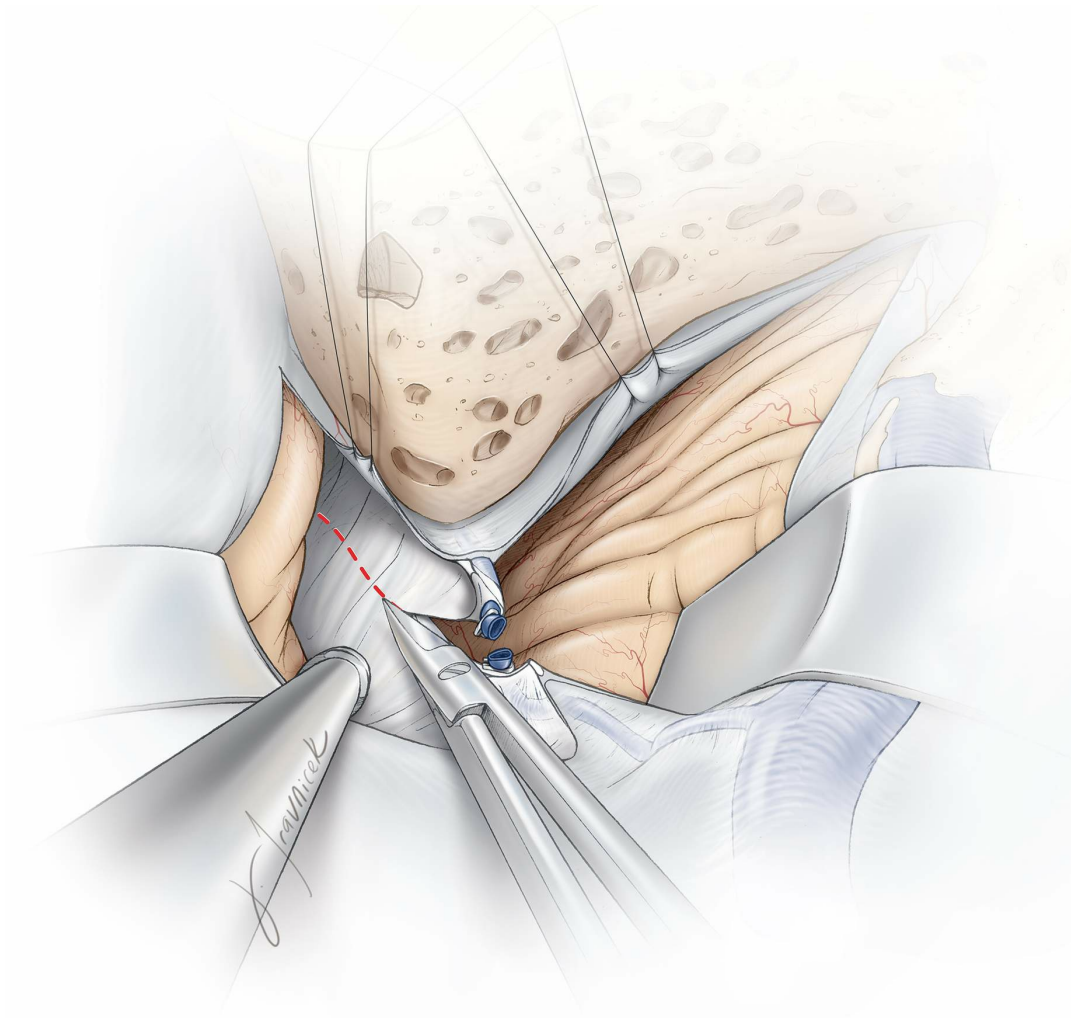
Figure 14: The superior petrosal sinus is now isolated, coagulated, or ligated with Weck clips. **The point where the sinus is divided must be anterior to the insertion point of the temporal lobe's draining veins (including the vein of Labbé) to preserve their outflow into the transverse-sigmoid sinuses.** If the vein of Labbé crosses the area of exposure, it can be partially untethered, mobilized, and protected.

