Surgical Approaches to the Skull Base

Dissection Manual

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A hands-on cadaver workshop with
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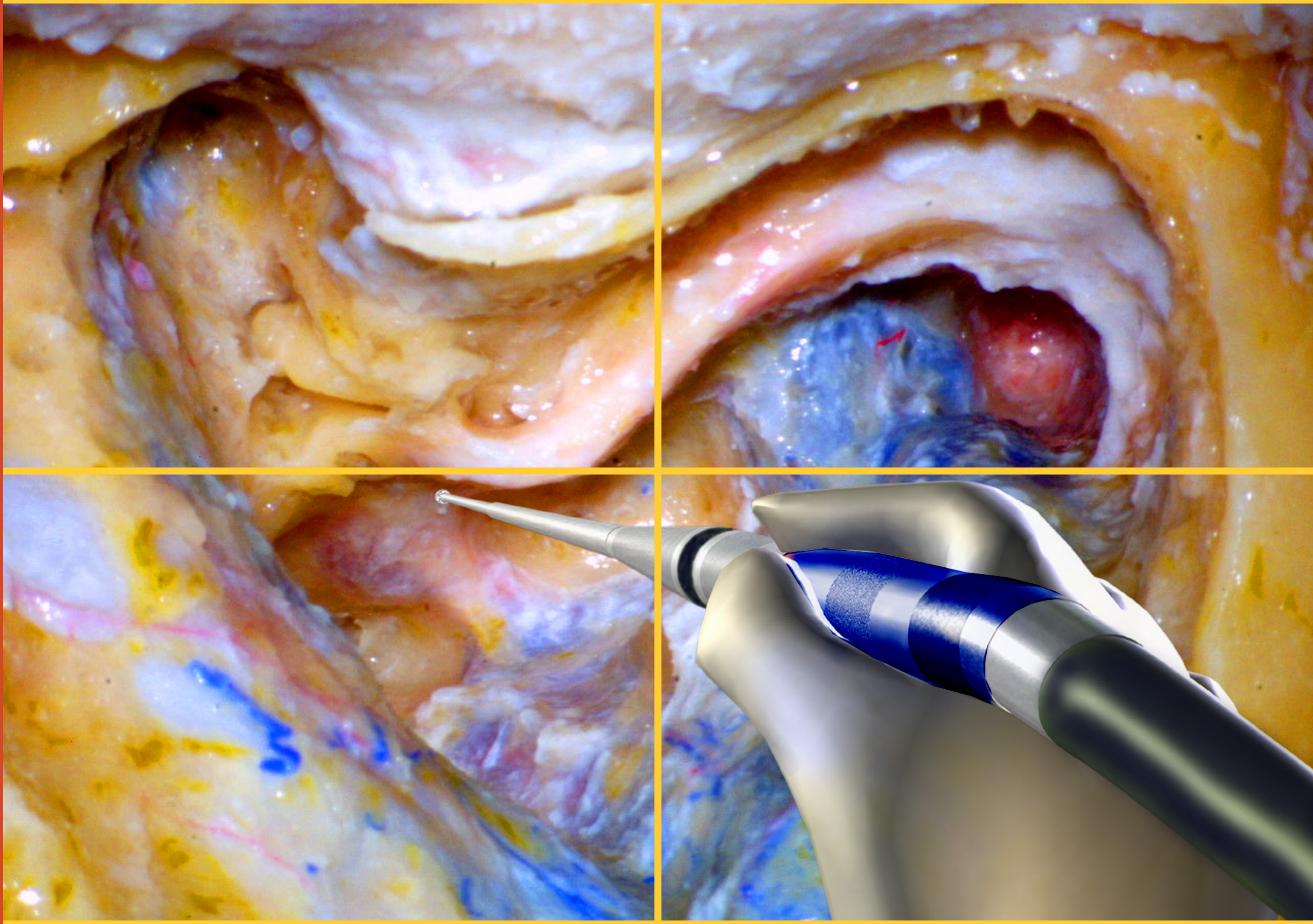

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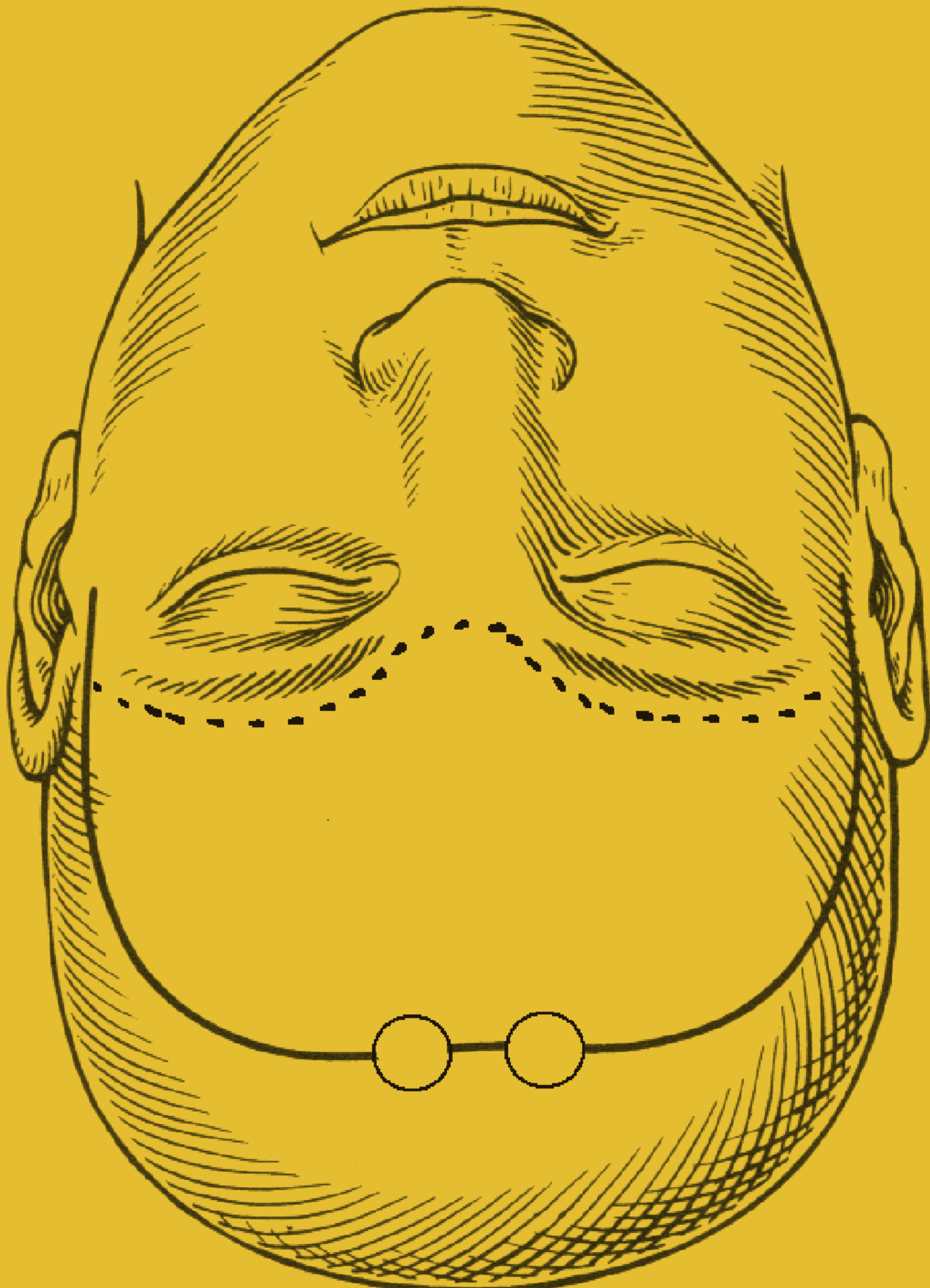
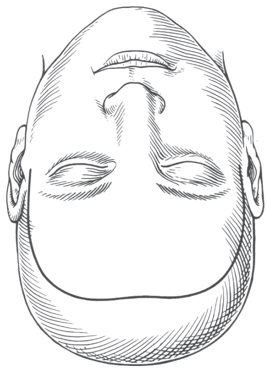


CHAPTER 1

Bifrontal Transbasal Approach

Bifrontal Transbasal Approach



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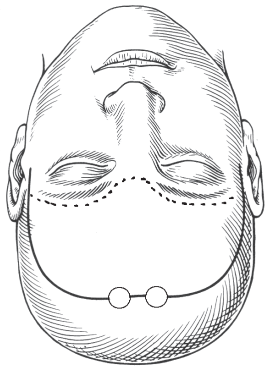

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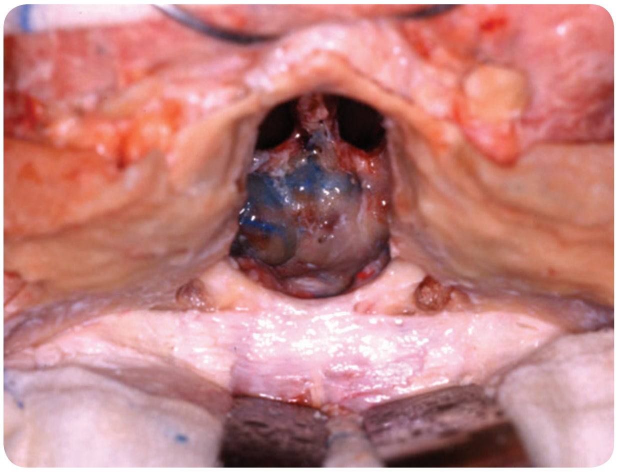

Figure 3:
View after bifrontal craniotomy, elevation of frontal dura, extradural bone removal to expose the bilateral optic sheaths. The planum sphenoidale has been removed to open the sphenoid sinus. The olfactory nerves are divided, the cribriform plate removed and the frontal sinus cranial-ized. This is a view to the floor of the sphenoid sinus with the midline nasal septum in view.

Position and incision

The head is placed with the face up, as in the supine position. The vertex is extended 15 degrees toward the floor. A bicoronal skin incision is extended from tragus to tragus running within the hairline **(Fig 1)**. In order to avoid inadvertent laceration to the superficial temporal artery or branches of the facial nerve, the incision begins about a centimeter anterior to the tragus The galea is detached from the pericranium using sharp dissection preserving the supraorbital and supratrochlear nerves and is elevated forward until the supraorbital rim is reached. The pericranium is incised along the skin incision and along the superior temporal line bilaterally and elevated anteriorly towards the supraorbital rim and, on the midline, as far as the nasofrontal suture.

Bifrontal craniotomy

The supraorbital nerves are freed from the supraorbital notch using an osteotome or a sagittal saw if needed. A burr hole is placed at the pterior on each side after cleaning the region from the temporalis muscle's attachment. Two more burr holes are placed on both sides of the midline just anterior to the coronal suture. Anteriorly the bone cut is placed as close as possible to the frontal floor following the supraorbital ridge on both sides. Once reached the midline the incision should curve inferiorly to cut across the glabella **(Fig 2)**.

Dural elevation

Using a periostal elevator, the dura is elevated from the floor of the frontal fossa. At the cribriform plate the arterior superior ethmoidal artery and the posterior superior ethmoidal arteries can be identified. The dura around the cribriform plate is incised on both sides and the olfactory nerves are divided. This will allow the subfrontal dura to be elevated posteriorly from the planum sphenoidale. Working laterally, the dura overlying the optic foramina is exposed and the emergenze of the optic nerves from their respective optic canals can be identified **(Fig 3)**.

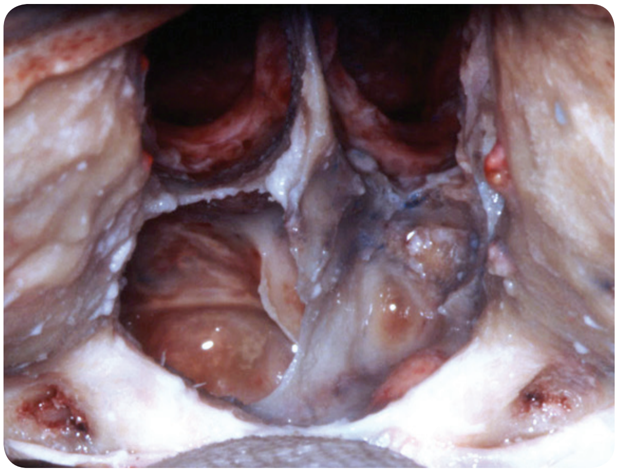

Figure 4:
Higher magnification view in a different specimen of the floor of the sphenoid sinus and the septae. The carotid eminence is well seen on the right side inferior to the optic canal.

Frontal sinus opening

The posterior wall of the frontal sinus is removed with the drill until the ostia of the sinus are visible. Sinus trabeculations and mucosa are removed with a pituitary rongeur. The ostia of the frontal sinus communicate with the ethmoid air cells and are enlarged with a cutting burr to unroof the underlying air cells. This bone work will reveal the midline nasal septum and the superior turbinates. The turbinates are removed to widen the opening into the nasal cavity. Bone removal is extended all around the medial frontal fossa floor. The lateral limits of the bone removal are the medial orbital walls. The optic nerves are skeletonized on each side for at least 180 degrees with a small diamond burr (continuous irrigation is critical in this step) **(Fig 4-6)**. Posteriorly the sphenoid sinus is opened and the orbit scheletonized on each side to provide an unobstructed line of view to deeper trajectory. With further drilling through the posterior wall of the sphenoid cavity sella dura is revealed **(Fig 5-6)**.

Figure 5:
The clivus has been drilled away to expose the clival dura. Notice the bilateral carotid eminences. The carotid genu in the cavernous sinus is seen as the artery exits foramen lacerum on the right side. It is also seen on the left but is not as prominent. The inferior extent of dura seen is at the foramen magnum.

Figure 6:
A view from left to right demonstrating the position of the carotid artery on the right. It is seen as it exits the foramen lacerum and then is not visualized in its intracavernous course. It is next seen in the subclinoidal segment on its anterior aspect forming the carotid eminence in the sphenoid sinus.

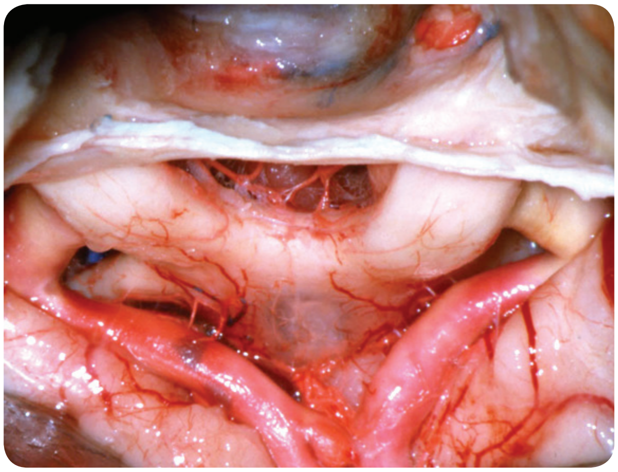

Figure 7:
The dura is opened to reveal the anterior communicating artery complex, optic chiasm, lamina terminalis and pituitary stalk.

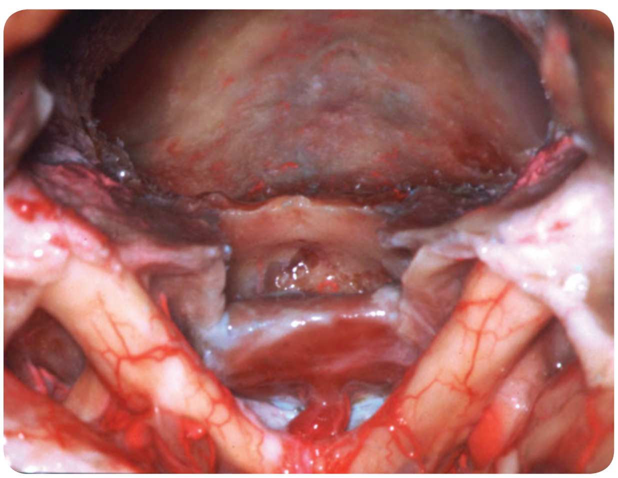

Figure 8:
The intercavernous sinus is interrupted and the diaphragma opened allowing superior mobilization of the pituitary gland in order to allow removal of the upper clivus and posterior clinoids.

Dura opening

The dura is opened in the midline at the tuberculum sphenoidale and the incision is extended bilaterally to open the optic nerve sheath. Retractors are placed on the frontal lobes and after dissecting the arachnoid, the optic apparatus, internal carotid arteries, anterior cerebral arteries and pituitary stalk are exposed **(Fig 7)**.

The exposure is completed with removal of the upper clivus, skeletonizing the pituitary fossa. The lateral margins of bone removal are the internal carotid arteries. The presence of the orbital bar doesn't allow for removal of clivus inferior to the pituitary fossa **(Fig 8)**.

Extended Transbasal Approach

This extended exposure implies removing the supraorbital bar resulting in an increased viewing angle of the upper clivus, inferior to the pituitary fossa.

The initial craniotomy is the same as in the standard transbasal approach **(Fig 2)**. The periorbita is dissected superiorly from the orbital roof to a depth of approximately 2 to 2.5 cm, laterally to the point of the inferior orbital fissure and medially to the anterior ethmoidal foramina. After the periorbita is carefully separated form the orbital wall on both sides, with an oscillating saw or an osteotome, the bone is incised through the nasofrontal suture. The osteotomy is completed with removal of the supraorbital rim on each side. This cut extends laterally to include the frontal zygomatic process. Approximately 2.5 cm of the orbital roof should be included in this cut so as to minimize the possibility of a postoperative enophthalmos (Fig 9). The bone removal of the frontal fossa floor is the same as in the standard transbasal approach with the addition of further removal of clivus inferior to the pituitary fossa. With further drilling through the posterior wall of the sphenoid cavity, sella dura is revealed. Working more caudally, the cancellous bone of the clivus can be progressively removed to expose clival dura from approximately 5 to 10 mm inferior to the posterior clinoids to the foramen magnum **(Fig 10)**.

This extended bone removal allows a better view across the frontal floor to the clivus inferior to the pituitary fossa with reduced frontal lobe retraction.

After the dura is incised down to the inferior extent of the bone removal, the pons, the upper medulla, and abducens nerves are visible. Also the anterior inferior cerebellar arteries and the basilar artery to the vertebro-basilar junction are visible **(Fig 11)**.

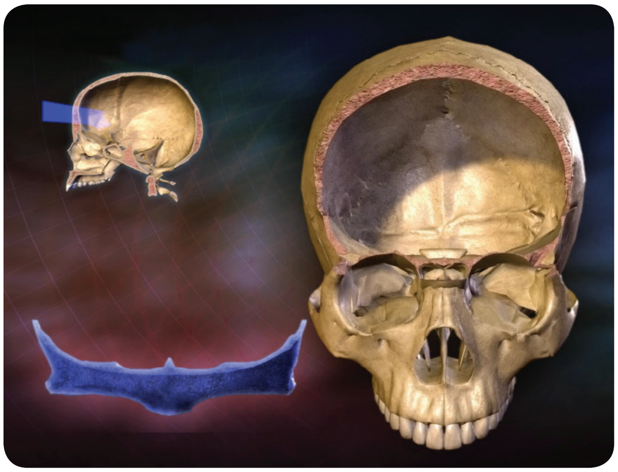

Figure 9
The supraorbital bar is removed.

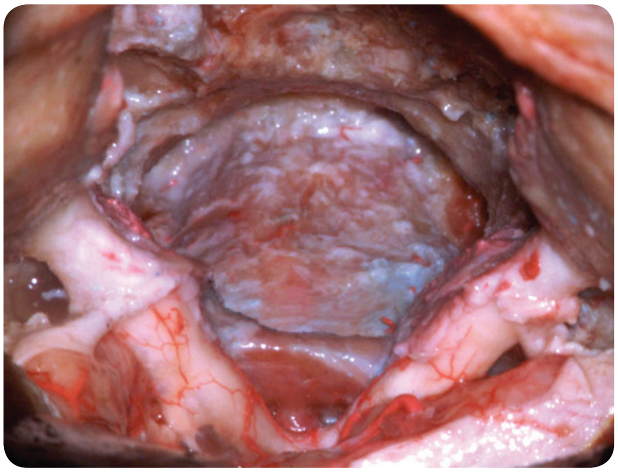

Figure 10
View after total removal of the clivus.

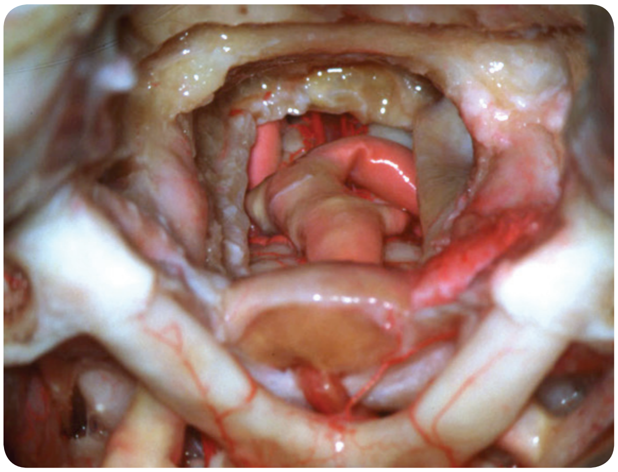

Figure 11
View of the basilar artery and V-B junction after dural opening.

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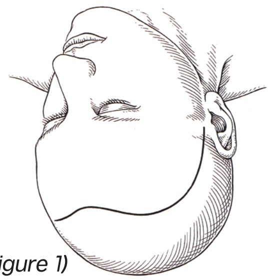
CHAPTER 2

Fronto-orbito-zygomatic Osteotomy

Fronto-orbito-zygomatic osteotomy

The orbitozygomatic approach offers a wide angle of exposure for the management of lesions involving the cavernous sinus, parasellar region, upper clivus, and adjacent neurovascular structures. It combines the pterional approach with different osteotomies that remove the superior and lateral walls of the ipsilateral orbit and zygomatic arch.

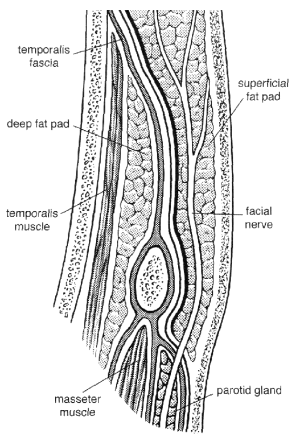


(Figure 1)

Position and incision

The head is rotated 15-20 degrees with the vertex oriented slightly downward.

The incision is a short bicoronal incision and will start from just anterior to the ipsilateral tragus, at the level of the inferior border of the zygomatic arch (it is useful to first palpate the zygoma), up to the superior temporal line. The incision then gently curves to terminate at the hairline superior to the contralateral midpupillary line. The posterior limb of the superficial temporal artery should be spared **(Fig 1)**.



(Figure 2)

The scalp flap is elevated to expose the underlying temporal fascia, covering the temporalis muscle. The temporalis muscle is covered by a temporal fat pad which consists of two parts, a superficial and a deep one.

Care should be taken to elevate the galeal layer with the scalp flap until a natural fascial plane between the two fat pads is identified (approximately at an imaginary line joining the frontozygomatic suture and the root of the zygomatic arch). The frontal branch of the facial nerve that supplies the frontal muscle lies in the subgaleal (superficial) fat pad. This superficial fat pad, housing the facial nerve branches, is elevated with the galeal layer. The deep fat pad, between the temporalis and the zygoma, is left intact (Fig 2).

The vascularized pericranial flap is elevated with a periosteal elevator until the supraorbital rim is exposed completely to the entrance of the orbit. Also the zygoma and the lateral orbital rim are fully exposed **(Fig 3)**.

The temporalis fascia and muscle are incised sharply along the margin of the superior temporal line, leaving a narrow myofascial cuff attached to the bone. The temporalis muscle is elevated and reflected inferiorly.

Using blunt dissection, the periorbita is freed gently from the lateral and superior aspects of the orbital walls. The supraorbital nerve is freed from its bony canal with a small chisel or diamond drill **(Fig 4)**.

Orbito-zygomatic craniotomy

After a standard pterional bone flap is elevated **(Fig 5)**, the orbital and zygomatic osteotomies are completed with a reciprocating saw **(Fig 7)**:

- The first cut is made across the root of the zygomatic process (care should be taken to avoid violation of the temporo-mandibular joint capsule) **(Fig 10)**.
- The second and third cuts divide the zygomatic bone just above the level of the malar eminence **(Fig 10)**.
- The fourth cut divides the superior orbital rim and roof **(Fig 9)**.

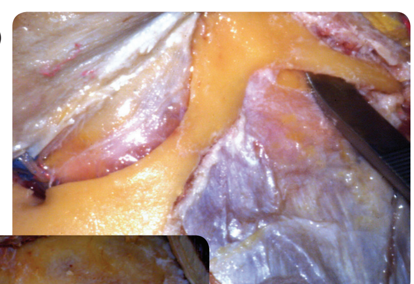
*The last two cuts free the lateral orbital wall by connecting the inferior and superior orbital fissures. The inferior orbital fissure is identified by direct vision or by palpating the infratemporal fossa with a No. 4 Penfield dissector **(Fig 9)**.*

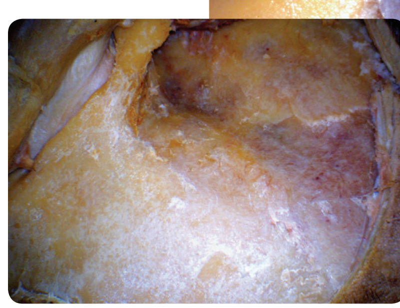
- The fifth cut is a short cut made from the inferior orbital fissure to the temporal fossa.
- The sixth and final cut extends from the lateral margin of the superior orbital fissure to join the fifth cut from the inferior orbital fissure **(Fig 10)**.

Removal of this additional bone along the cranial base decreases the needed retraction and increases the angle over which structures at the depth of the microsurgical corridor can be viewed **(Fig 8)**.

The fronto-orbito-zygomatic osteotomy can be completed with removal of the anterior and posterior clinoid process and the upper portion of the clivus to better expose the region of the basilar apex and the interpeduncular fossa **(Chapter 3)**.

(Figure3)





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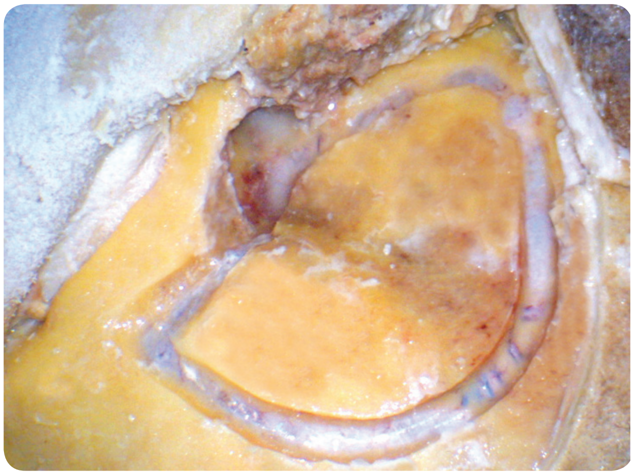

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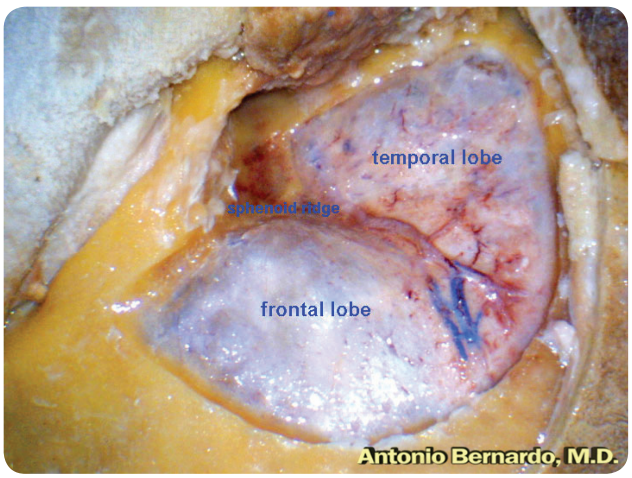

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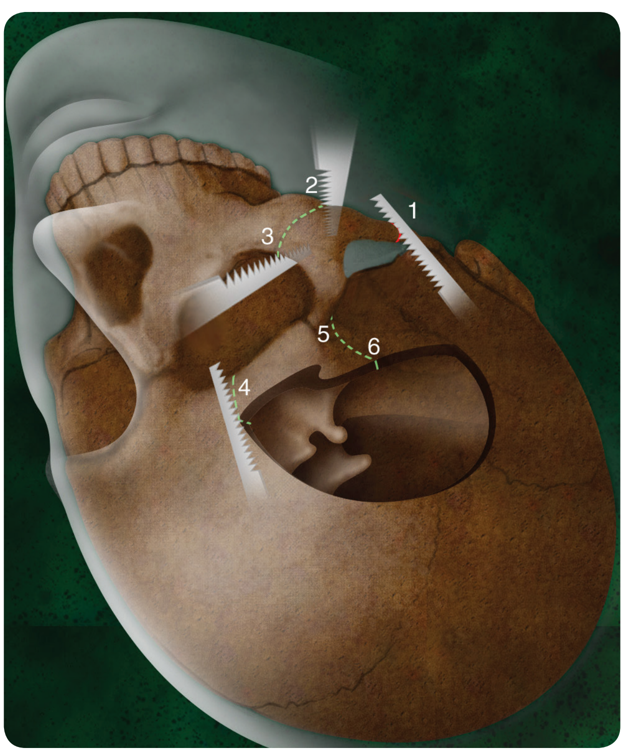

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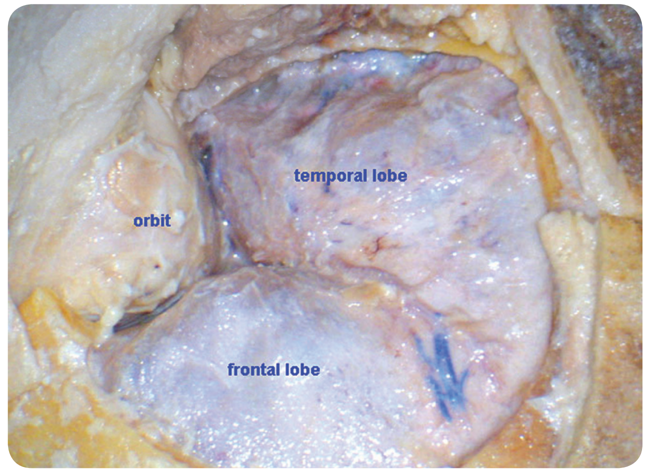

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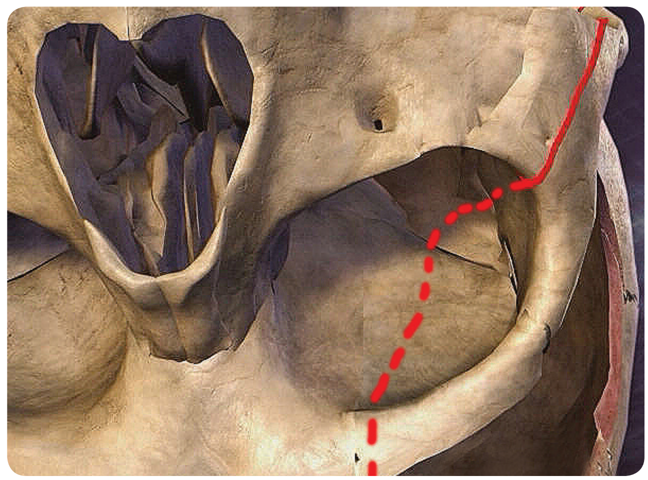

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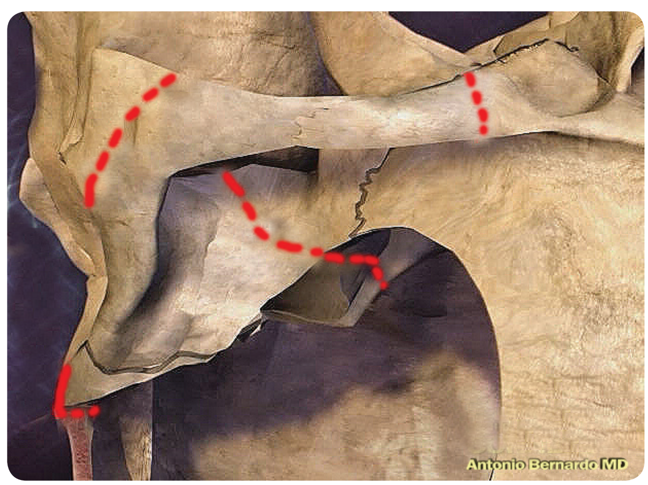

(Figure 10)

Orbito-zygomatic

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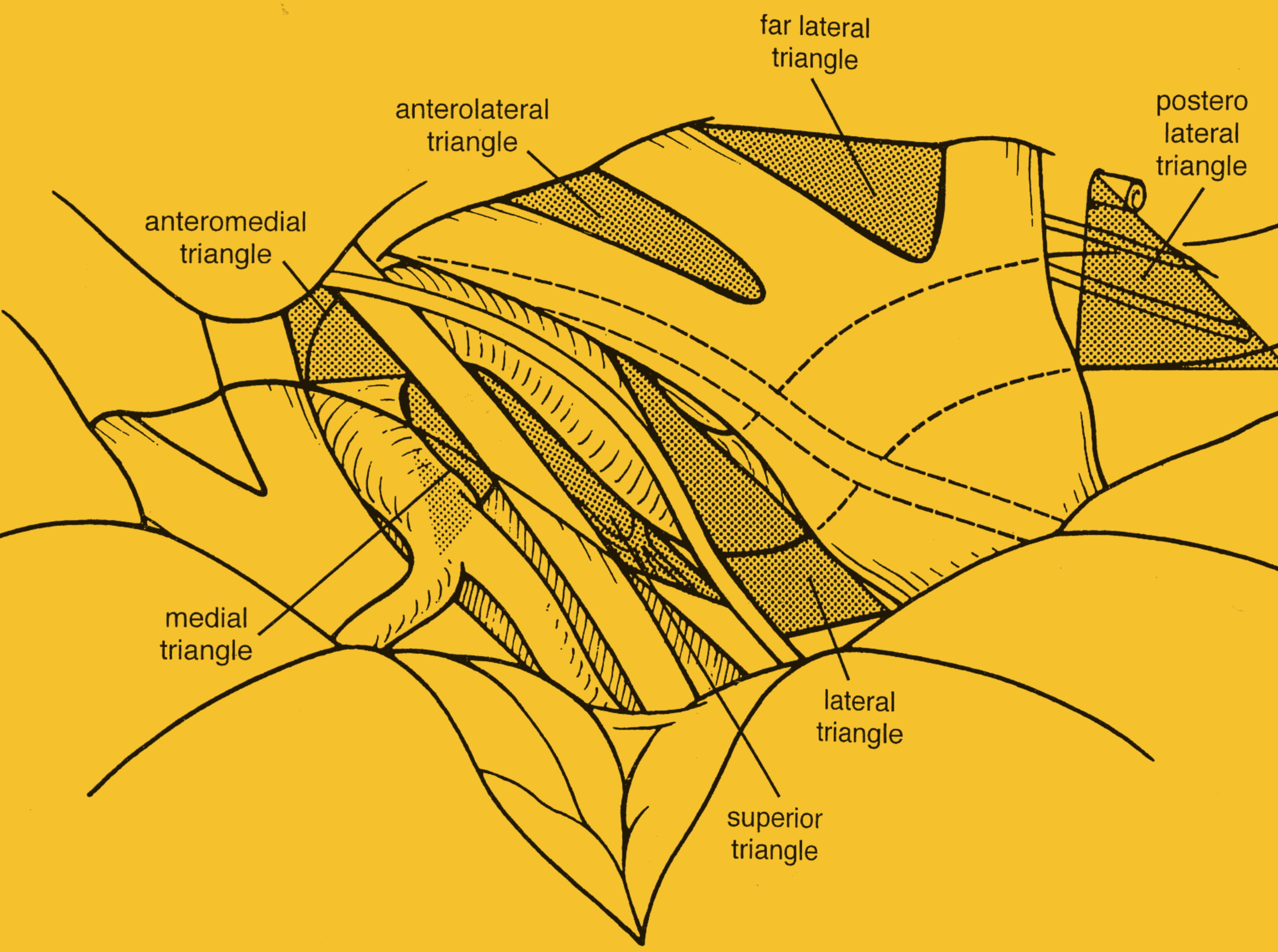
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CHAPTER 3

Extradural Exposure of the Cavernous Sinus: Dissection Technique.

Extradural exposure of the cavernous sinus: dissection technique.

Located in the midportion of the brain, the cavernous sinus houses the carotid artery and multiple cranial nerves. Accurate extradural exposure is essential either as initial preparation for a combined intra-extradural approach, or as the main avenue of surgical exposure.

A frontotemporal orbito-zygomatic craniotomy is executed with extensive bone resection to expose the superior orbital fissure and part of the orbital content as described in the previous chapter.

Extensive bone resection.

Medial exposure of the cavernous sinus and exposure of the subclinoid CA are obtained by drilling out the sphenoidal ridge, the remainder of the orbital roof, the anterior clinoid process, and the optic strut and by "unroofing" the optic nerve. The dura is elevated from the anterior portion of the frontal fossa floor and from the sphenoid ridge. Using a high speed drill the sphenoid ridge is progressively flattened until the most lateral aspect of the lesser wing and the base of the anterior clinoid process are reached. In a similar fashion the bony convolutions of the orbital roof are smoothed down **(Fig 1-2)**.

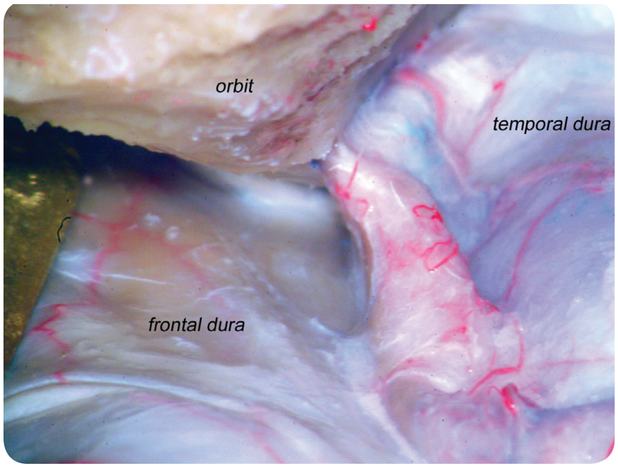
Identification and dissection of the dural bridge:

On the lateral side of the the SOF, between the greater and the lesser wings of the sphenoidal bone, the periosteoum of the orbit is continuous with the periosteal dura of the middle fossa forming the dural bridge (Fig 1). This dural bridge is usually very short (3-4 mm) and houses the orbito-meningeal artery which is divided and cut. Resection of this dural bridge allows improved exposure of the anterior clinoid process, the superior orbital fissure (SOF) and the anterior portion of the cavernous sinus.

Clinoid process removal.

Removal of the anterior clinoid process exposes the subclinoid portion of the carotid artery, which is both extradural and extracavernous, and provides distal control of the CA.

The anterior clinoid process is located between the superior orbital fissure laterally and the optic canal medially. The dura lying on the superior and inferior surface of the anterior clinoid process is gentle detached from the bony surface and the process is removed piecemeally **(Fig 2)**. With a small diamond burr the center of the clinoid process is hollowed out living a small shell of cortical bone which can be fractured into small little pieces and finally removed **(Fig 3)**. When removing the anterior clinoid process, it is important to bear in mind the surrounding structures: on the medial side lies the optic nerve, while the oculomotor nerve covered by the dura is lateral to the process; inferiorly, in the antero-medial triangle, runs the subclinoidal segment of the carotid artery. Once the anterior clinoid process has been completely removed, the paraclinoid ICA becomes visible and the optic canal results opened on its lateral side (Fig 4). At this point, the optic struct, which connects the anterior clinoid process with the lateral aspect of the body of the sphenoid bone needs to be carefully removed.



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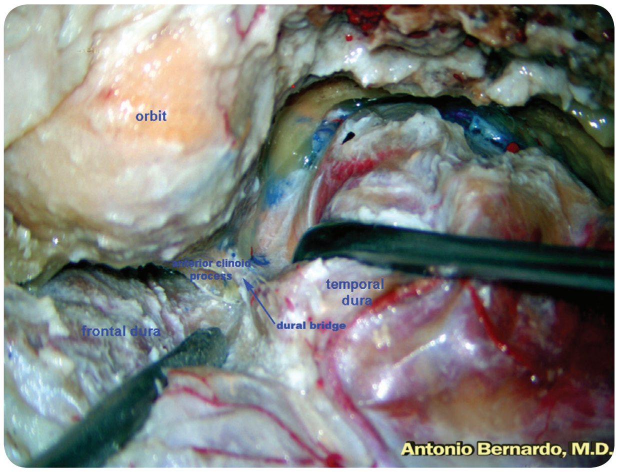


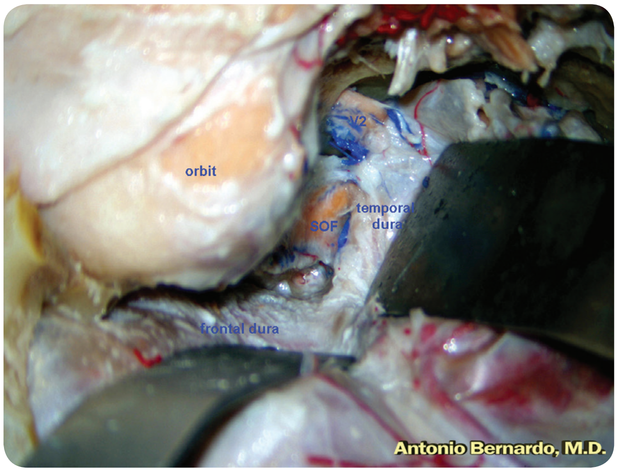
(Figure 2)

Unroofing the optic nerve.

The optic canal is unroofed to expose and mobilize the optic nerve

The dura is further gently elevated from the floor of the anterior cranial fossa towards the tuberculum sellae until the exit point of the optic nerve from its canal is located. The bony roof of the optic canal is then reduced with a diamond burr until only a depressible shell of bone remains over the nerve (care should be taken to avoid entering the ethmoid sinus, which is medial to the optic canal). This shell is then fractured and completely removed. This allows mobilization of the optic nerve, which is essential to avoid optic nerve injury during subsequent dissection of the anterior clinoid proces. At the end of this stage the optic nerve, free of its bony roof, can be slightly mobilized medially.

At the end of this exercise it will be possible to visualize the optic nerve in the optic canal, the paraclinoidal ICA, and to identify the proximal and distal dural rings (the latter becoming continous with the optic dural sheat) (Fig. 4).



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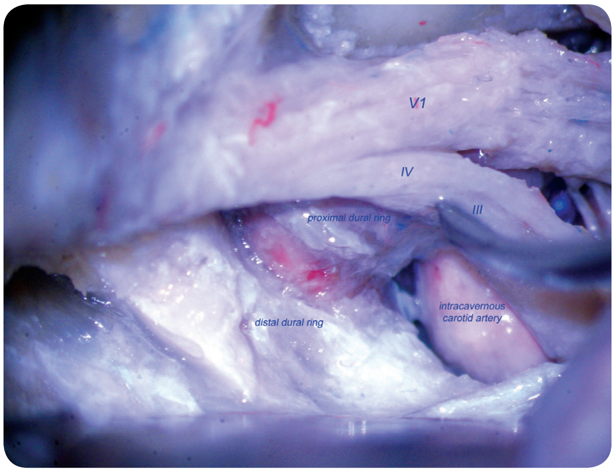


(Figure 4)

Extradural exposure of the cavernous sinus.

Once the dural bridge has been resected, the anterior half of the cavernous sinus is exposed extradurally. The dura of the middle fossa is elevated in an anterior to posterior direction from the middle fossa until the maxillary and mandibular divisions are identified exiting their respective bony foramina **(Fig 5)**. Carefully the interface between the temporal dura and the outer cavernous membrane which is composed by the periosteum lining the middle fossa floor is identified. It is very important at this point to keep the dissection in this interface.

The middle meningeal artery is identified and divided to allow exposure of the middle fossa floor. V3 and foramen ovale are revealed after continued dural elevation **(Fig 6)**.

The greater superficial petrosal nerve (GSPN) is identified running on the superior surface of the petrous bone emerging from the facial hiatus and is dissected free of the dura (Fig 6).