Preoperative assessment of the temporal lobe's venous drainage patterns using CT/catheter angiography or magnetic resonance venography is beneficial in tailoring the safe zones for tentorial transection. **If the superior petrosal sinus is intimately involved with the venous drainage of the region, an incision along the tentorium medial to the superior petrosal sinus will spare this sinus and allow an operative corridor, albeit limited, to the petroclival region around the sinus.**

Figure 15: After the superior petrosal sinus is divided, the dural incision is continued on the tentorium parallel to the posterior edge of the petrous pyramid toward the tentorial incisura. It is often tempting to incise the tentorium more posteriorly because of the wider exposure in that region. Completing the dural incision more posteriorly (and not along the petrous pyramid) will lead to a tentorial flap along the ridge that may limit the surgical corridor.
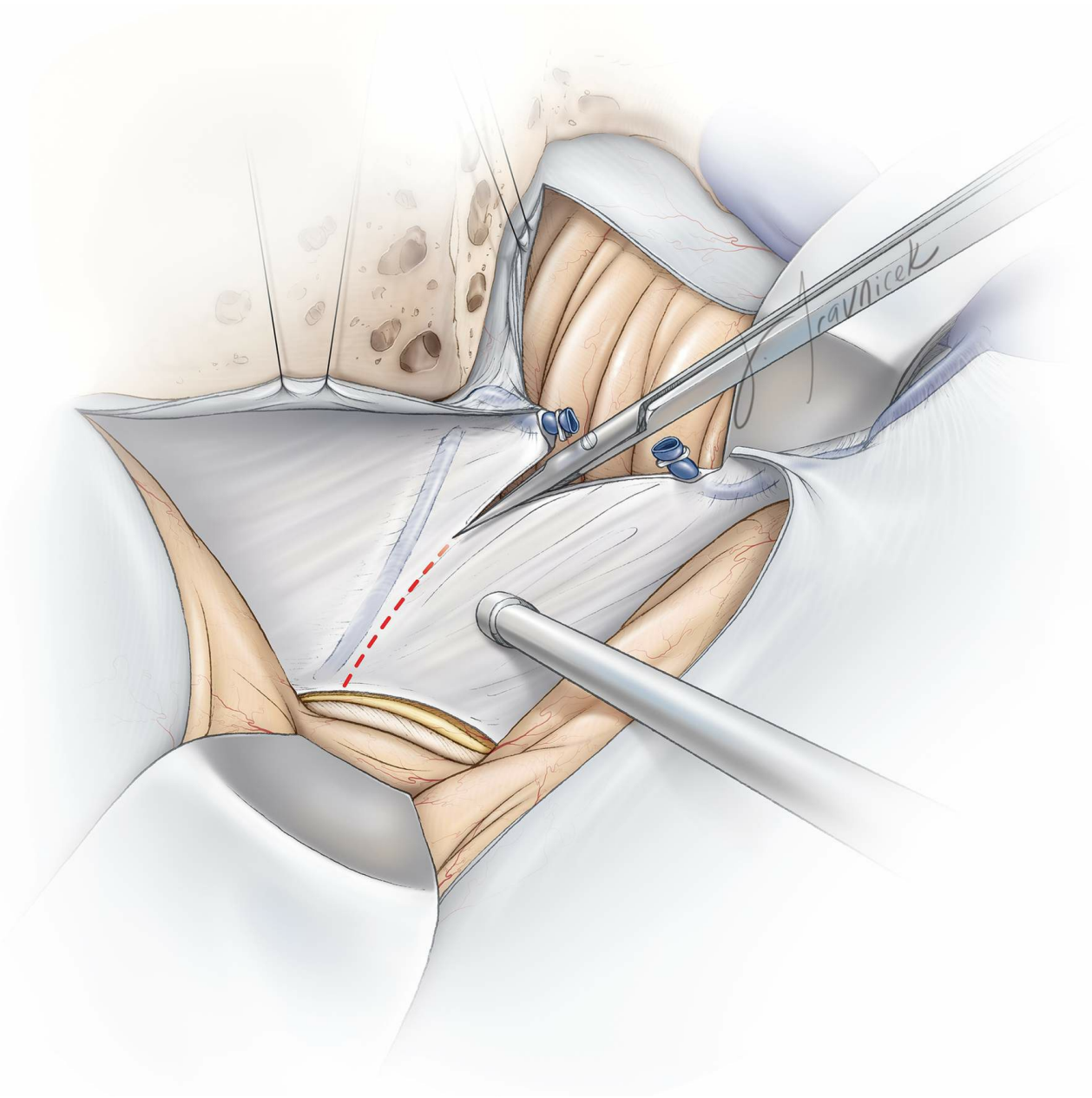
Figure 16: Before the medial edge of the tentorium is transected, CN IV must be identified to the point where it enters the dura. To protect this nerve, I cut the tentorium posterior to the point where the nerve enters the tentorial edge.
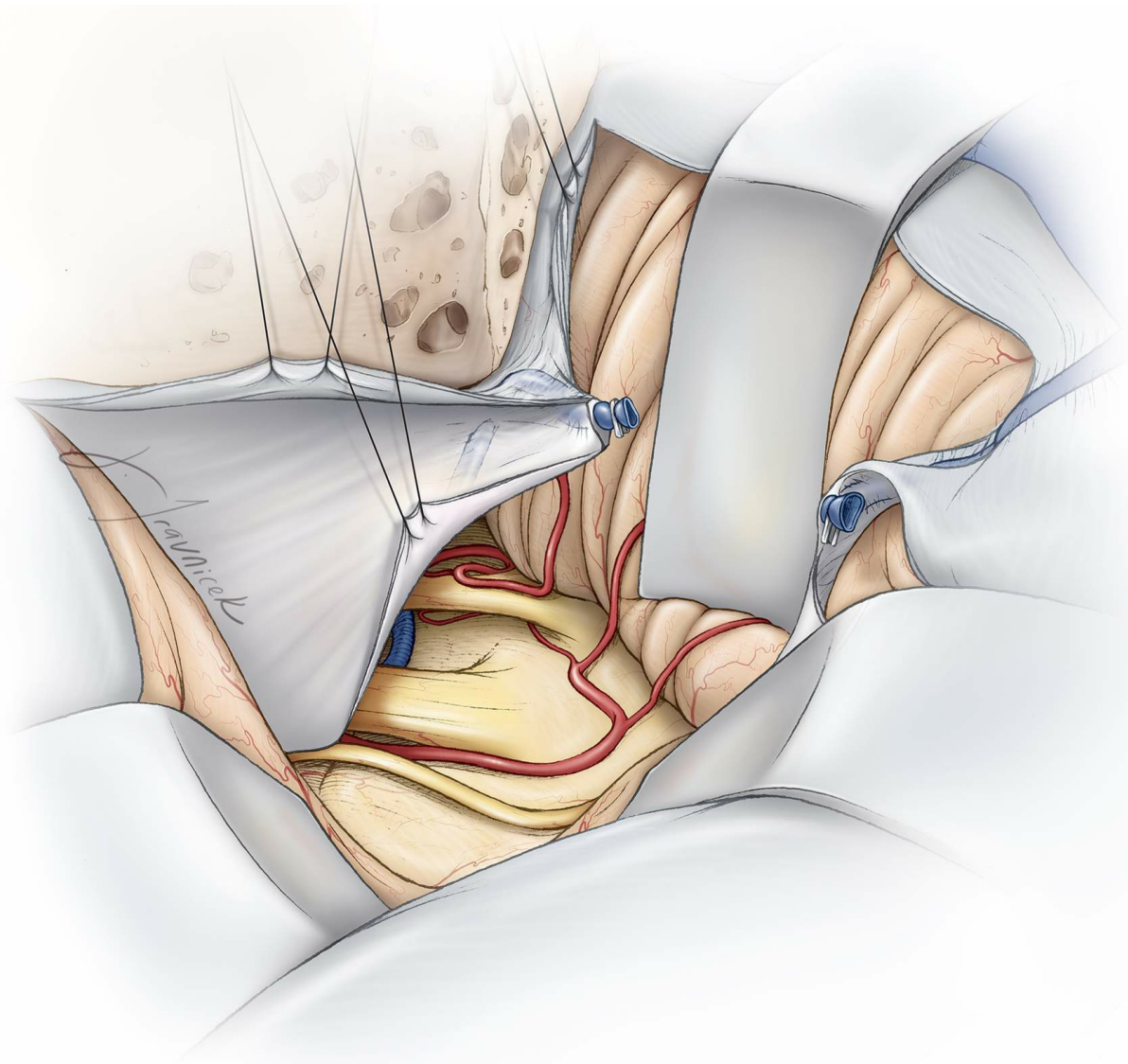
Figure 17: The posterior tentorial flap is then elevated with the temporal lobe and held in place using a retractor blade. Another retractor blade