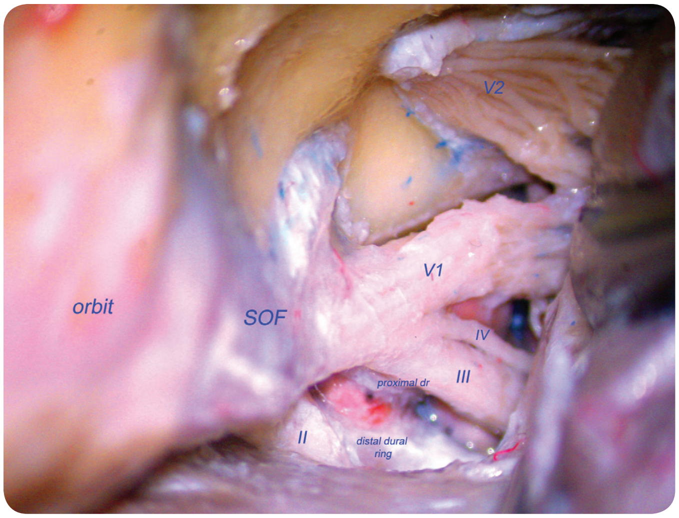
The course of the GSPN will help in identifying the intrapetrous carotid artery which runs in most of the cases underneath the nerve. The intrapetrous ICA is exposed in the Glasscock triangle between the facial hiatus, the anterior aspect of the foramen ovale, and the intersection of the greater superficial petrosal nerve and the lateral aspect of the V3 (Fig 6) (see also Chapter 4 > anterior transpetrosal approach).

The temporal lobe dura, finally free of any tethering points, is gently detached and elevated until the oculomotor and throclear nerves are identified exposing the entire lateral wall of the cavernous **(Fig 7)**.

Once exposed, the cavernous sinus can be accessed trough several entry points defined as cavernous sinus triangles: anteromedial, paramedial, oculomotor, superolateral (Parkinson's), anterolateral, lateral, posterolateral (Glasscock's), posteromedial (Kawase's), inferomedial and inferolateral (trigeminal) **(Fig 8)**.

The superolateral (Parkinson's) triangle is consistently situated between the fourth and fifth cranial nerves (Fig 9), and can be enlarged by depressing the ophthalmic division of the trigeminal nerve and elevating the trochlear nerve. Inferior displacement of the ophthalmic division exposes the abducens nerve **(Fig 10)**. The posterior-superior, anterior-inferior, and lateral venous spaces and lateral surface of the C5 and C6 segment can be well exposed trough this surgical window. The VI nerve can be followed posteriorly in its course through the Dorello's canal **(Fig 11)**.

The ***petrous part of the internal carotid artery*** can be exposed by drilling away the posterolateral (Glasscock's) triangle. The ***pituitary gland*** can be exposed through the anteromedial triangle. Exposure of the ***mid-portion of the basilar artery*** can be also achieved through the Parkinson's triangle **(Fig 12, 13, 14)**.



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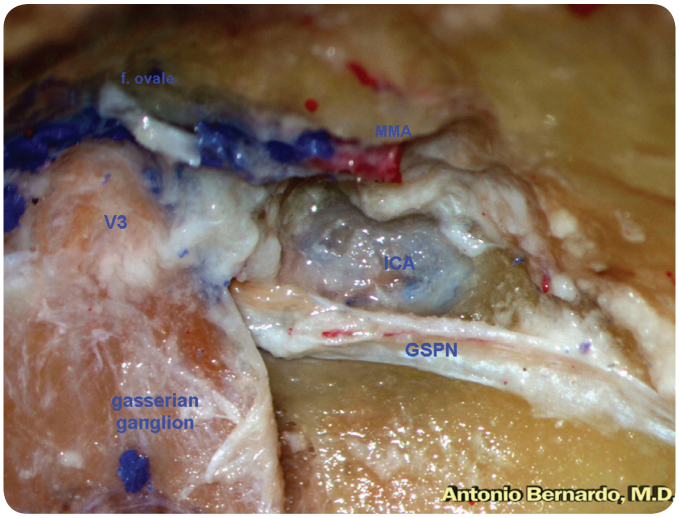
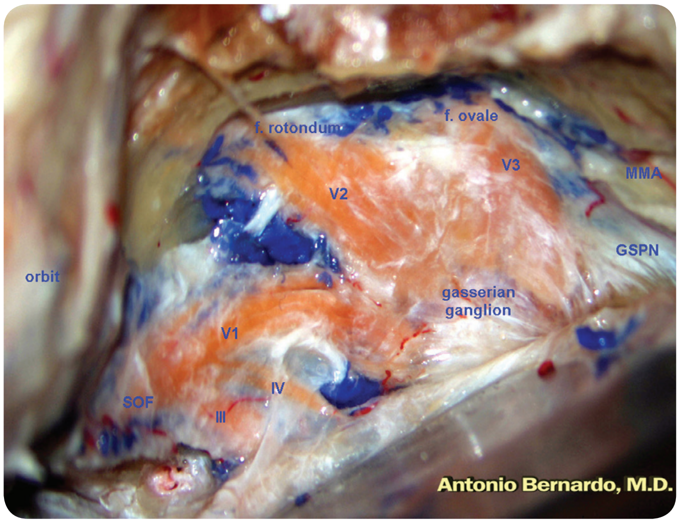


(Figure 6)



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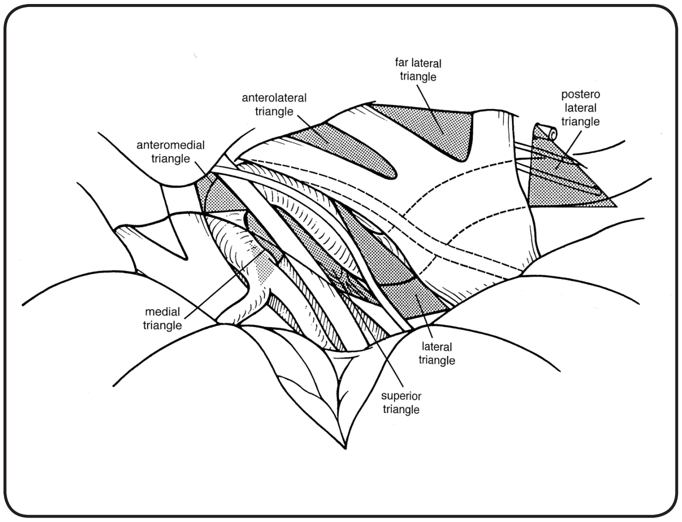

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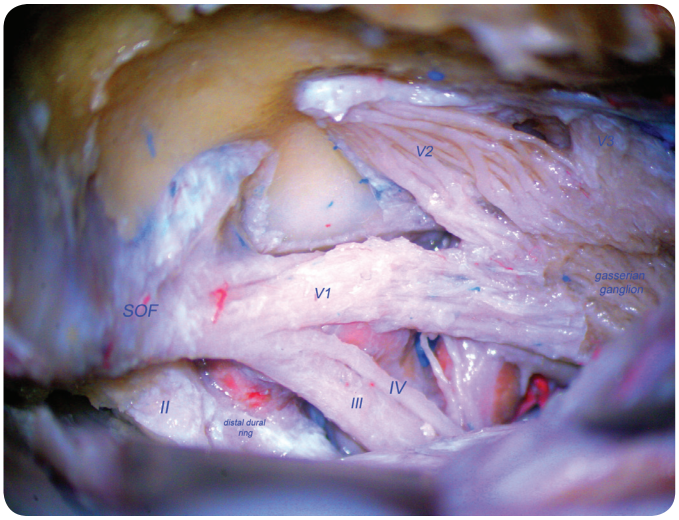

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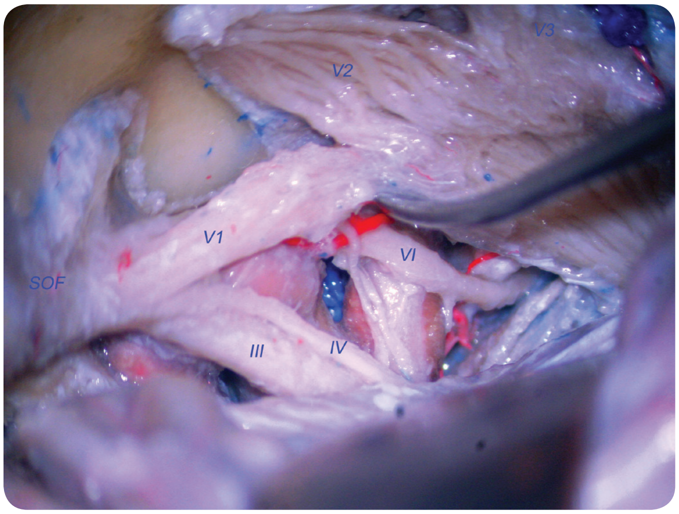

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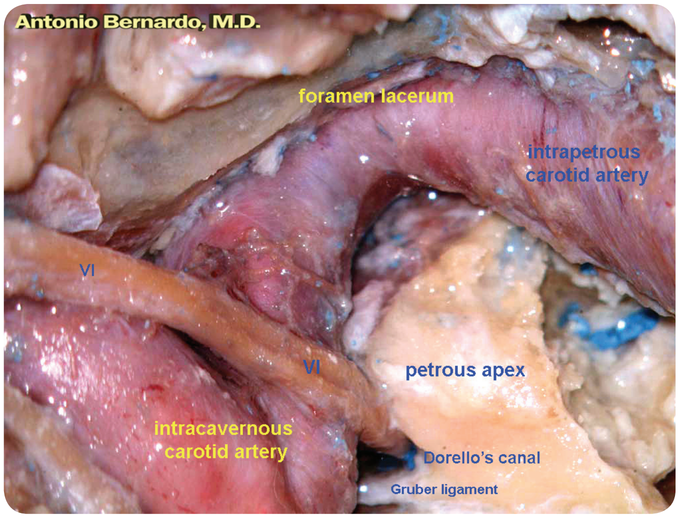

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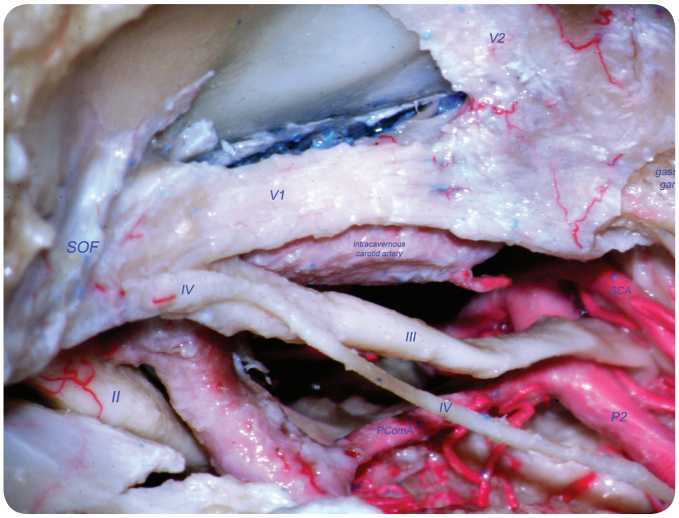

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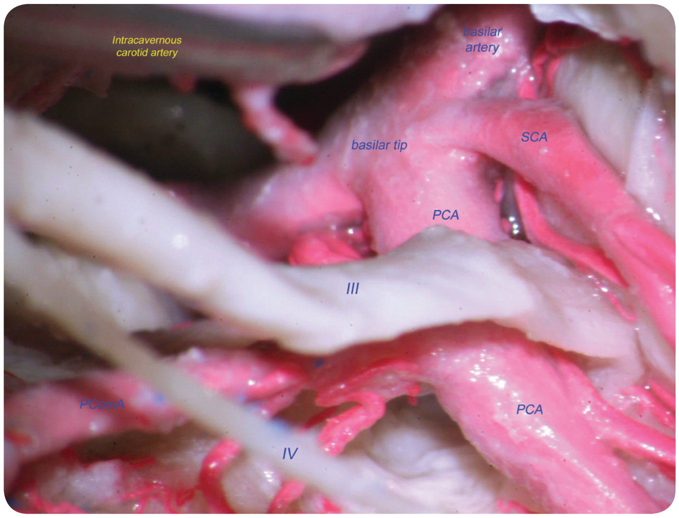

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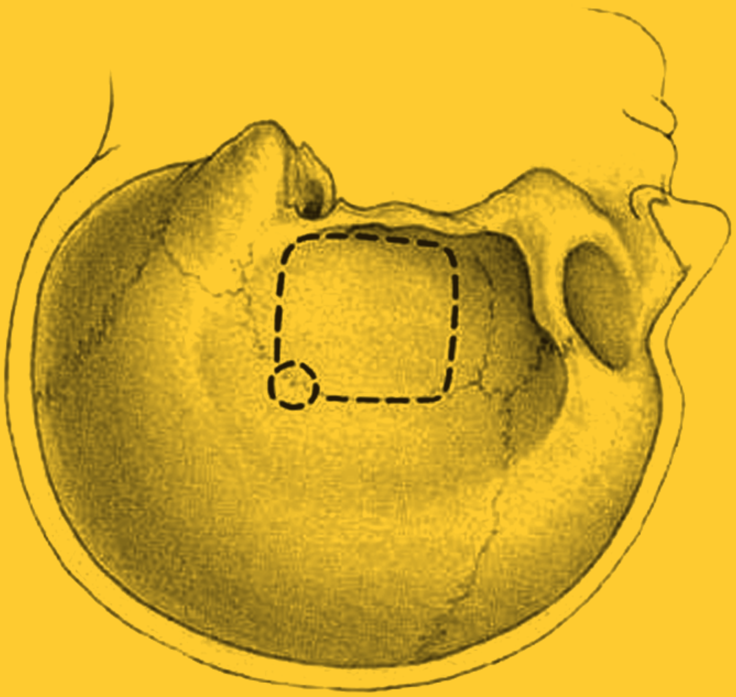
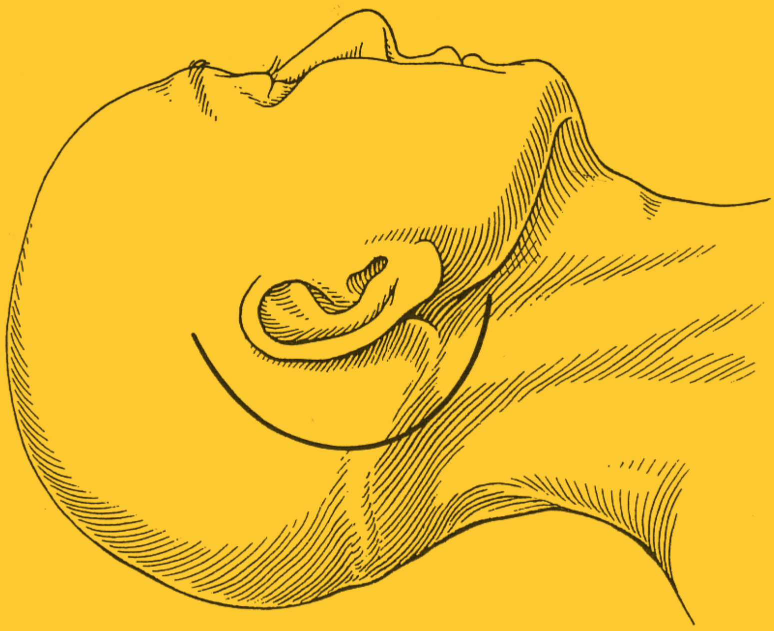
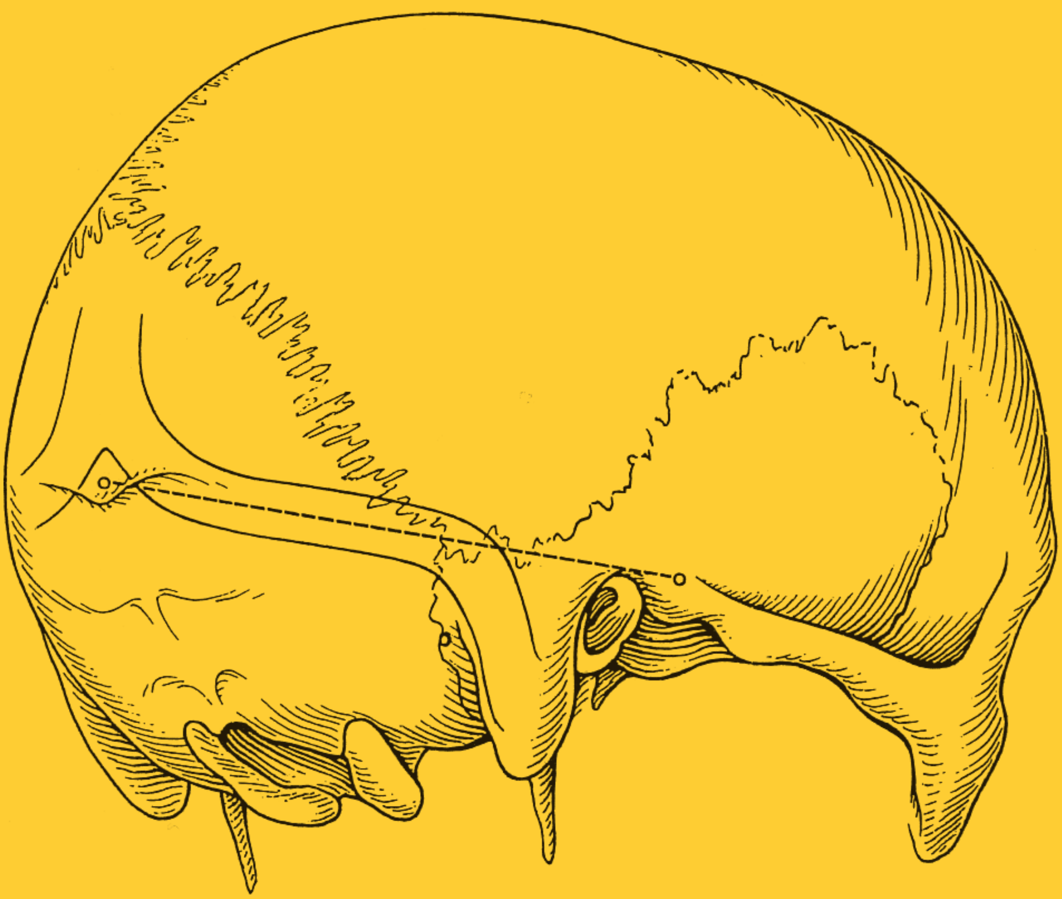




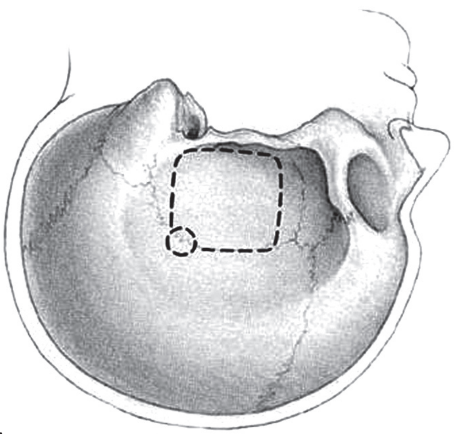


CHAPTER 4

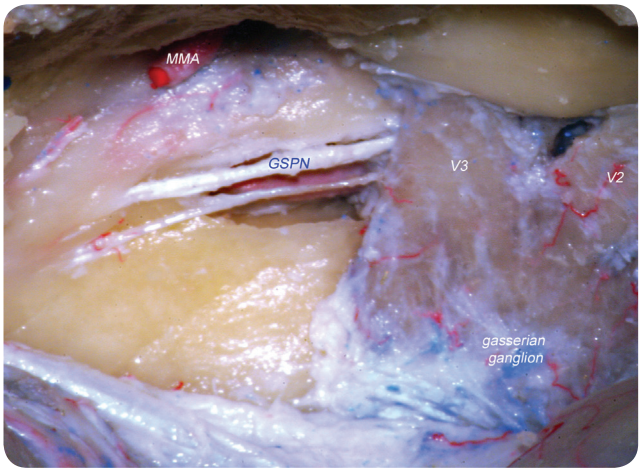
Transpetrosal Approaches

Anterior petrosal approach

The middle fossa transpetrosal approach with an anterior petrosectomy as described by Kawase is an effective approach to difficult-to-access petroclival tumors and basilar artery aneurysms. This surgical approach exposes a significant window of posterior fossa dura between V3, IAC, and intrapetrous ICA, below the petrous ridge, providing an unobstructed view across the middle fossa floor to the upper half of the clivus and the petrous apex, without needing to perform zygomatic osteotomy.



(Figure 1)



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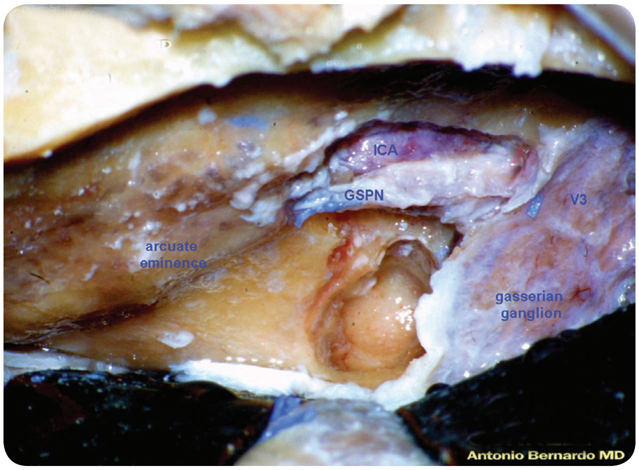


(Figure 3)

Position and incision

The speciment is positioned in a 90 degree lateral as in the standard subtemporal approach **(Fig 1)**. This position will help to provide an unobstructed view across the middle fossa floor, without needing to perform zygomatic osteotomy.

Craniotomy

After performing a standard subtemporal craniotomy, any remaining bone is removed to the level of the middle fossa floor, using a cutting burr, or a rounger and the dura is elevated along the petrous ridge, exposing the superior surface of the petrous bone.

Dissection

On the superior surface of the petrous bone, the ***greater superficial petrosal nerve (GSPN)*** and ***tegmen tympani*** are identified **(Fig 2)**. The GSPN exits its bony canal at the facial hiatus to continue its medial course in the major petrosal groove.

The meningeal artery is divided at the foramen spinosum and the mandibular division of the trigeminal nerve is exposed as it enters the foramen ovale. The dura is further elevated from the superior surface of the petrous bone **(Fig 2)**.

Following the dural elevation, the ***arcuate eminence*** (superficial projection of the superior semicircular canal) is visualized **(Fig 3)**, and the intrapetrous carotid artery exposed (the artery follows the course of the GSPN and, most of the times, is covered by a thin shell of bone in the intrapetrous horizontal segment). Still using the medium diamond burr, the artery is expo sed by removing the bone between the GSPN and the foramen spinosum **(Fig 3)**.

The goal of this stage of the operation is to create a maximal window to the clivus in the anteromedial petrous pyramid while preserving the internal structures of the temporal bone.

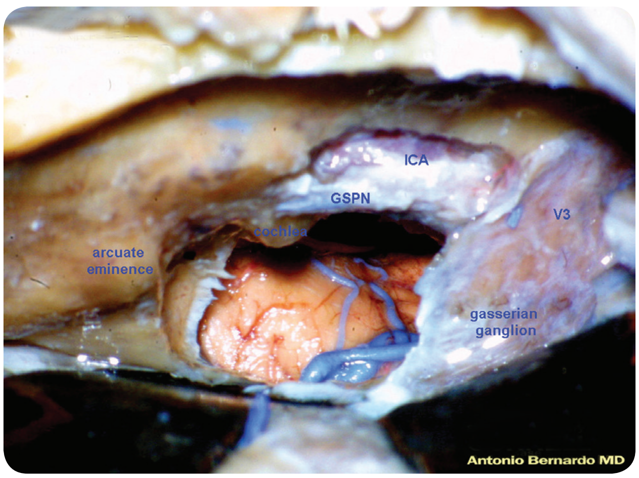
The bisecting line of the angle provided by the greater superficial nerve and the arcuate eminence will correspond in most cases to the internal acoustic canal. Drilling along this bisection axis will expose the entire IAC towards the geniculate ganglion.

The cochlea is located in the angle between the carotid artery and the internal acoustic canal.

Bone is removed in the premeatal triangle, identified as the portion of the petrous bone medial to the intrapetrous carotid artery, anterior to the IAC, and posterior to V3 (Kawase triangle). This portion of soft, porous bone between the IAC and the carotid artery can be now safely removed, paying special attention to avoid the lateral volume of bone housing the cochlea **(Fig 3)**. Bone is also removed between the ICA and the superior semicircular canal (post-meatal triangle), unroofing approximately 270 degrees of the circumference of the IAC **(Fig 3)**.

The final stage of bone removal will expose a significant window of posterior fossa dura between V3 anteriorly, IAC posteriorly, intrapetrous ICA laterally, below the petrous ridge. The inferior petrosal sinus will limit the exposure inferiorly (Fig 4).

The dura is incised with two cuts in a T fashion: the first cut is superior and parallel to the superior petrosal sinus, the second dural cut is perpendicular to the first running towards the inferior petrosal sinus.



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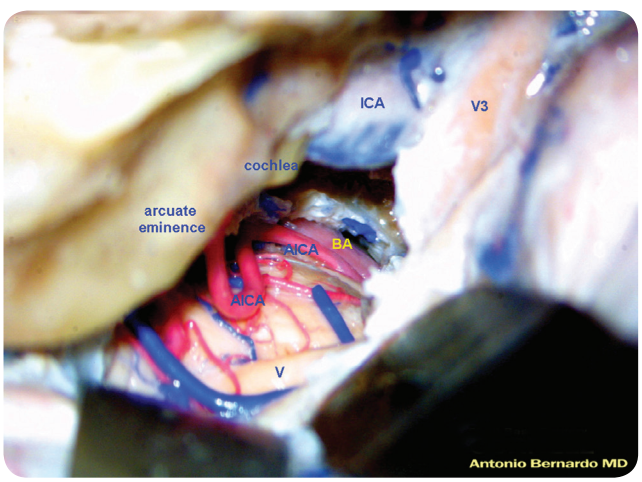
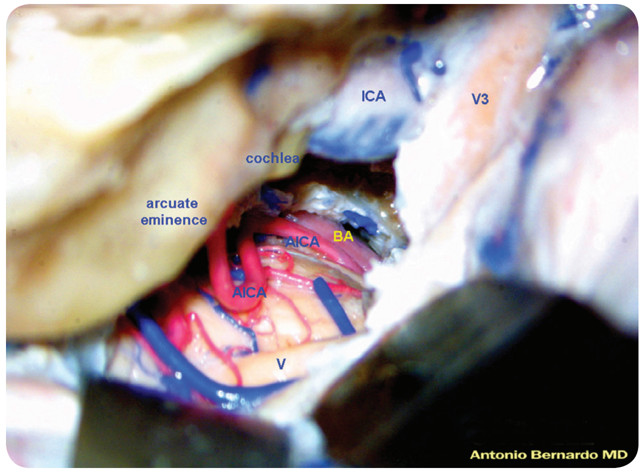


(Figure 5)

Once the dura is opened the ***basilar artery*** is identified in the depth of the exposure, the ***AICA*** is located together with the ***VI nerve***, while the **V nerve** will limit the exposure superiorly **(Fig 6, 7)**. Drilling within the clivus beyond the inferior petrosal sinus will expose the vertebro-basilar junction **(Fig 8)**.



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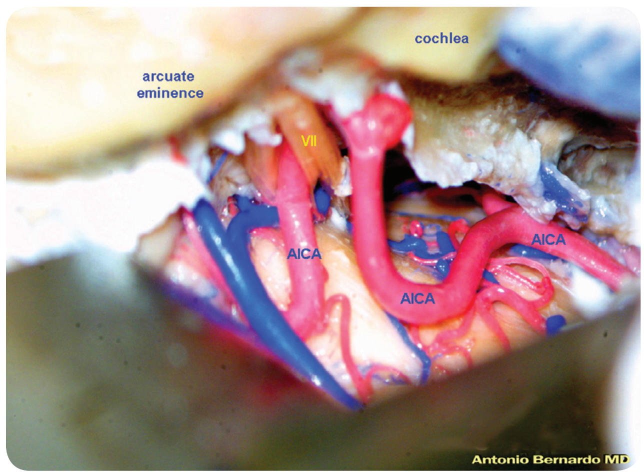

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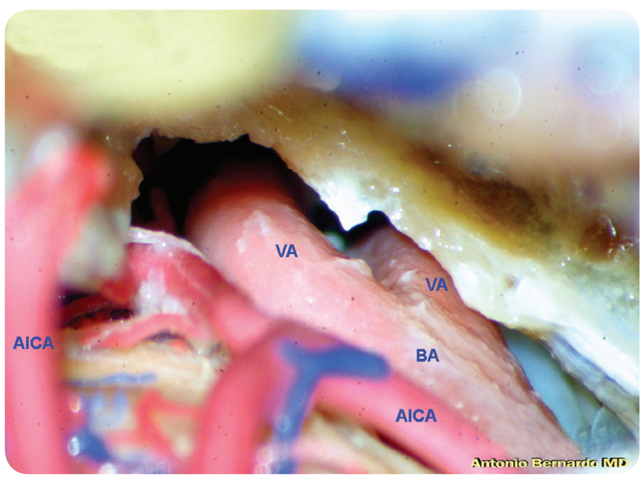

(Figure 8)

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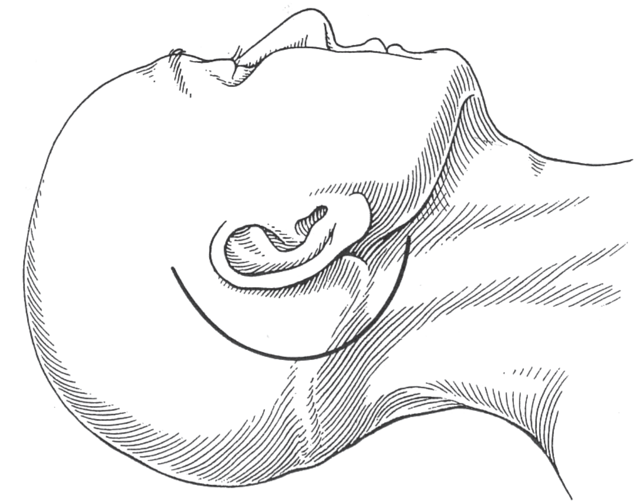
NOTES

Translabyrinthine approach

The objective of transtemporal surgery is obtaining wide skull base exposure by precise dissection of the temporal bone.

The translabyrinthine approach is commonly used in neurosurgical practice for the removal of acoustic neuromas and other neoplasms of the cerebellopontine angle. In addition, the translabyrinthine and peri-labyrinthine exposures form an important component of other transpetrosal cranial base strategies and are thus an important component of the neurosurgeon's armamentarium.

Knowledge of the temporal bone anatomy is essential to identify external features during surgical exposure and also in gaining three-dimensional orientation.



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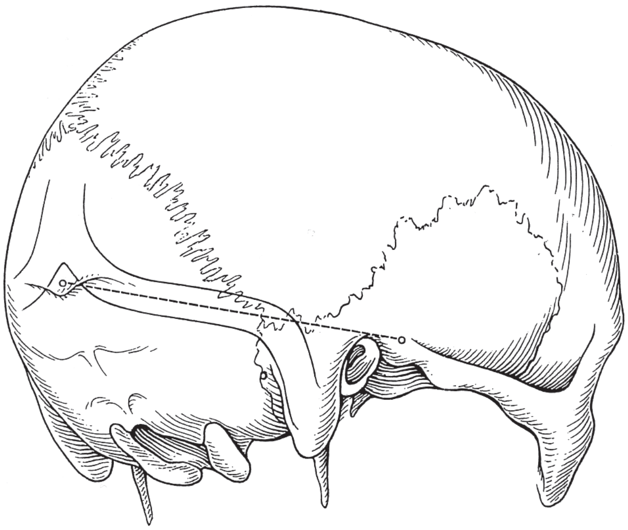


(Figure 2)

Landmarks

Temporal bone surgery is based upon landmarks. Landmarks should always be identified before cutting and should always be preserved until other landmarks are located at deeper levels.

There are several bony landmarks, readily palpable through the skin overlying the occipital and mastoid areas, which are helpful to the surgeon in planning the approach:

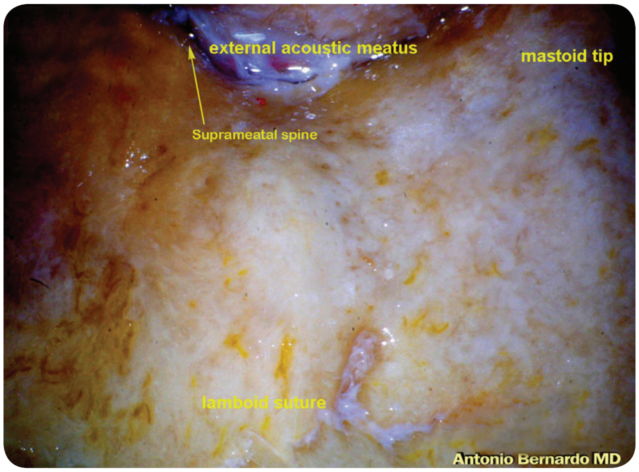
The ***external auditory meatus***, the ***mastoid tip***, the root of the ***zygoma***, the ***external occipital protuberance***, and the supramastoid crest (Fig 3). The transverse sinus lies deep to this superior nuchal line between the inion and the asterion **(Fig 2)**. The asterion, defined by the convergence of the lambdoid, occipitomastoid, and parietomastoid sutures , typically overlies the transverse-sigmoid sinus junction (Fig 2). The ***suprameatal spine***, or Henle's spine, is a small bony prominence that is located at the posterosuperior rim of the external auditory meatus and is a useful guide in exposing the incus **(Fig 3)**. In the inferior portion of the mastoid, the ***digastric ridge*** constitutes an important landmark to locate the facial nerve at the stylomastoid foramen. The ridge is formed by the impression of the digastric groove, which houses the origin of the posterior belly of the digastric muscle.

The mastoid bone is largely composed of air cells. These air cells communicate with the middle ear cavity via the mastoid ***antrum*** **(Fig 4)**. The sinodural angle begins at the convergence of the middle fossa plate dura and the sigmoid sinus. It continues forward to the antrum. In this angle the superior petrosal sinus joins the transverse-sigmoid sinus junction. The ***fallopian canal*** houses the ***facial nerve***. It runs on the anterior wall of the petrous bone, approximately 12 to 15 mm deep to the auditory meatus. The canal runs parallel to, and below, the lateral semicircular canal for a short distance before turning downward **(Fig 5)**. The corda tympani exits the nerve in the fallopian canal at the level of the external auditory canal and travels at an acute angle to the nerve into the tympanic cavity.

The nerve is surrounded by a nerve sheath in its course inside the fallopian canal. The sheath merges with the periosteum of the stylomastoid foramen at its exit for the mastoid tip at the level of the digastric groove **(Fig 5)**. The "retrofacial air cells" is the part of petrous bone between the fallopian canal and the presigmoid dura. This space houses the ***jugular bulb*** **(Fig 6)**.

The ***labyrinth*** lies in denser, harder bone, medial to the tympanic cavity, posterior to the cochlea and to the internal acustic meatus, and consists of three ***semicircular canals***, superior, posterior and horizontal (or anterior). The axes of the anterior and posterior canals are at right angles to each other **(Fig 8)**. The horizontal semicircular canal is plainly seen in the open antrum, oriented in the axial plane. The ascending limb of the posterior semicircular canal joins the posterior limb of the superior semicircular canal to form the common crus. The ***vestibule*** is the middle part of the bony labyrinth and lies medial to the timpanic cavity, posterior to the cochlea and anterior to the semicircular canal. It contains the ***utricule*** and ***saccule*** of the membranous labyrinth and it is an important surgical landmark as its anterior wall is the last bone structure in the process of exposing the posterior wall of the internal acoustic meatus.

The ***cochlea*** is the most anterior part of the labyrinth, lying anterior to the vestibule, anterior to the tympanic portion of the facial nerve, medial to the genu of the intrapetrous carotid artery.



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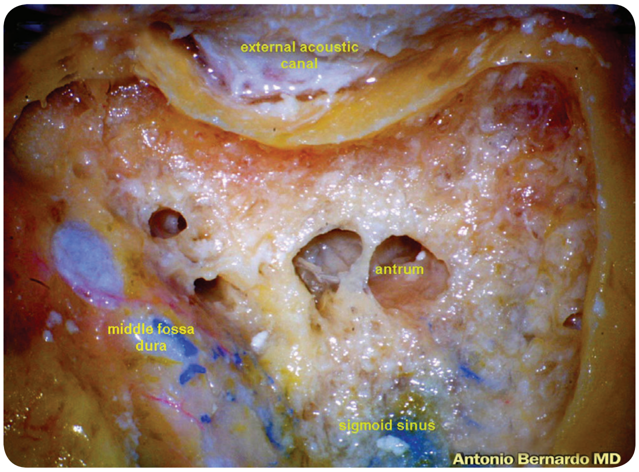


(Figure 4)

Dissection

Mastoidectomy and facial nerve dissection are two common surgical steps in performing posterior transpetrosal approaches.

Position and incision
The head is placed in the lateral position, with the mastoid surface at the highest point. A C-shaped scalp incision is started above the pinna of the ear, it curves posteriorly and inferiorly behind the body of the mastoid and ends below the mastoid tip **(Fig 1)**. The incision is carried directly down the bone. The scalp flap is elevated and retracted anteriorly.

Superficial bone removal
Using the high-speed drill with a large cutting burr and continuous suction/irrigation, the cortex over the mastoid bone is removed. The mastoid cortex is removed in a systematic, progressive fashion with the deepest portion of penetration in the triangle of Macewen, which is the area of mastoid behind the spine of Henle and which actually overlies the mastoid antrum **(Fig 4)**. The superior limit of the dissection corresponds to a line extending from the zygomatic root to the asterion.

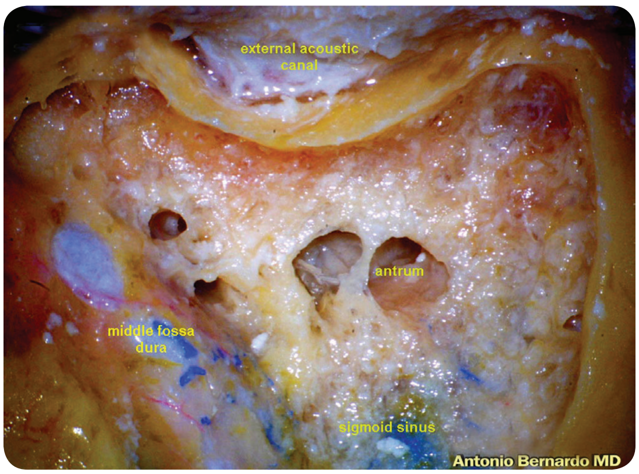
Sigmoid sinus skeletonization
As the cortical bone is removed, air cells will be opened. Posteriorly the sigmoid sinus is uncovered. The sigmoid sinus usually lays a few millimeters deep to the cortex in the mastoid cavity and generally appears in the posterior portion of the dissection as a blue discoloration of smooth dural bony plate. Thinned dural plate usually can be identified by changes in the sound of the burr vibrating on it. Once the sigmoid sinus has been located, the area between the sigmoid and the middle fossa plate, or the sinudural angle, can be fully evacuated of air cells **(Fig 4)**. It is always advisable to leave a thin depressible shell of bone over the sinus so to protect the sinus from inadvertent injury while continuing the dissection towards deeper target. A uniform depth is maintained while exposing the sigmoid sinus and the air cells. Drilling should never proceed too deep in any particular place **(Fig 4)**.

Middle fossa dura exposure

Once completed skeletonizing the sigmoid sinus, mastoid air cells are removed anteriorly and superiorly to expose the middle fossa dura. Exposing the middle dura is critical for best possible access into the antrum and epitympanic areas. Subsequently, the air cells surrounding the inferior segment of the sigmoid sinus and the digastric ridge are removed. When adequate cortical removal has been accomplished, a kidney bean-shaped cavity will result extending from the mastoid tip inferiorly to the sinudural angle superiorly, to the posterior bony canal anteriorly. *This type of cortical removal is basic to all posterior approaches on the mastoid cavity* **(Fig 4)**.

Opening the antrum

Next step is opening the mastoid antrum in the superior portion of the exposure. By keeping the external canal wall bone thin and avoiding the nearby middle fossa dura, progressively deeper penetration will reveal the antrum. Normally the antrum can be identified as a larger air-containing space, where at bottom, lies the basic landmark of the labyrinthine bone of the horizontal semicircular canal **(Fig 4)**.



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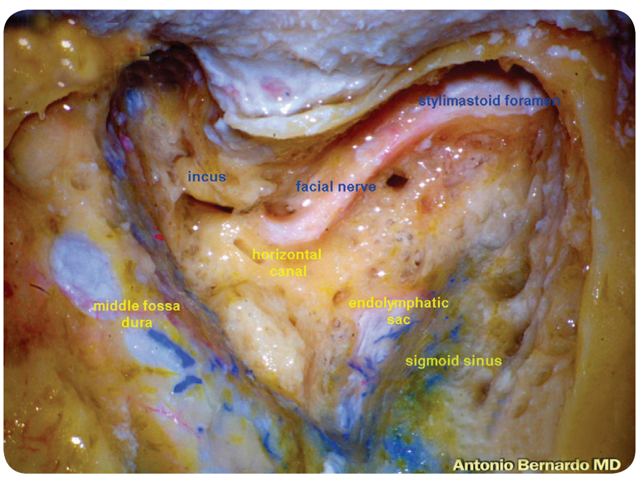


(Figure 5)

Identification of the incus

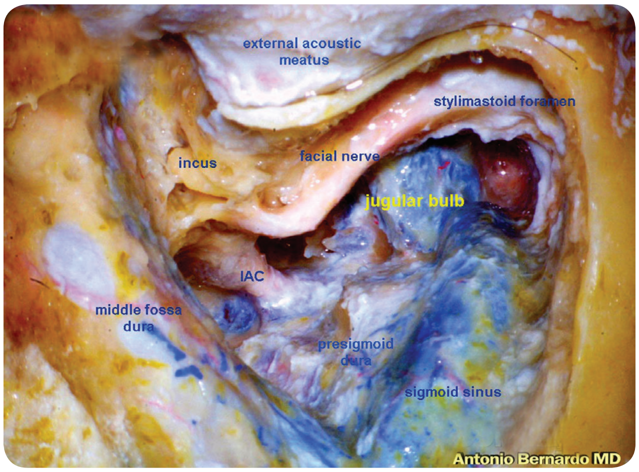
Removing bone in the zygomatic root overlying the antrum, at the level of the spine of Henle, results in exposing the incus, in the fossa incudis **(Fig 5)**. The superficial landmark for the incus is the spine of Henle. By drilling deeper, to thin the posterior bony wall of the external canal at the level of the spine of Henle, the incus is exposed. Locating the incus will help to identify the facial nerve which lies in the same surgical plane **(Fig 5)**.

Facial nerve dissection

The facial nerve is normally located inferior and slightly medial to the horizontal semicircular canal by thinning the posterior canal wall bone and carefully removing bone in the facial recess area **(Fig 5)**. The facial recess area is delineated by the fossa incudis, the chorda tympani, and the facial nerve. Dissection of the facial recess begins by identifying the external genu, or the descending portion of the facial nerve in the mastoid cavity. Generally, this dissection is accomplished with a cutting burr until a change in bone character is identified: further dissection is performed with a diamond burr and profuse irrigation is used to prevent frictional heating of the nerve. A thin shell of bone is left on the facial nerve. Identification of a facial recess cell tract is often possible by thinning the posterior wall of the external canal **(Fig 5)**.

The facial nerve is located and uncovered as it parallels the horizontal semicircular canal using a small diamond burr under high magnification. Once the facial sheath is safely identified, the nerve is skeletonized distally along its descending portion in the mastoid bone to the ***stylomastoid foramen*** **(Fig 5)**. A thin layer of bone is preserved over the facial nerve. Inferiorly the chorda-tympani nerve is detected as it leaves the facial nerve.

With the fallopian canal defined, the remaining air cells ***(retrofacial air cells)*** between the facial nerve and the jugular bulb are removed. Removal of these air cells extending from the mastoid into the middle ear will result in skeletonization of the lateral portion of the jugular bulb **(Fig 6)**.