holds the cerebellum inferiorly. The presigmoid dura, temporal dura, and tentorium are retracted using retention sutures. Note that the sutures are placed as deep as possible and close to the petrous edge to maximize exposure.
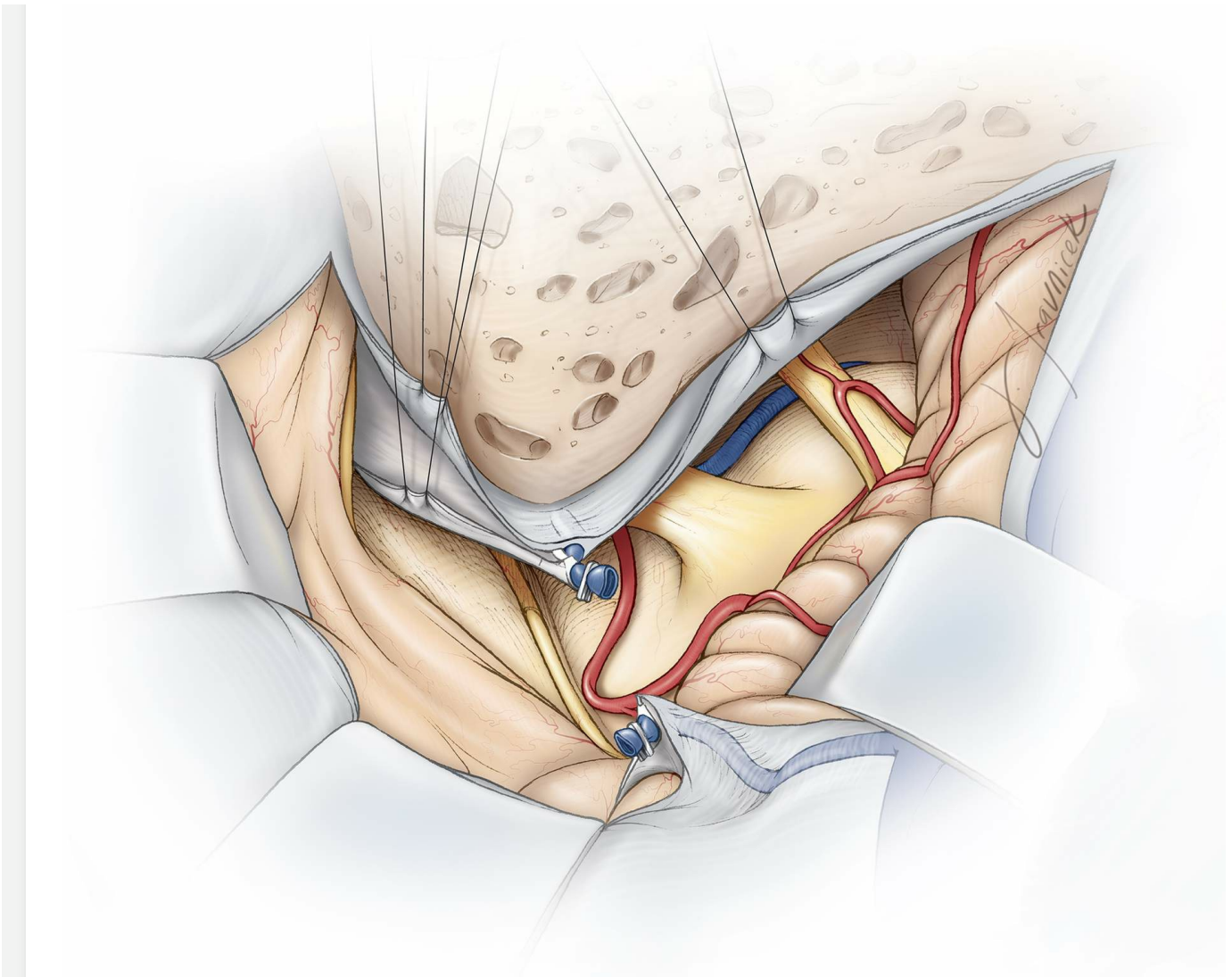
Figure 18: Gentle posterior retraction of the sigmoid sinus allows a direct panoramic view of the anterolateral brainstem and the origins of the cranial nerves along the petroclival space. As mentioned above, more extensive bone resection of the labyrinth is usually not necessary to remove lesions along the anterolateral brainstem because the operator can typically expand the operative corridor through lesional intracapsular decompression.