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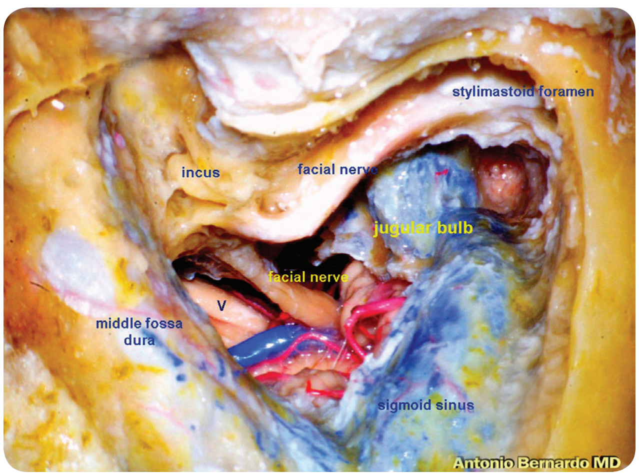

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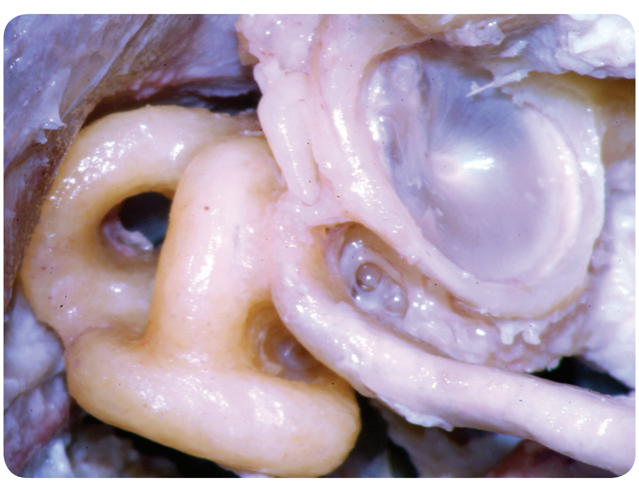

(Figure 8)

Labyrinth dissection

The sinodural angle must be completely drilled out to provide adequate exposure of the area of the vestibule later. The middle fossa plate must have been thinned completely to provide acces to the superior semicircular canal. The posterior fossa dura between the sigmoid sinus and the labyrinth is uncovered. These maneuvers will result in complete isolation of the labyrinthine complex. Inferior to the posterior canal, the posterior fossa dural plate overlies the ***endolymphatic sac***. The sac is located in a thickened portion of the posterior fossa dura, medial to the sigmoid sinus and inferior to the posterior canal. The exact location of the sac, which varies, is usually identified by the presence of thickened white dura (Fig 5). The middle fossa dura is skeletonized and the bone in the sinodural angle is completely removed **(Fig 5)**.

By removing cells between the horizontal canal and the sinodural angle, one encounters the hardest bone of the body, the so called "hard angle", which is part of the otic capsule. The first portions of the labyrinth removed are the upper part of the posterior semicircular canal and the superior aspect of the lateral canal. The dissection further advances into the horizontal semicircular canal and care must be exercised to preserve the anterior wall of the horizontal canal which will serve as a protection for the horizontal portion of the facial nerve. All three semicircular canals must be opened and the common crus exposed. The endolymphatic aqueduct is severed at its operculum, and the vestibule is opened widely **(Fig 6)**. In approaching the internal auditory canal, it must be kept in mind that the anterior wall of the vestibule represents the posterior wall of the canal. Drilling at this level will expose the internal auditory canal fundus, where the nerve enters the inner ear structures. The internal auditory canal lies in the bone deep to the labyrinth. The internal auditory canal must be exposed by 270 degrees in circumference to achieve proper dural exposure. Troughs are drilled above and below the canal, parallel to its long axis. Bone is removed along the posterior petrous face medial to the porus acusticus and, inferiorly, between the IAC and the jugular bulb revealing the dura overlying the ninth nerve **(Fig 6)**.

Dural incision

The dural is incised at the sinodural angle towards the porus acusticus, exposing the content of the internal auditory canal and the cerebellopontine angle. Cranial nerves IX and X will limit the exposure inferiorly, while the trigeminal nerve will limit the exposure superiorly **(Fig 7)**.

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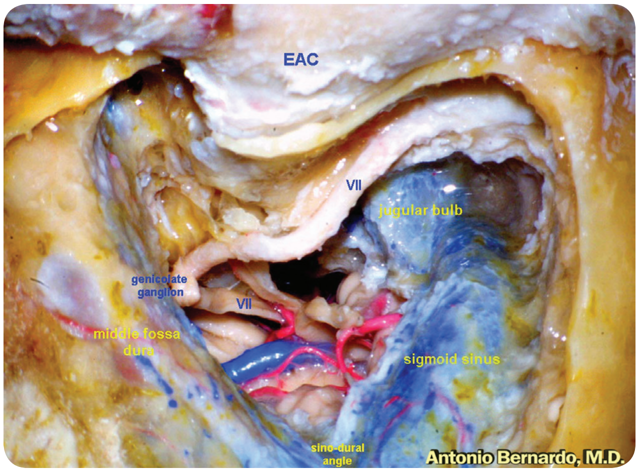
NOTES

Transcochlear approach

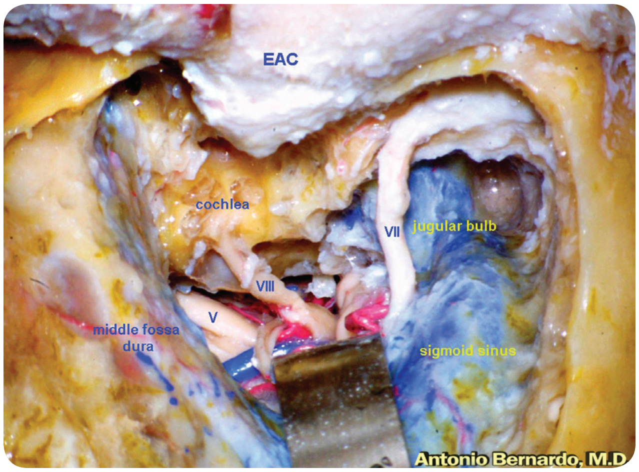
While the ***translabyrinthine approach*** (TL) offers wide exposure of the CPA, the cochlea and petrous apex block access to the anterior aspects of the CPA and the ventral brain stem.

The transcochlear approach, by definition, remove the cochlea following a TL approach to extend the exposure anteriorly. Transcochlear approach combines the translabyrinthine dissection with removal of the cochlea; however, wide access to the anterior CPA is provided by posterior transposition of the facial nerve. Thus, the exposure extends from the sigmoid sinus posteriorly to the petrous carotid artery anteriorly. By rerouting the facial nerve and exenterating the entire otic capsule, petrous apex, and lateral aspect of the clivus, an unobstructed view of the ventral aspect of the pons is obtained

The mastoidectomy, the facial nerve dissection and the skeletonization of the internal auditory canal are performed as in the traslabyrinthine route (see Chapter 4 > translabyrinthine approach).



(Figure 1)

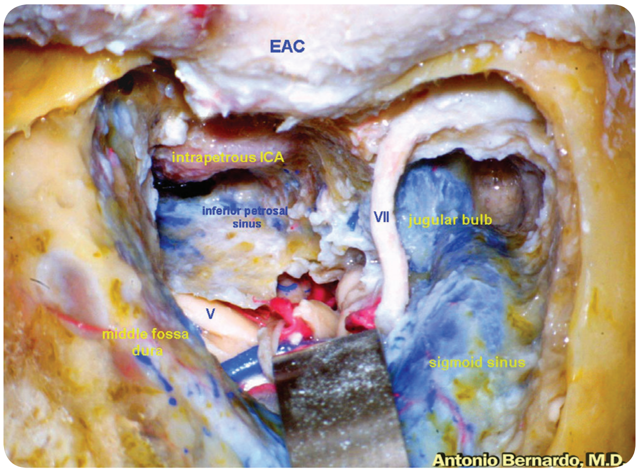


(Figure 2)

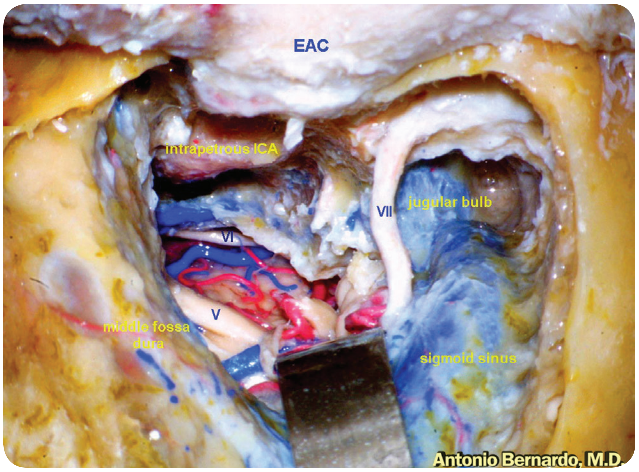
The ***posterior wall of the external auditory*** canal is removed, opening the ***middle ear*** cavity. The ossicles and tympanic membrane are removed.

The descending portion of the ***facial nerve*** is decompressed. An essential element of the transcochlear approach is to open the ***fallopian canal*** without injuring the facial nerve. The same surgical techniques as in the translabyrinthine approach are used to localize and expose the facial nerve in its tympanic and fallopian segments. During the initial stages of the dissection, a cutting burr rapidly locates the nerve, leaving a thin bony covering in place. A diamond burr is then used to partially remove the last eggshell-thin bone from the epineurium. Once the entire horizontal and descending portions of the nerve have been exposed, the remaining egg-shelled-thin bone is gently peeled off the sheath of the facial nerve using any thin, sharp pick tool. Elevation of the facial nerve from its bony channels proceeds from inferior to superior. The ***chorda tympani*** is transected sharply. With a small diamond burr, the tympanic portion of the facial nerve is skeletonized to the geniculate ganglion **(Fig 1)**. The anterior aspect of the ganglion is exposed to visualize the ***greater superficial petrosal nerve*** which is sectioned at its origin from the ganglion, permitting posterior displacement of the nerve **(Fig 1)**.

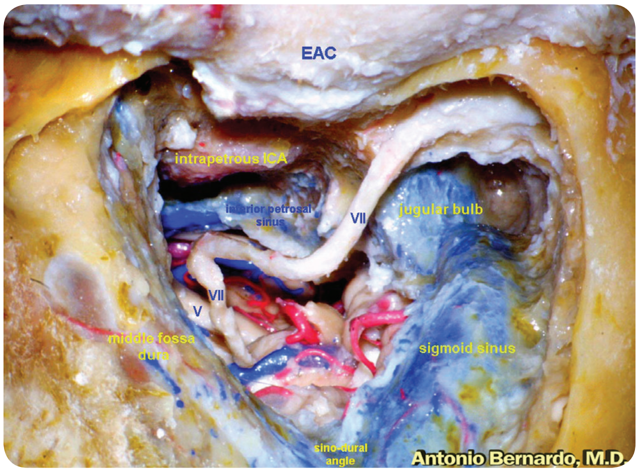
The dura of the internal auditory canal is opened and the facial nerve is separated from the ***vestibulocochlear complex***. The eight nerve (cochlear and both vestibular branches) is transected. After the necessary amount of sharp arachnoid dissection the facial nerve is reflected out of its position in the internal auditory canal and fallopian canal **(Fig 2)** and transposed posteriorly **(Fig 2)**. For the remainder of the procedure the nerve is kept out of the surgical field with a nerve retractor. With the facial nerve out of the field, using a medium diamond burr, the basal turn of the cochlea is opened. The cochlea is located directly below the geniculate ganglion, surrounded by compact bone and is removed by drilling anteriorly **(Fig 2)**.



(Figure 3)



(Figure 4)



(Figure 5)

Anteriorly, a thin wall of bone separates the choclea from the ***intrapetrous carotid artery (jugulocarotid spine)***. Removal of this thin wall of bone exposes the genu of the intrapetrous carotid artery **(Fig 3)**.

Once the intrapetrous carotid artery is localized and partially exposed, the petrous apex is removed. The superior limit of the exposure will be the dural-periosteal lining of Mecke's cave. Inferiorly, the jugular bulb will form the bottom portion of the exposure. Bone removal progresses medially to the clivus, working in a surgical corridor defined by the two ***petrosal sinuses, inferior and superior*** **(Fig 3)**.

The dura is opened in a T fashion with first cut parallel to the sigmoid sinus. The second cut is perpendicular to the first and, after involving the porus acusticus, will continue anteriorly towards the clivus and parallel to the inferior petrosal sinus. *After dural opening, the fifth, seventh, ninth, tenth, and eleventh cranial nerves, the clivus, both the vertebral arteries and the basilar artery are routinely seen* **(Fig 4)**.

The advantage of this approach as compared to the translabyrinthine, previously described, is that the exposure includes, in addition to the contents of the cerebello-pontine angle, an unobstructed view to the lateral and anterior faces of the pons, to the basilar artery and both sixth nerves **(Fig 4)**

The transcochlear approach can be combined to other skull base surgical procedures such as far lateral transjugular approach and to transtentorial resection to improve exposure of the clivus and petroclival region.

Temporary facial nerve paralysis may occurr with the posterior transposition of the facial nerve.

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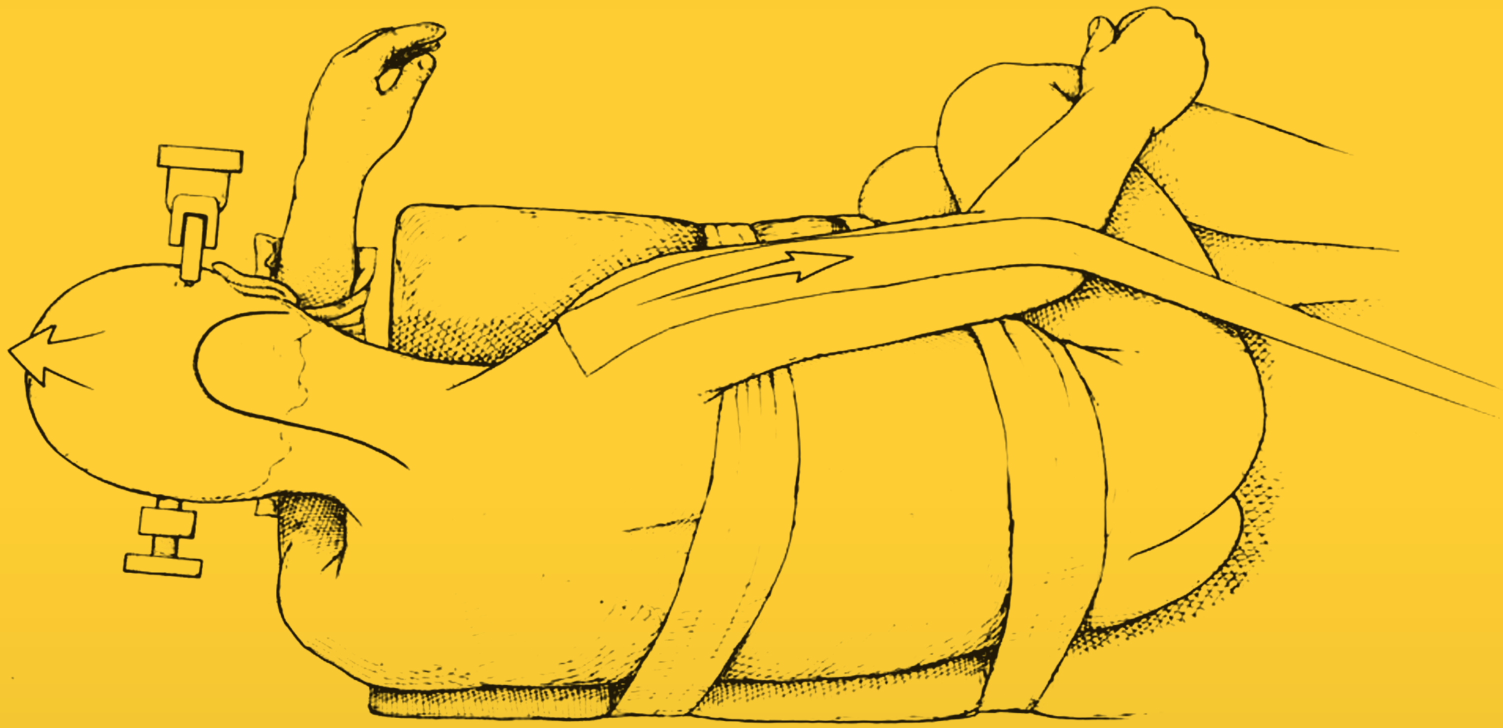
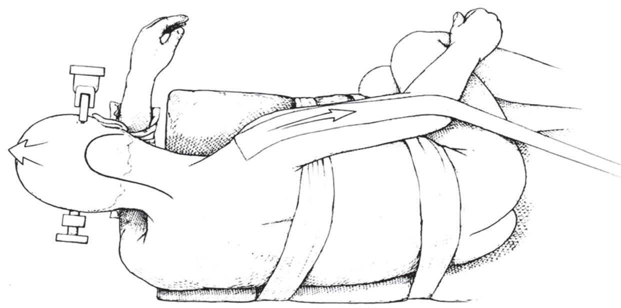


CHAPTER 5

Far Lateral Trans-Condylar Approach

Far Lateral Trans-Condylar Approach



(Figure 1)

Position and Incision

The head is placed in the lateral position with the face oriented slightly downward toward the floor, resulting in the ear and the mastoid as the highest structures. The vertex of the head must be oriented slightly downwar **(Fig 1)**.

A retroauricular curvilinear skin incision starts approximately 2 to 3 cm behind the ear and continues inferiorly into the neck over the posterior border of the sternocleidomastoid muscle to C-3 or C-4 **(Fig. 1)**. The incision is made through the galea, and this scalp layer is elevated to expose the underlying pericranium above the superficial neck fascia, (in surgery, this fascia may be harvested as a fascial graft for later watertight dural closure).

The pericranium and the superficial fascia are then retracted anteriorly to expose the underlying musculature.

Muscle Dissection and the Suboccipital Triangle (laboratory exercise)

Anatomically, three layers of muscle are identified during the dissection. The first, the superficial layer ***(trapezius and sternocleidomastoid)*** **(Fig 2),** and the second, the middle layer (splenius capitis, longissimus capitis, and semispinalis capitis) (Fig 3), are incised and reflected as a single layer to expose the suboccipital triangle **(Fig. 4)**, which is bound by the third, deep layer of muscles (medially by the ***rectus capitis posterior major***, inferiorly by the inferior oblique, and superolaterally by the ***superior oblique muscle***).

Reflection of the skin and superficial fascia will expose the superficial layer of muscles, which is composed of the trapezius and sternocleidomastied muscles.

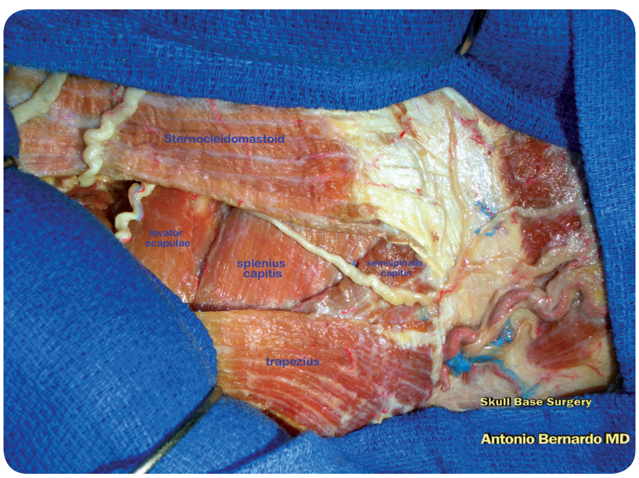


*Figure 2:
superficial layer of muscle*

Step 1. The sternocleidomastoid muscle is detached from the mastoid process and reflected anteriorly.

Step 2. The middle layer muscles, comprised of the splenius capitis, longissimus capitis, semispinalis capitis, and splenius cervicis, are reflected posteriorly. The splenius cervicis attaches to the transverse process of C1-3 and is the key to locate the vertebral artery as it passes between the spinous processes of C1 and C2.

Step 3. Once the middle layer of muscles is reflected, the deep layer will be visible, composed of the ***obliquus capitis superior, obliquus capitis inferior***, and the rectus capitis major and minor **(Fig 4)**.

Suboccipital triangle

At this point the suboccipital triangle will also be visible. The suboccipital triangle, which involves the dorsal ramus of the C-1 nerve root and the V3 (horizontal segment) of the VA, can be opened by detaching the insertions of the superior and inferior oblique muscles from the transverse process of C-1 and reflecting them posteriorly. The rectus capitis major is detached from the inferior nuchal line and reflected posteriorly. The C-1 lamina and VA will then become more apparent. The VA is encased in a dense venous plexus as it exits the C1 transverse foramen, and courses posteriorly in the vertebral groove of the C1 posterior arch. (several small muscular branches of the vertebral arteries are present along this segment, and can be coagulated and divided at surgery without consequences) **(Fig 5)**.

The ***atlantooccipital membrane*** is sharply divided to expose the underlying dura. The entire extradural course of the vertebral artery from C2 to the occiput should be now visible **(Fig 6)**.

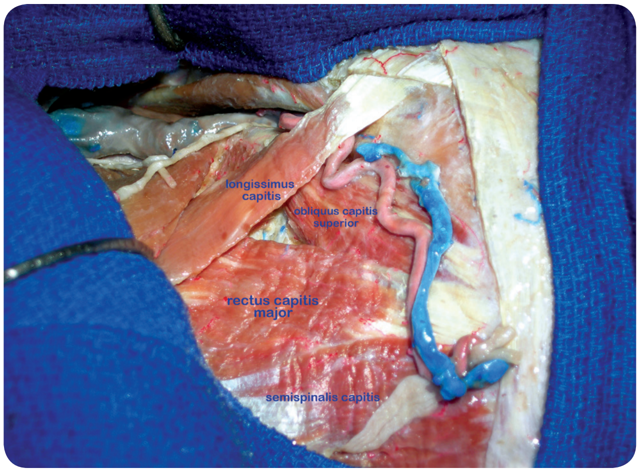


Figure 3:
middle layer of muscle

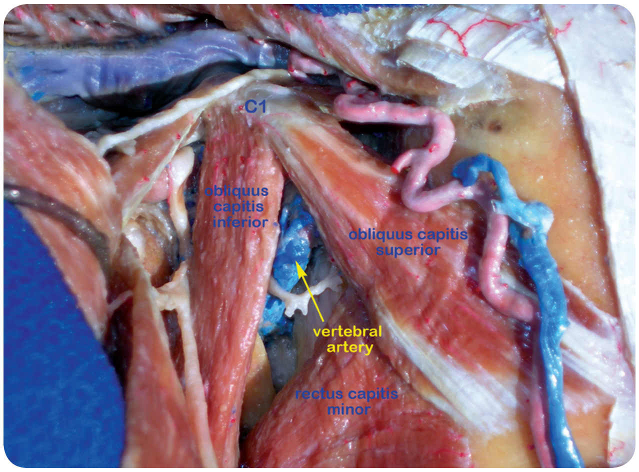


Figure 4:
deep layer of muscle - suboccipital triangle

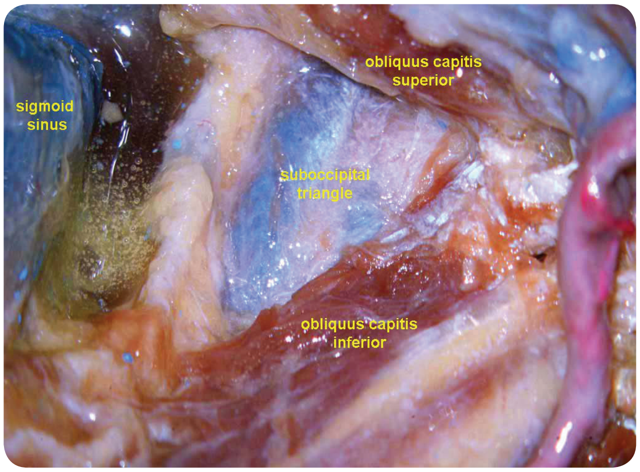


Figure 5:
The vertebral artery in the suboccipital triangle is encased in a dense venous plexus.

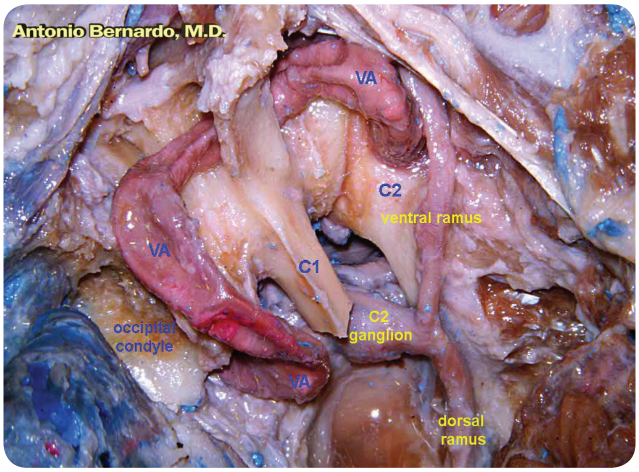


Figure 6:
The atlantooccipital membrane *is sharply divided to expose the underlying dura. The entire extradural course of the vertebral artery from C2 to the occiput should be now visible.*

Suboccipital craniotomy and C1 hemilaminectomy

A suboccipital craniotomy is performed. The craniotomy extends to the sigmoid sinus anteriorly and to the foramen magnum inferiorly **(Fig 7)**. The sigmoid sinus and jugular bulb are exposed with high speed drill. - the posterior condylar emissary vein will be encountered as the region of the occipital condyle is reached.

Exposure will be improved inferiorly by performing a hemilaminectomy of C1 (Fig 7).

Transcondylar resection

Extradural resection of the occipital condyle will improve exposure of the ventral aspect of craniovertebral junction, avoiding brainstem retraction.

With a medium diamond burr, the posterior aspect of the condyle can be removed. No more than the posterior one-third of the condyle needs to be removed **(Fig 8)**. Bone removal between the jugular bulb and the condyle will result in the skeletonization of the hypoglossal canal, which is located approximately 15 mm deep to the lateral surface of the condyle **(Fig 9).** However in most instances it's not necessary to remove condyole beyond the point of entrance of the vertebral artery in the dura **(Fig 8)**.

Jugular tubercle

Extradural removal of the jugular tubercle (medial and inferior to the jugular bulb) improves intradural exposure across the anterior surface of the brainstem and mid-clivus. While resecting, care should be taken not to injury IX, X, and XI cranial nerves, which course in very close proximity.

Intradural exposure

A curvilinear incision of the dura mater is made several millimeters posterior to the sigmoid sinus, extending inferiorly toward the C-2 lamina, staying posterior to the VA, where it pierces the dura. A short, horizontal incision is made just above the vertebral artery dural entrance in a T-shaped fashion.

A dural cuff is preserved around the VA for later watertight closure. A suture is placed in this dural ring and retracted anteriorly.

After the arachnoid is dissected, the following structures can be visualized: *cranial nerve V trhough XII, the basilar artery, the VA, the vertebrobasilar junction, the posterior inferior cerebellar artery, and the anterior inferior cerebellar artery* **(Fig 10)**.

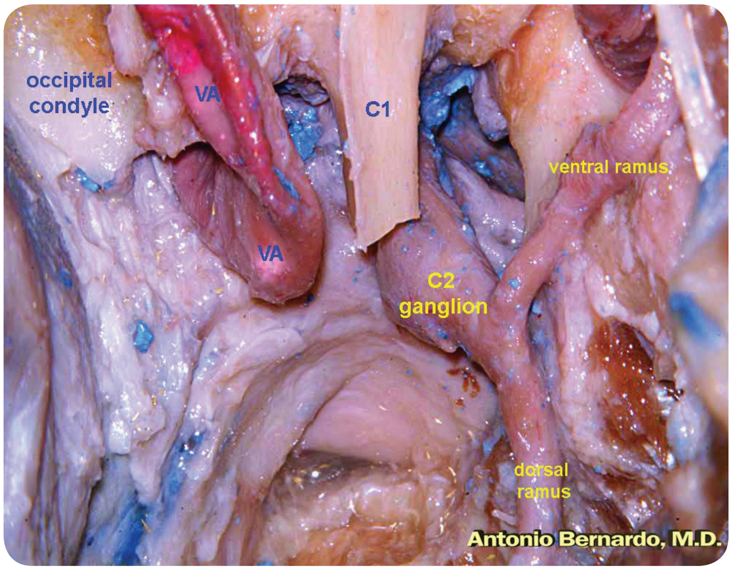


Figure 7
Exposure will be improved inferiorly by performing a hemilaminectomy of C1

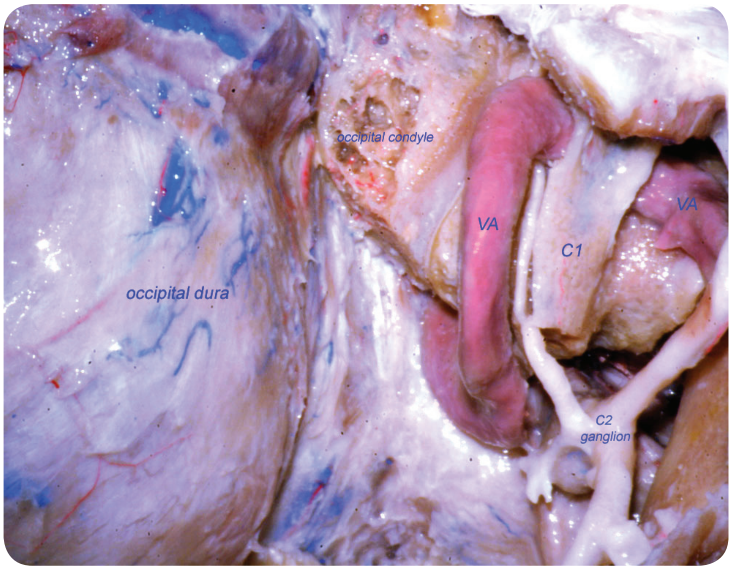


Figure 8
With a medium diamond burr, the posterior aspect of the condyle *can be removed. No more than the posterior one-third of the condyle needs to be removed.*

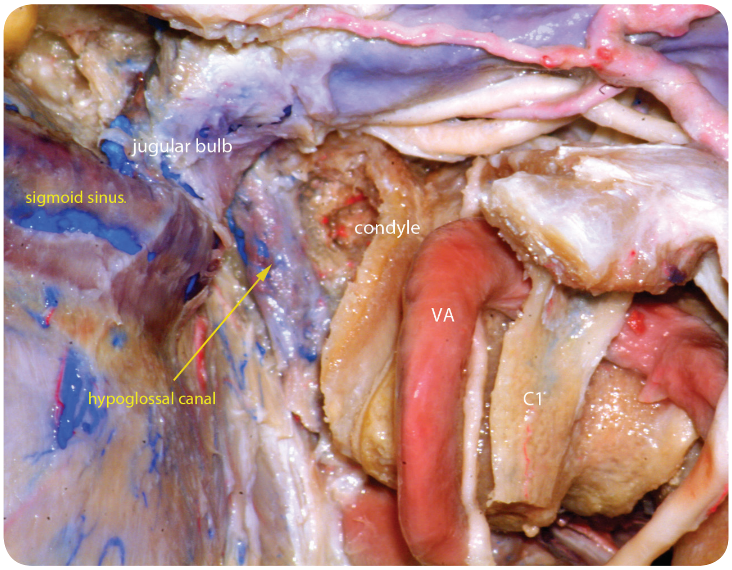


Figure 9
Condyle resection may result in skeletonization of the hypoglossal canal, which is located approximately 15 mm deep to the lateral surface of the condyle.

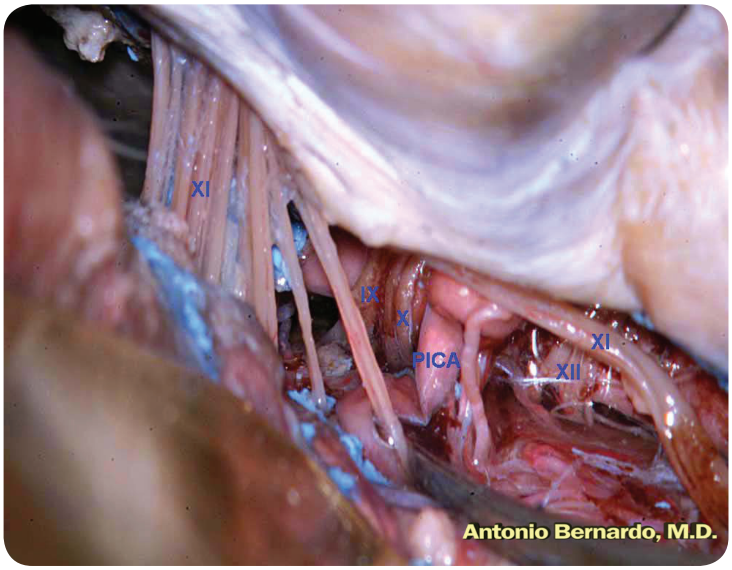


Figure 10
After the arachnoid is dissected, the following structures can be visualized: cranial nerve V *trhough XII, the basilar artery, the VA, the vertebrobasilar junction, the posterior inferior cerebellar artery, and the anterior inferior cerebellar artery.*

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NOTES


OPMi Pentero

CHAPTER 6

Jugular Foramen Exposure: Combined Transmastoid Trancervical Dissection

Jugular Foramen Exposure: Combined Transmastoid Trancervical Dissection

The ***jugular foramen*** is bounded by the temporal and occipital bones. The foramen can be divided into two compartments, separated by a dural membrane: the anterior and medial compartment, or pars nervosa, contains the ***glossopharyngeal nerve*** and the ***inferior petrosal sinus***; the posterior and lateral compartment, or pars venosa, contains the ***jugular bulb,*** the ***vagus nerve***, and the accessory nerve. Lesions occuring in the jugular foramen may involve adjacent structures, such as the jugular bulb, carotid artery, middle ear, petrous apex, clivus, infratemporal fossa, and posterior fossa.

Skull base surgical approaches such as far lateral and transpetrosal combined with inframastoid transcervical dissection provide good exposure of the jugular foramen region and surrounding extracranial structures.

These combined approaches can be simplified in a stepwise fashion:

1. *upper cervical dissection* to expose the jugular vein and surrounding structures up to the base of the skull (inframastoid exposure)
2. *presigmoid mastoidectomy* to expose the presigmoid posterior fossa and preserving the labyrinthine structures (transmastoid sublabyrinthine exposure).

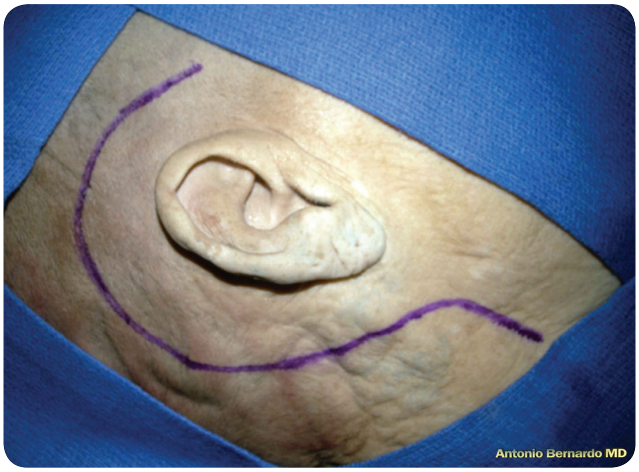
   and, if needed,

3. *far lateral suboccipital craniotomy* with partial extradural resection of the condyle and hemilaminectomy of C1 for lesion with intradural extension

Cervical dissection

Position and incision
The head is positioned in the lateral position with the mastoid surface at the highest point

A long, "lazy S" type of incision is made beginning at the level of the pinna, continuing around the ear, over the mastoid tip, and into the neck over the anterior margin of the sternocleidomastoid muscle at about C4 level. **(Fig 1)**



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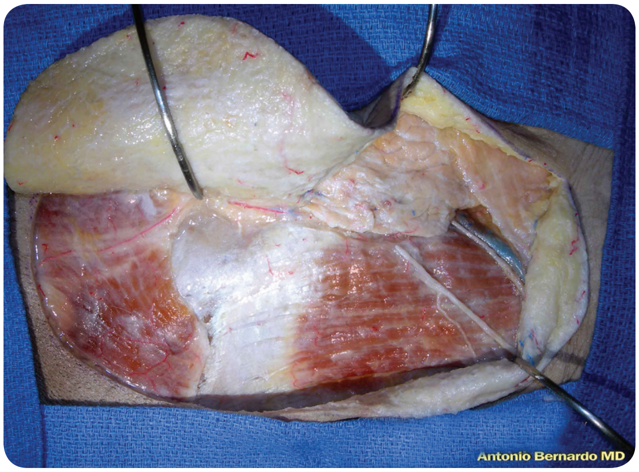

(Figure 2)

The subcutaneous layer is elevated from the fascial layer covering the sternocleidomastoid muscle. Over the mastoid the skin flap is elevated anteriorly until the external auditory meatus is exposed. **(Fig 2)**

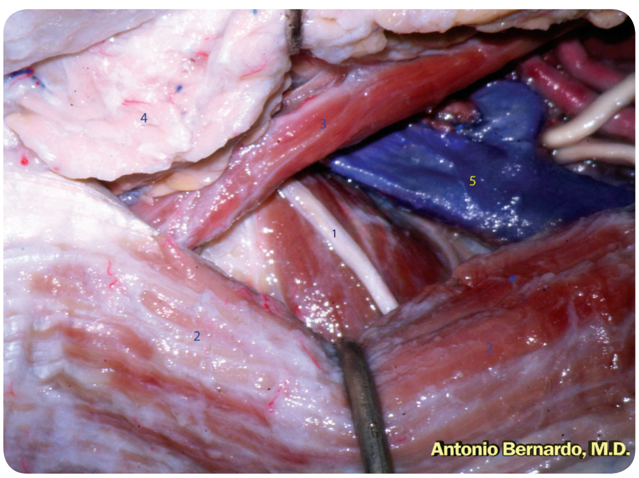

Figure 3: the spinal accessory nerve is exposed as it passes deep to the sternocleidomastoid muscle. 1- spinal accessory nerve, 2- sternocleidomastoid muscle, 3- digastric muscle, 4- parotid gland, 5- internal jugular vein.

Carotid sheath exposure

The fascia on the anterior border of the sternocleidomastoid muscle is opened and the carotid sheath is exposed. The anterior portion of the sternocleidomastoid muscle is retracted posteriorly to achieve adequate exposure of the ***posterior belly*** of the ***digastric muscle***. The posterior belly of the digastric muscle is retracted supero-anteriorly to cover and protect the facial nerve. The spinal accessory nerve is identified as it passes deep to the sternocleidomastoid muscle until its entrance into the carotid sheath **(Fig 3)**. The ***hypoglossal nerve***, which runs over the internal jugular vein on the lateral surface of the carotid sheath, is identified.

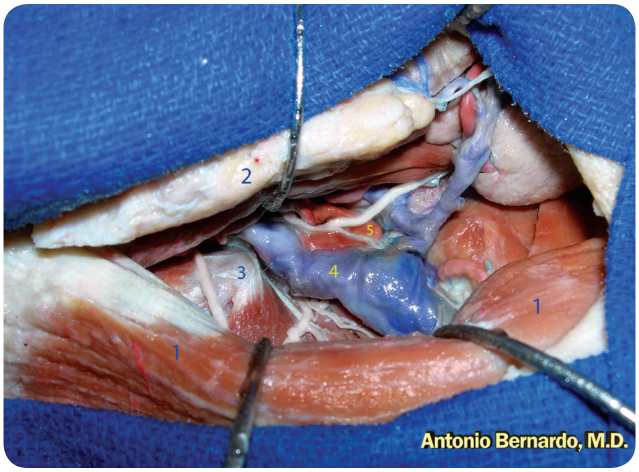

Figure 4:
The fascia on the anterior border of the sternocleidomastoid muscle has been opened, the sternocleidomastoid muscle has been retracted posteriorly, the parotid gland and the digastric muscle have been retracted anteriorly and the carotid sheath has been opened. 1- sternocleidomastoid muscle, 2- - parotid gland, 3- transverse process of C1, 4- internal jugular vein, 5- carotid bifurcation.

The ***carotid sheath*** is sharply opened from the region of the carotid artery bifurcation to the angle of the mandible and the nervous structures are sequentially identified **(Fig 4-5-6-7)**:

The most superficial nerve in the carotid sheath is the ***hypoglossal nerve***, coursing over the internal and external carotid arteries, just above the carotid bifurcation. The ***ansa cervicalis*** is identified leaving the hypoglossal nerve near the posterior aspect of the internal carotid artery. The ***glossopharyngeal nerve*** is consistently located far superior, crossing through the carotid sheath, superficial to the internal carotid artery and curving around the stylopharyngeus muscle. The ***vagus nerve*** is localized deep in the carotid sheath, running between the internal jugular vein and the internal carotid artery.

The dissection is completed superiorly by exposing the ***posterior border of the parotid gland*** over the angle of the mandible. The ***facial nerve*** is identified as it exits the stylomastoid foramen and travels thorough connective tissue to enter the posterior border of the parotid gland.

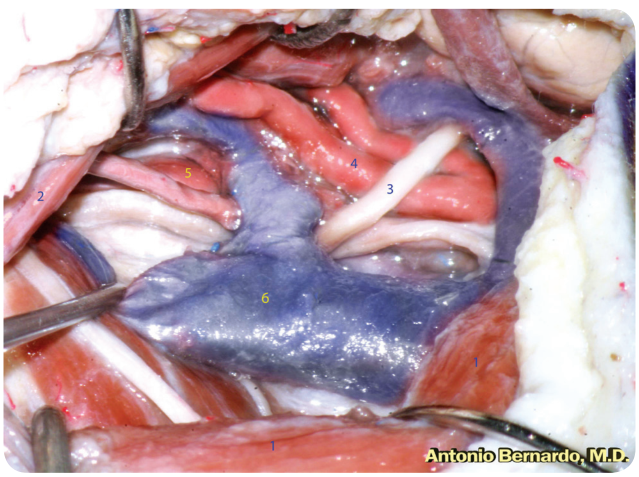

Figure 5:
The carotid sheath has been opened from the region of the carotid artery bifurcation to the angle of the mandible and the nervous structures are identified: 1- sternocleidomastoid muscle, 2- posterior belly of digastric muscle, 3- hypoglossal n., 4- external carotid artery, 5- internal carotid artery, 6- internal jugular vein.

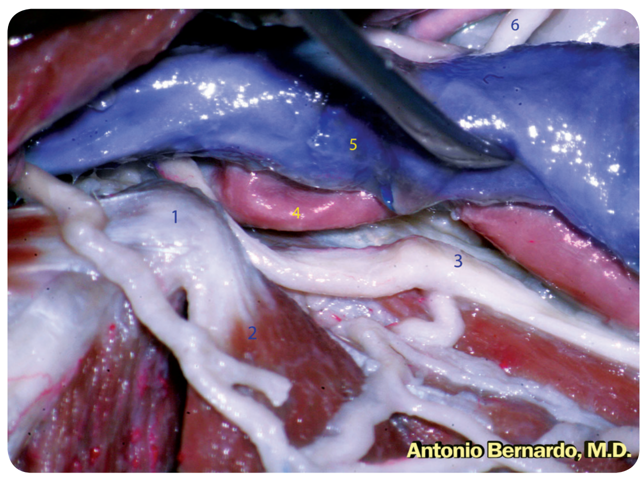

Figure 6:
Detaching the sternocleidomastoid muscle allows a wider view of the contents of the carotid sheath. The transverse process of C1 is identified. 1- transverse process of C1, 2- splenius cervicis muscle, 3- vagus n., 4- internal carotid artery, 5- internal jugular vein, 6- hypoglossal nerve.

Sublabyrinthine dissection

Once the cervical dissection is completed, a presigmoid infralabyrinthine mastoidectomy is performed exposing the presigmoid posterior fossa dura and sparing the labyrinthine structures (see Chapter 3 for mastoidectomy techniques)

The main goal of the procedure is to perform the most extensive removal of bone while preserving the internal structures of the temporal bone

The sigmoid sinus is uncovered posteriorly. ***The posterior semicircular canal are skeletonized*** but not violated to maximize the working space

The ***facial nerve is located in the fallopian canal,*** and the retrofacial air cells are removed allowing exposure of the sigmoid sinus in continuity with the jugular bulb

Further bone removal of the infralabyrinthine portion of the mastoid and complete skeletonization of the jugular bulb achieves full exposure of the jugular foramen.

The ***posterior belly of the digastric muscle is detached*** from the base of the skull providing good exposure of the inframastoid region with complete visualization of the extracranial aspect of the jugular foramen and good control of the structures exiting it **(Fig 8)**.

Far Lateral craniotomy

The exposure can be completed by a far lateral suboccipital craniotomy with partial extradural resection of the condyle and hemilaminectomy of C1 (see Chapter 4) for intradural exposure of the jugular foramen.