Closure

Following surgical treatment of the pathology at hand, closure begins. The dura is approximated primarily, but watertight closure is not feasible and additional measures are taken to prevent CSF leakage. All exposed air cells are meticulously waxed, and strips of adipose tissue or fascia lata are placed across the dural opening to seal the dural defect.

Additionally, the vascularized periosteal flap that was harvested during

exposure is used to cover the defect in the dura. The bone flap is replaced and secured using miniplates, and the rest of closure is conducted in a standard fashion.

A lumbar drain is continued to remove 8cc/hour of CSF for 48 hours after surgery. Patients are mobilized as soon as possible.

Pearls and Pitfalls

- Posterior petrosectomy is rarely needed, even in a busy skull base surgery practice. Retromastoid craniotomy and its expansion through unroofing of the sigmoid sinus and the transtentorial routes typically allows adequate exposure of some petroclival tumors. Nonetheless, a petrosectomy provides the surgeon with multiple flexible operative working angles to handle a fibrous and vascular meningioma. This corridor leads to tumor devascularization early in surgery while minimizing brain retraction.

- The use of lumbar CSF drainage facilitates intracranial decompression, therefore expediting dissection of the dural venous sinuses away from the inner skull during craniotomy and bone work.

- Collaboration with our otology colleagues is paramount during execution of mastoidectomy while protecting the labyrinth.

- Unlike the transverse sinus, the sigmoid sinus is embedded in the skull bone; patience and meticulous bone drilling is require for its preservation. If necessary, a thin shell of bone should be left on the sigmoid sinus to maximize its protection.

- The incision along the tentorium should be completed as close to the petrous ridge as possible to avoid creation of a sizable tentorial flap that could interfere with the operative corridor.

For additional illustrations of combined transpetrosal-middle fossa approaches, please refer to the Jackler Atlas by clicking on the image below:
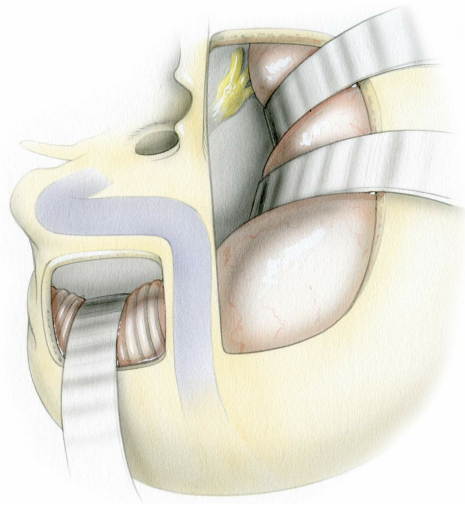
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