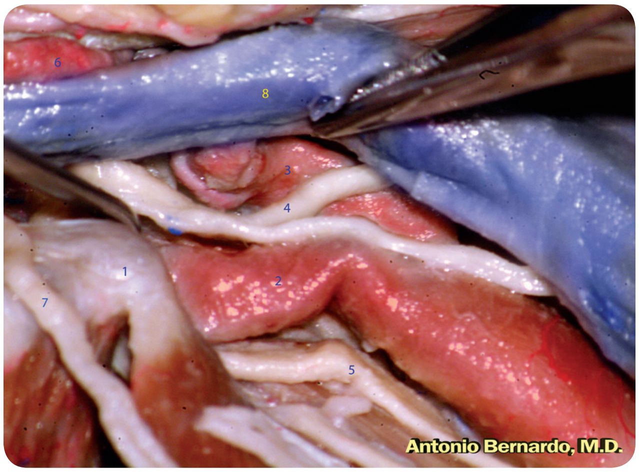

Figure 7:
The internal jugular vein has been retracted anteriorly and the carotid bifurcation visualized. 1- transverse process of C1, 2- internal carotid artery, 3- external carotid artery, 4- hypoglossal n., 5- vagus n., 6- occipital artery, 7- spinal accessory n., 8- internal jugular vein.

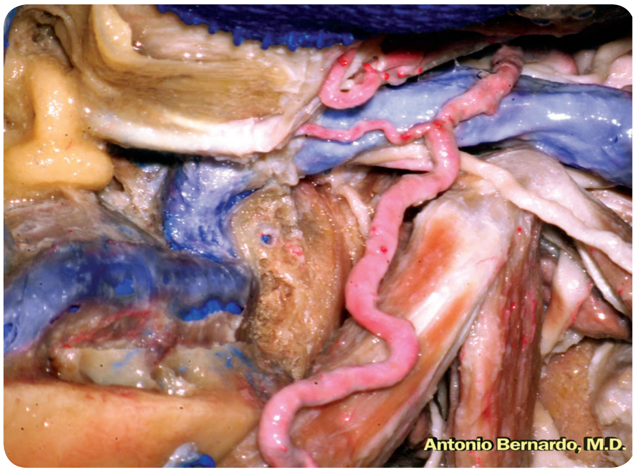

Figure 8:
Anatomical view of the final approach after the detachment of the digastric muscle: the jugular bulb and the facial nerve have been scheletonized, the digastric muscle has been detached and the mastoid tip completely removed.

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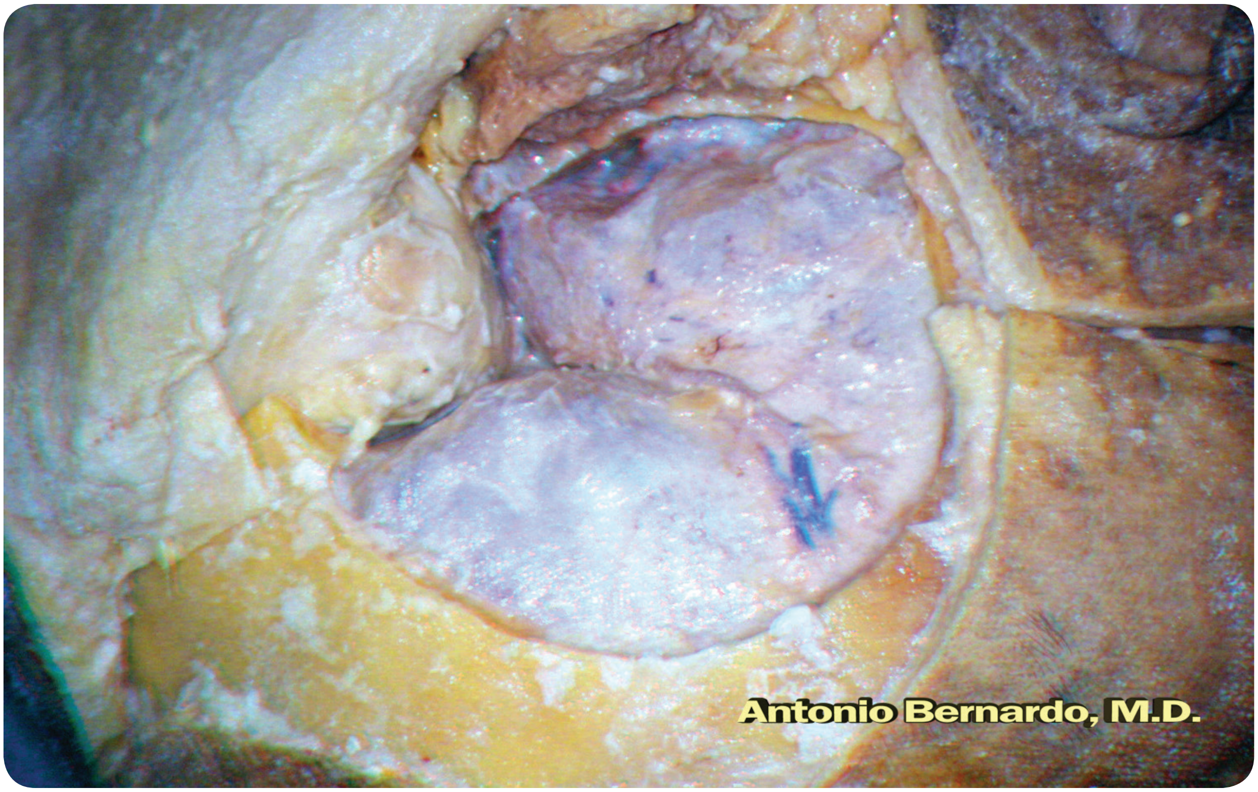
CHAPTER 7

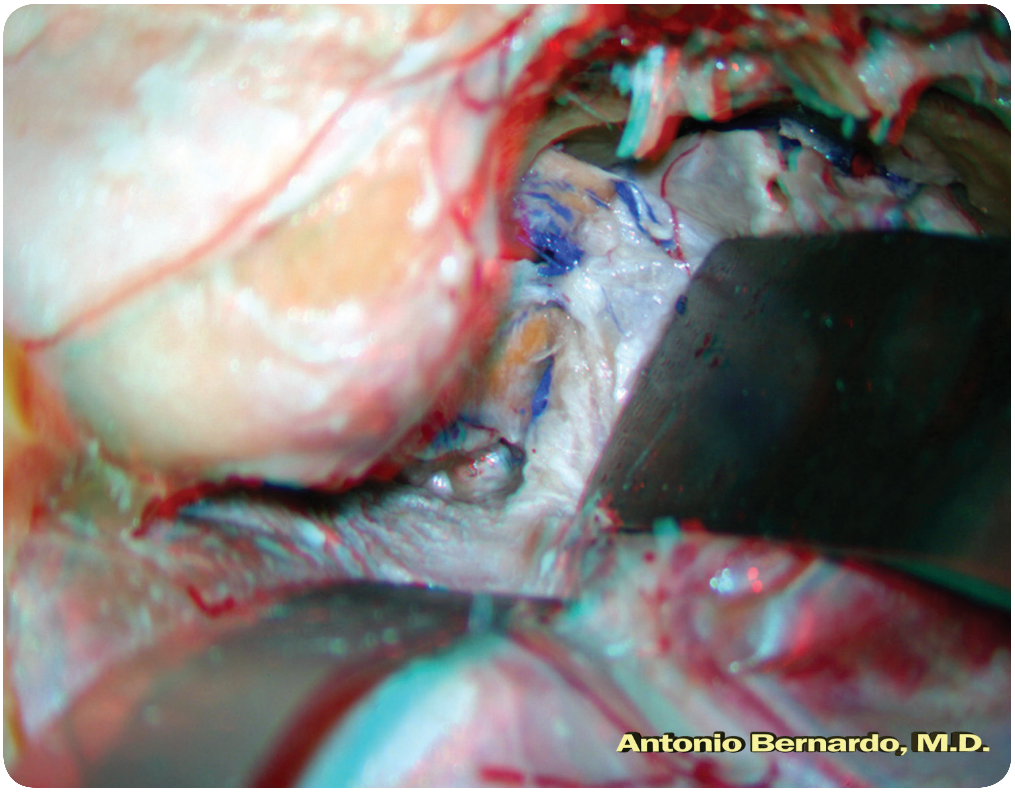
3-D Anatomy

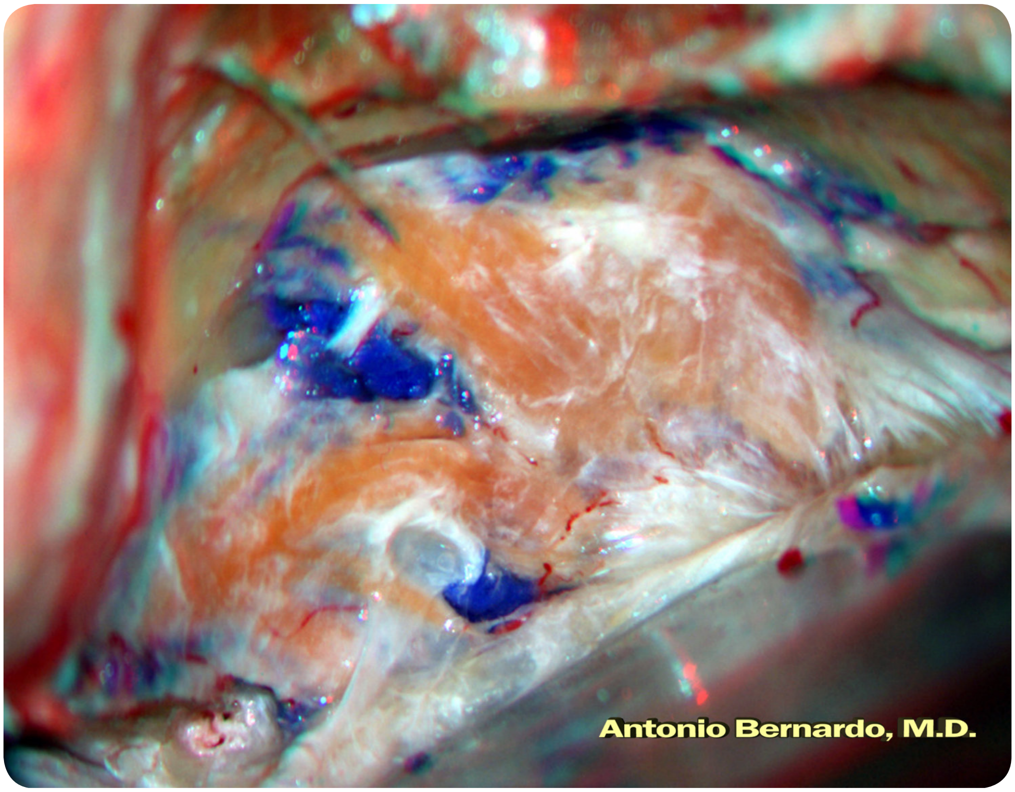
(use 3-D glasses provided: red color on left eye)

Fronto-orbito-zygomatic Approach

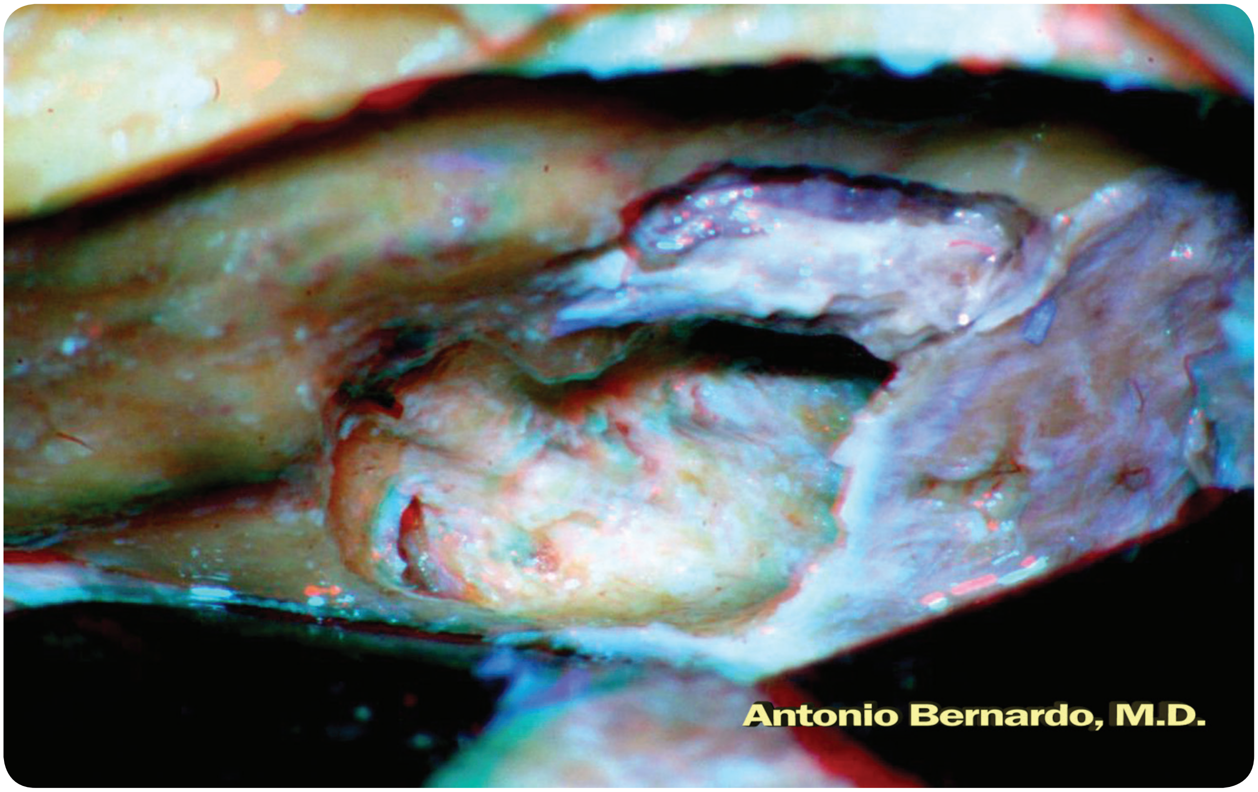


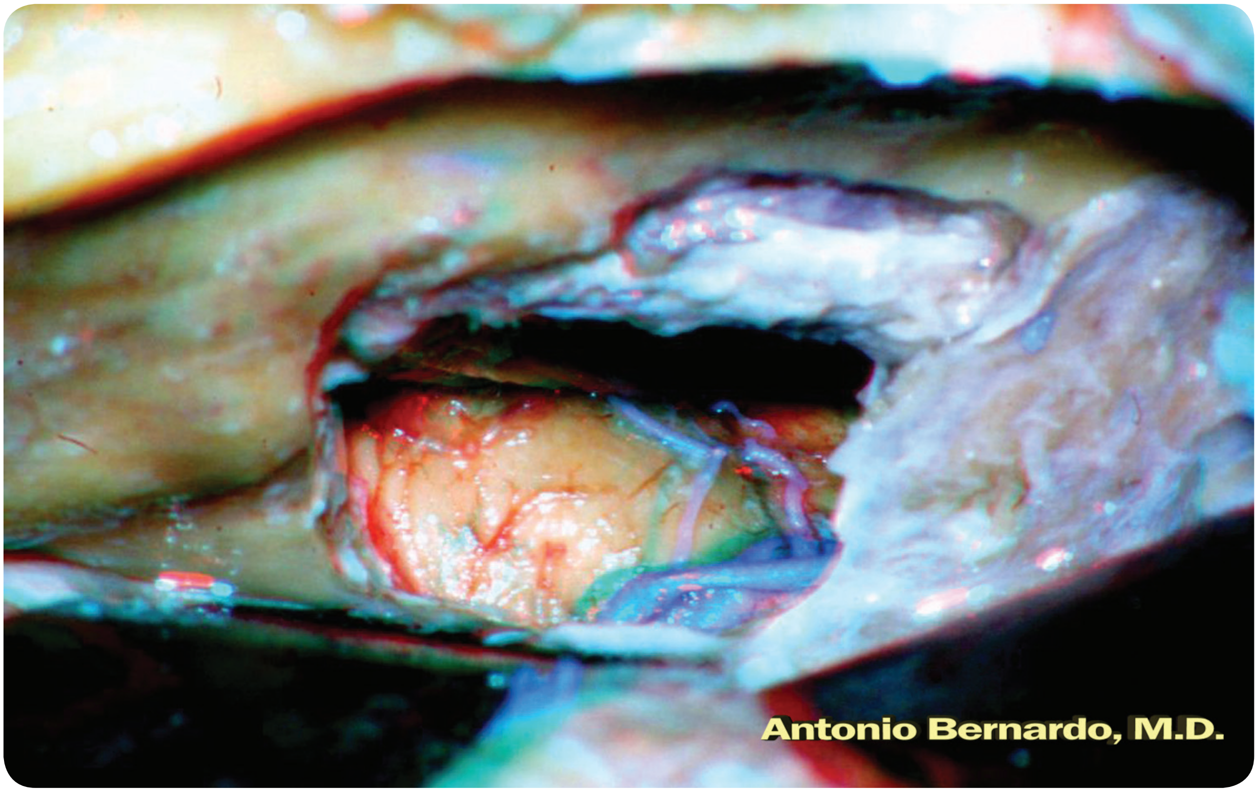
Cavernous Sinus Approach



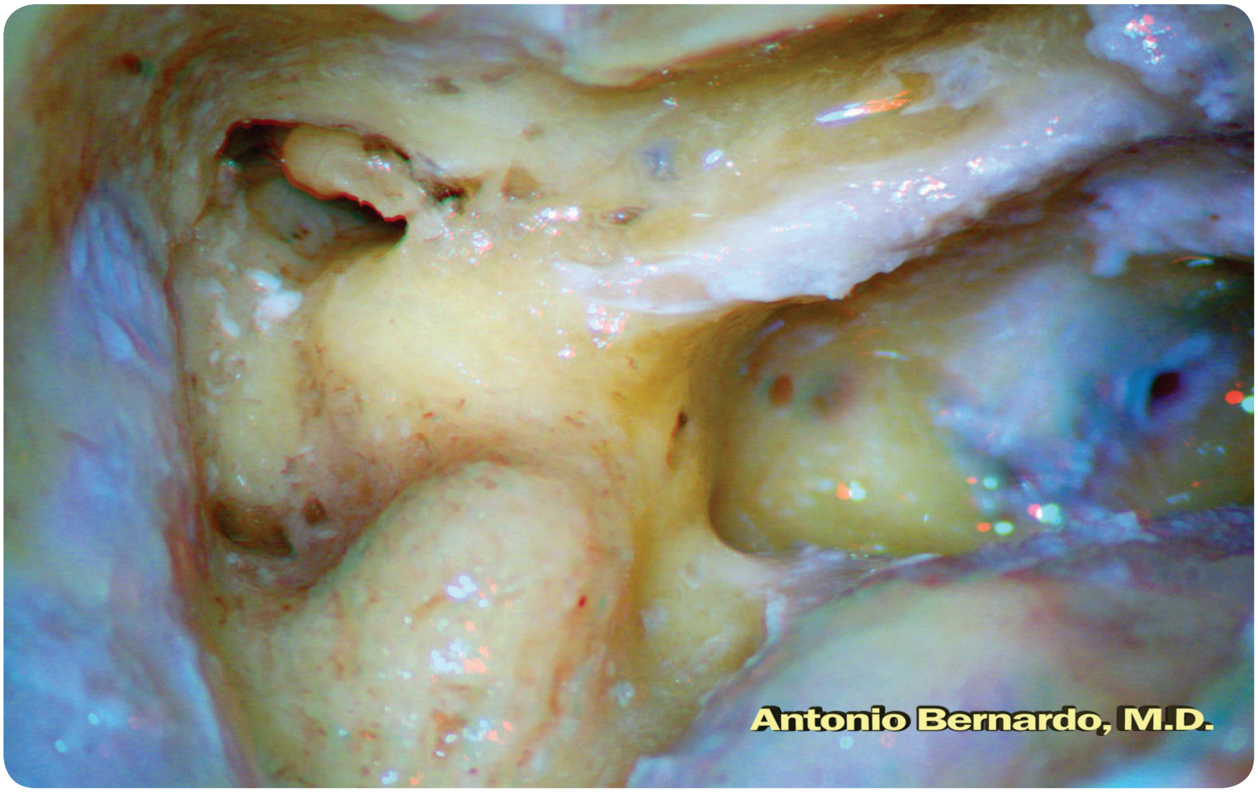


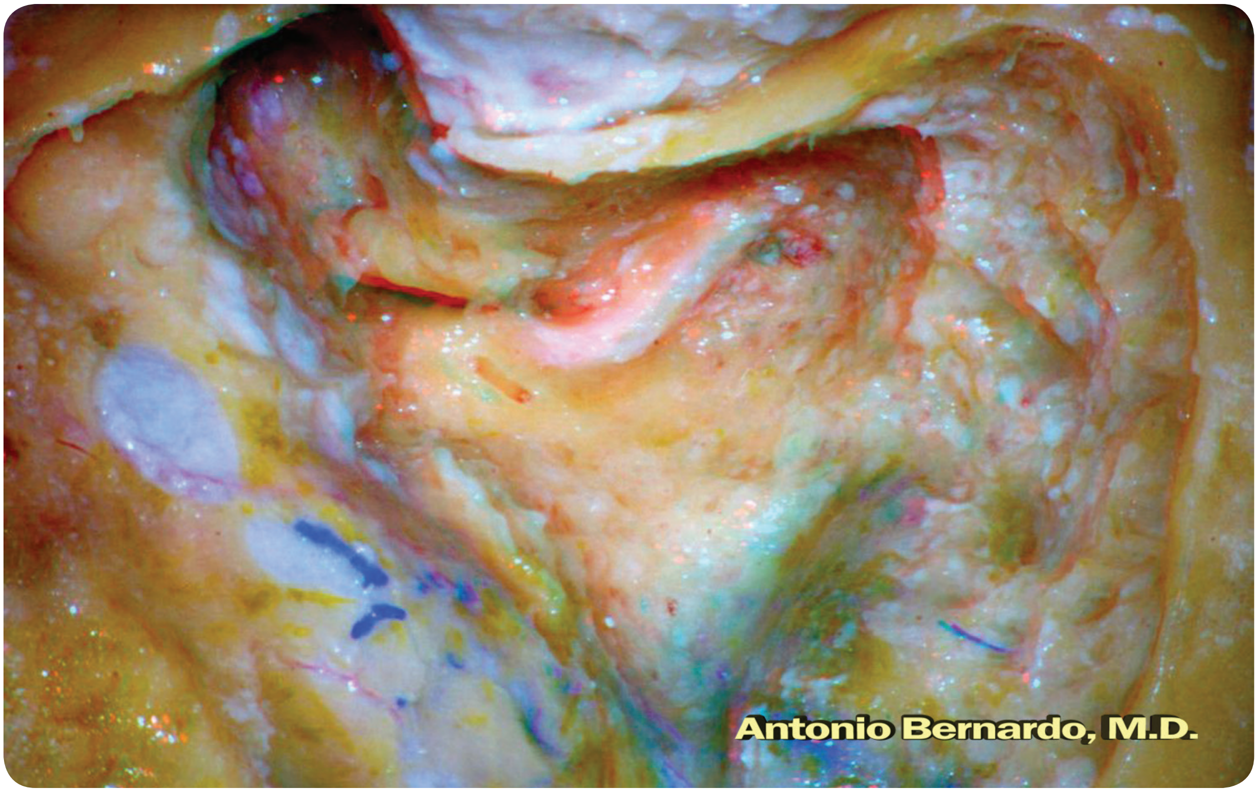
Anterior Petrosal Approach



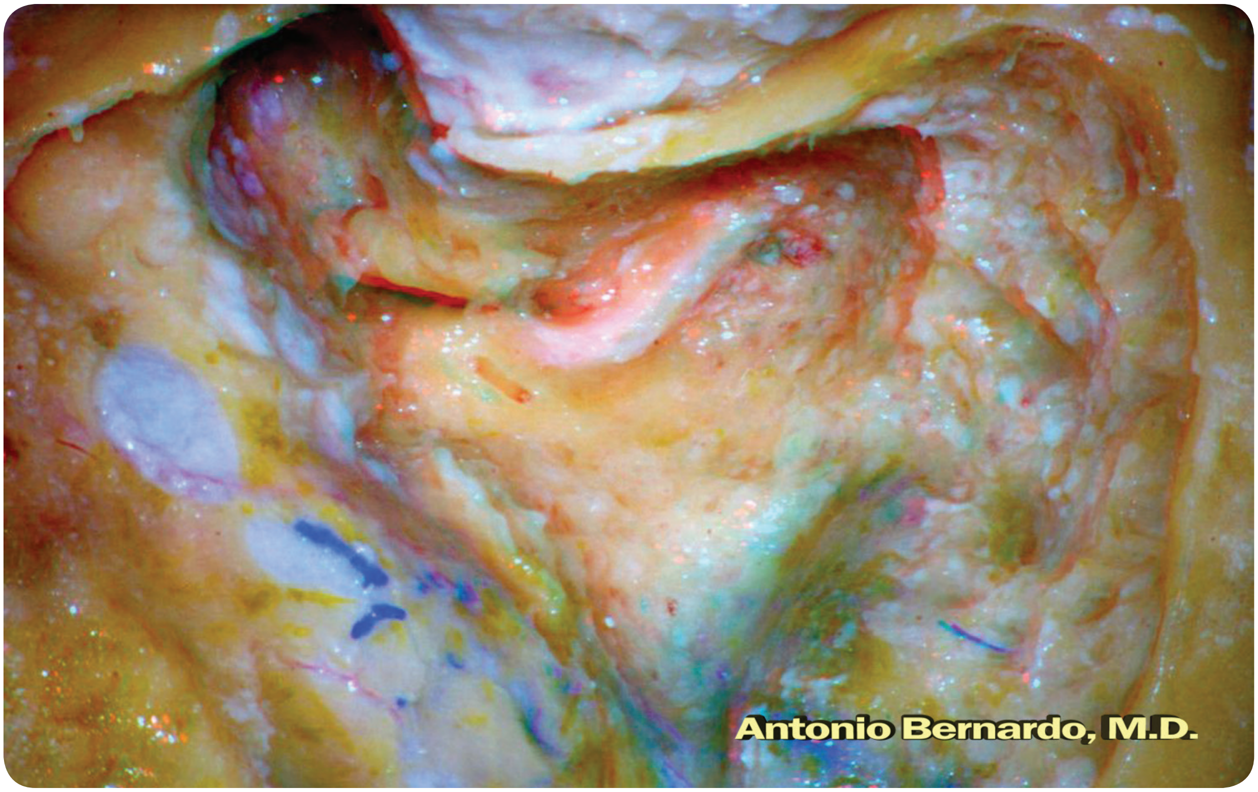


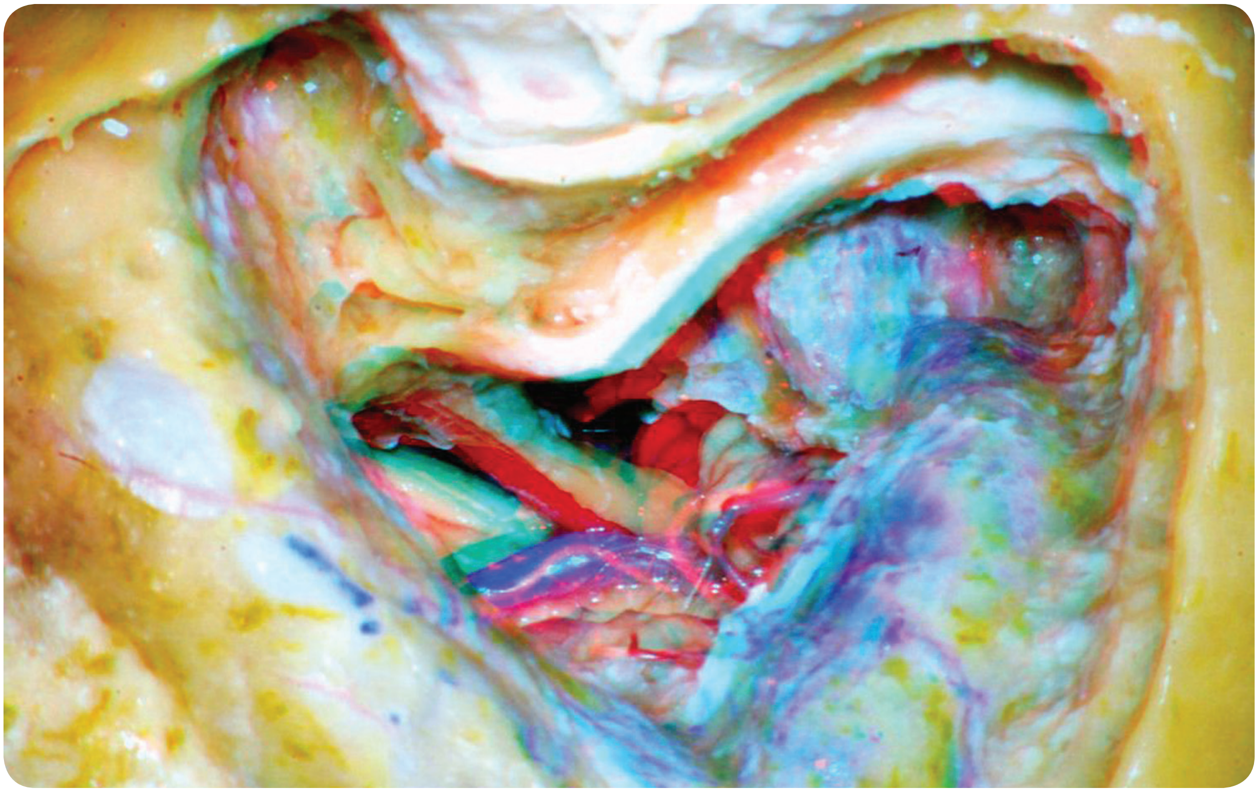
Translabyrinthine Approach



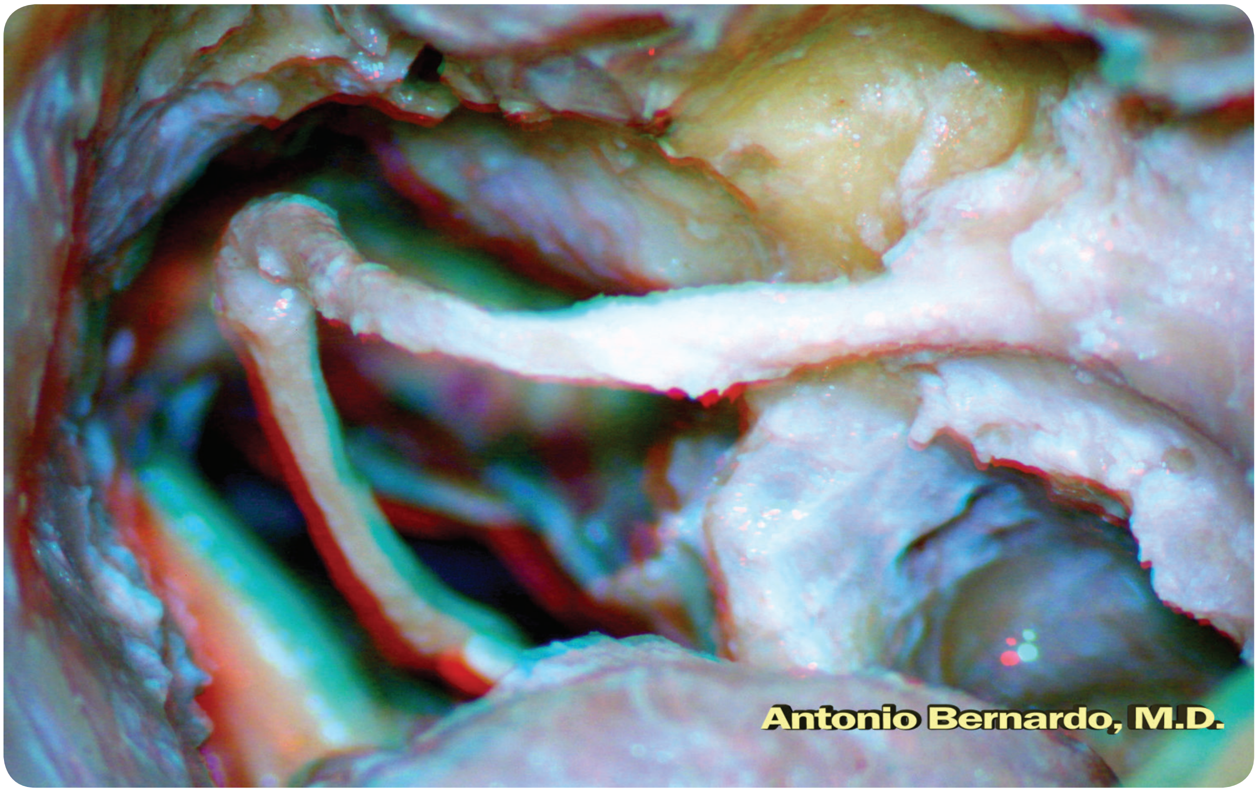


Translabyrinthine Approach

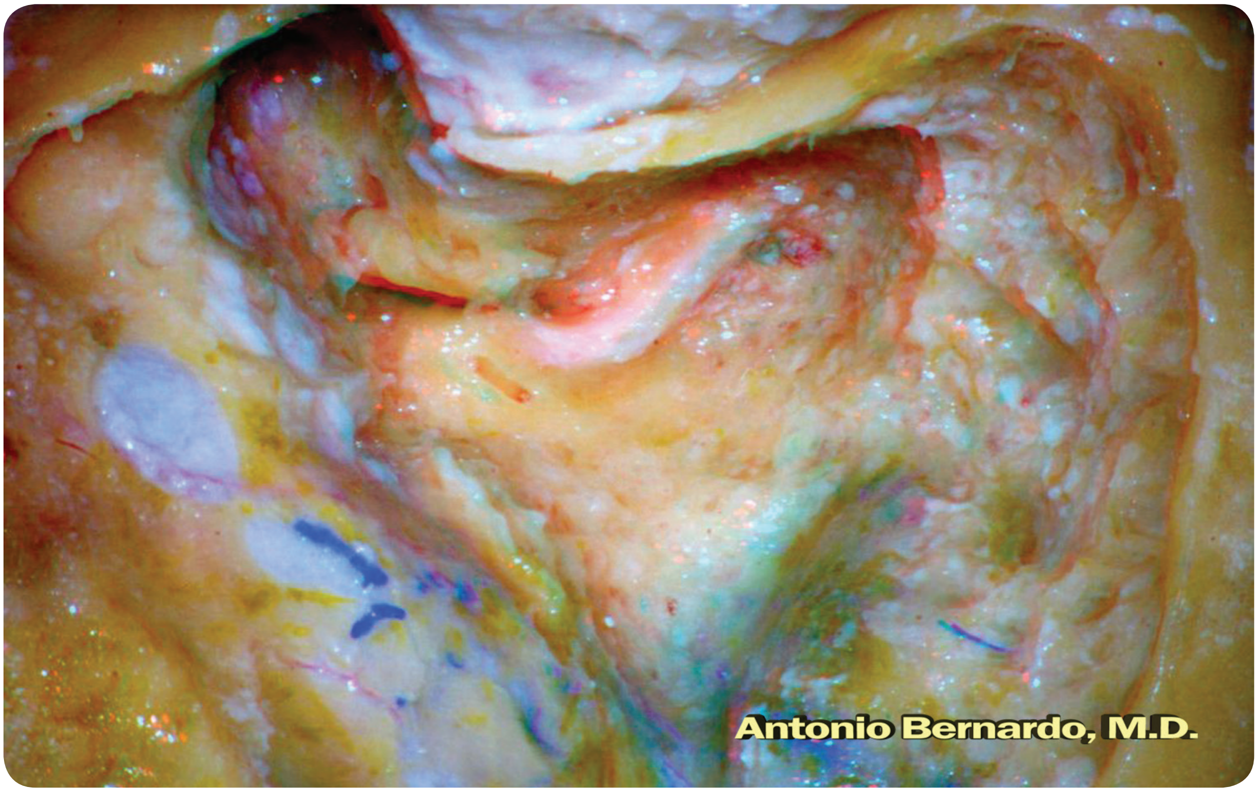


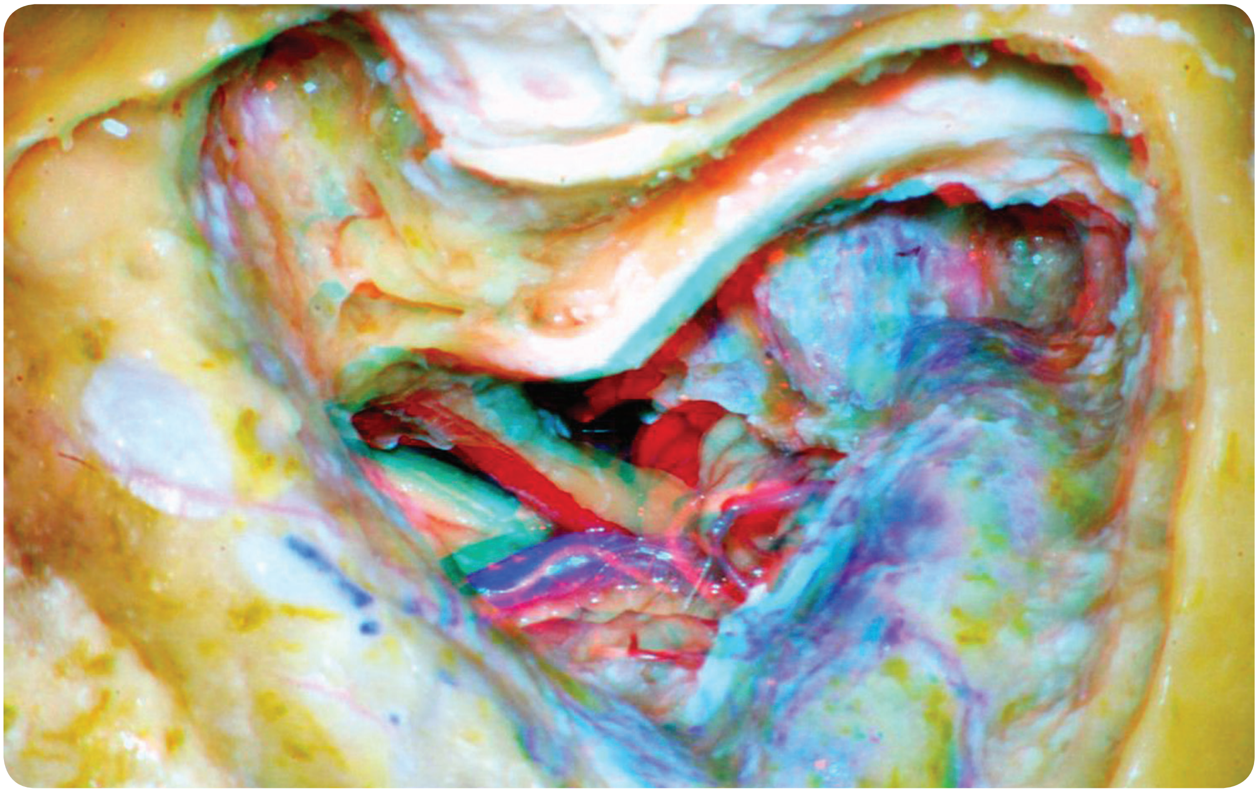


Transcochlear Approach

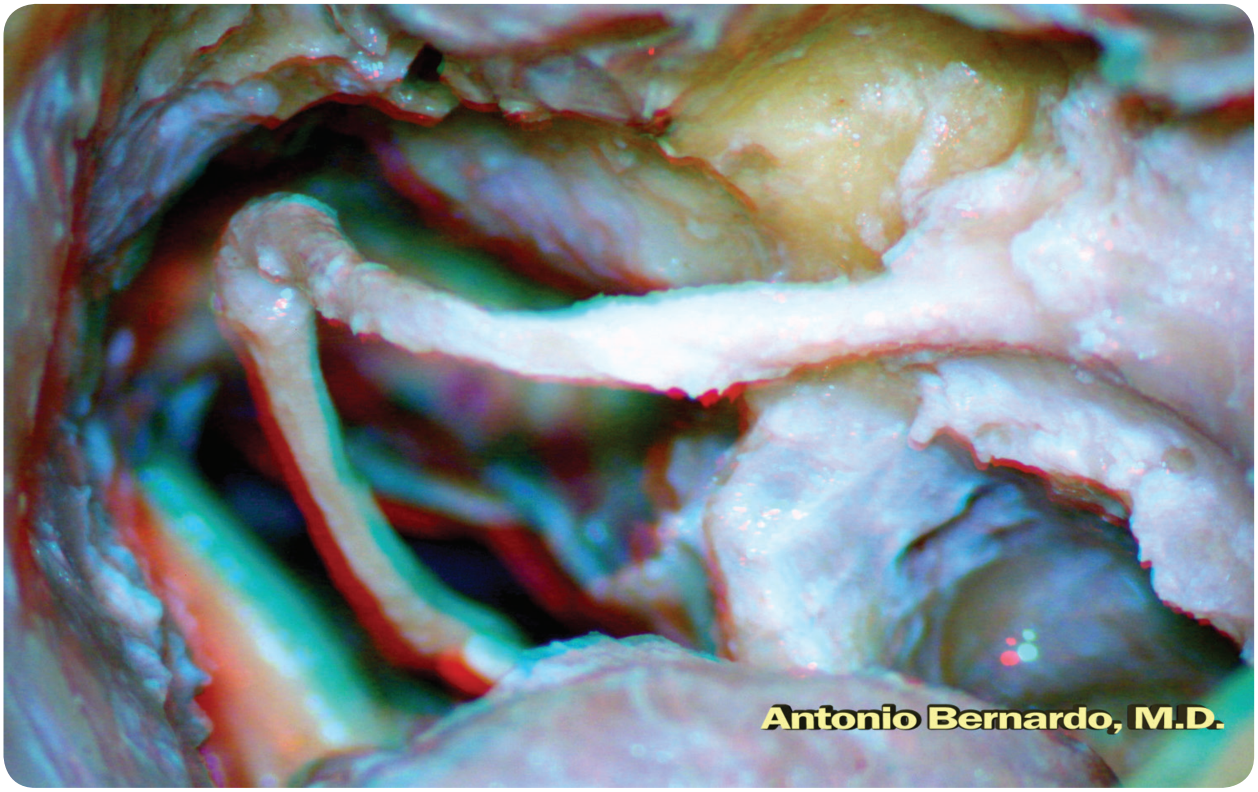


Translabyrinthine Approach



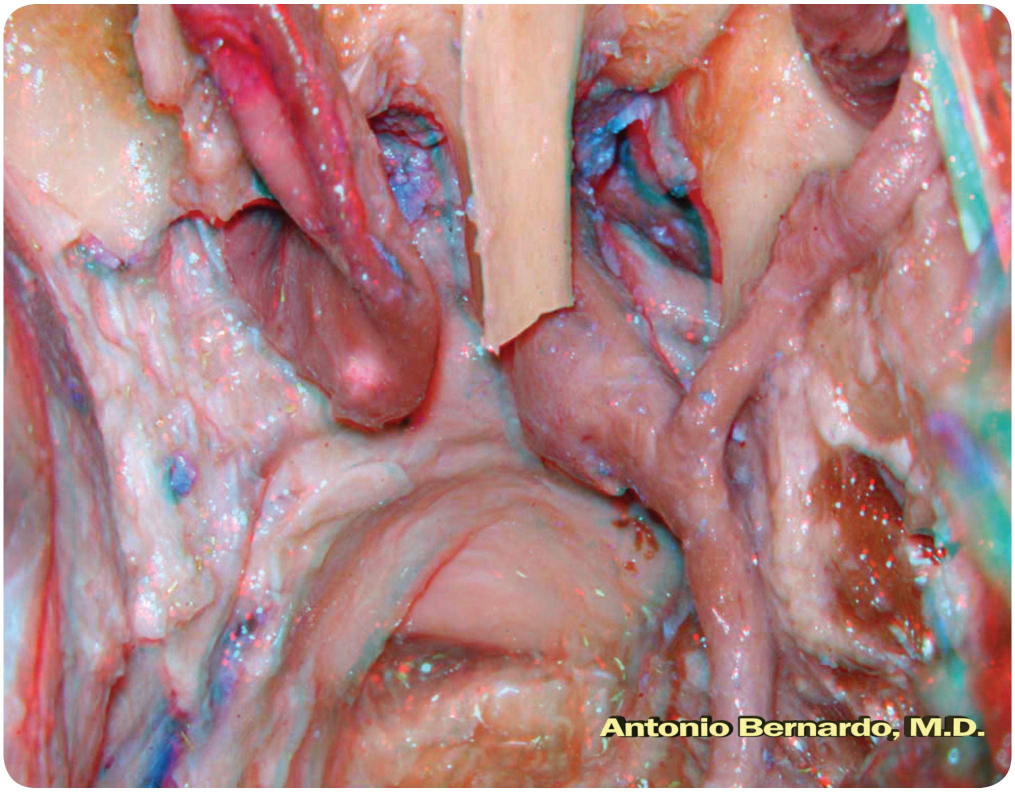


Transcochlear Approach



Transcochlear Approach

Far Lateral Trans-Condylar Approach



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