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Extradural Total Petrous Apex Resection With Trigeminal Translocation for Improved Exposure of the Posterior Cavernous Sinus and Petroclival Region

Abstract—We have analyzed a strategy for improved exposure of the posterior cavernous sinus and petroclival region through an extradural subtemporal approach to be utilized in the removal of neoplastic processes with involvement of the apical petrous bone and posterior cavernous sinus. This surgical approach includes the following elements for improved exposure of the posterior cavernous sinus through the middle fossa corridor: (1) maximal extradural exposure and mobilization of the trigeminal nerve complex, allowing its elevation and anterior displacement, (2) complete extradural removal of the anterior petrous pyramid from the porus acousticus to the petrous apex under direct vision, (3) total exposure of the abducens nerve from the posterior fossa to its point of cross over the intracavernous carotid artery, and (4) wide extradural exposure of the cavernous carotid artery in the foramen lacerum region. This strategy can be combined with other related approaches; specifically, frontotemporal or posterior transpetrosal exposures for extensive lesions.

Microsurgical dissection and morphometric analysis were performed in 20 fixed cadaver specimens for the purposes of validating the method for clinical application and determining the key elements to maximization of exposure. The trigeminal complex could be anteromedially retracted 4.8 mm ± 1.3 (range = 3 to 6 mm) without skeletonization of V_2 and V_3. Liberating these two divisions from their bony canals to their first peripheral branch (10.4 mm ± 2.5 and 5.4 mm ± 1.1, respectively) resulted in increased mobilization an average of 9.1 mm ± 1.7 (7 to 14 mm). Further mobilization is achieved by dividing the attachment between the trigeminal connective tissue sheath and the fibrous carotid ring at the foramen lacerum. An average of 13.0 mm ± 3.1 (7 to 20 mm) of the posterior intracavernous carotid artery was exposed. Detailed microanatomic observations and a comprehensive morphometric analysis of the relevant anatomic relationships were made. (*Skull Base Surgery, 6(2):95–103, 1996*)

The posterior cavernous sinus is that portion of the sinus that contains the lateral and posterior-superior venous spaces.[1–3] The roof of this space is formed by the trigeminal ganglion, the floor being the apical portion of the petrous pyramid. This space contains the sixth cranial nerve, from its entrance at Dorello's foramen to its point of cross over the C_5 ascending segment of the cavernous carotid artery.[2,3] Neoplastic processes involving this space, either from within the cavernous sinus or from the petroclival region, present difficult problems in terms of adequate surgical exposure.

A frontotemporal transcavernous approach, as origi-

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nally described by Dolenc, is satisfactory for lesions that have their greatest mass in the anterior and medial aspect of the cavernous sinus.[4–6] However, when more lateral and posterior access is necessary, obstruction by the trigeminal ganglion often requires intradural lateral transposition of the nerve, which is difficult without placing retraction stress on V_1 and the abducens nerve. A significant degree of temporal lobe retraction is also necessary, with sacrifice of the temporal tip bridging veins. In our experience, this maneuver has resulted in a significant incidence of cranial nerve morbidity and postoperative temporal lobe swelling. The posterior combined petrosal approach suffers the opposite disadvantage in that cavernous sinus access is limited, mostly by the long and narrow operative corridor.[7–12]

An approach through the middle fossa transpetrosal route is good for exposing the inferior and lateral portion of the space, but again, the trigeminal complex provides an obstruction, limiting the view directly under the ganglion and to the medial portion of the posterior cavernous sinus.[13–15] This strategy does, however, provide a relatively short operative distance through which to work and enjoys a natural combinability with both posterior and frontotemporal exposures. Frustrated by the limitations in exposure of this area by our current methods, we performed a laboratory study of the feasibility of expanding the middle fossa transpetrosal approach to include exposure of the entire posterior cavernous sinus region.

MATERIALS AND METHODS

Twenty fixed human cadaver heads, injected with silicone, were dissected using microsurgical technique. All morphometric relationships were measured in millimeters using small calipers or paper rulers. The heads were positioned in the 90° lateral orientation. A question mark-shaped incision is made beginning just anterior to the tragus and continued superiorly above the pinna, ending anterior and superior at the superior temporal line. The scalp and temporalis muscle are elevated and retracted anteriorly.

A 5×5-cm temporal craniotomy is made, centered two-thirds anterior to the external auditory meatus. The inferior margin of the craniotomy is made flush with the floor of the middle fossa. Beginning posteriorly, over the petrous ridge, the dura is elevated until the arcuate eminence is identified. Dural elevation then proceeds anteriorly, revealing the periosteal covering of the major petrosal groove and exposing the middle meningeal artery as it exits the foramen spinosum. The middle meningeal artery is divided and the dura further elevated to reveal the foramen ovale. At this point, the cleavage plane between the temporal dura and the connective tissue sheath of the trigeminal nerve, the outer cavernous membrane, is developed sharply. The dura propia is elevated from the trigeminal third and second divisions. The foramen rotundum is exposed anteriorly. The temporal lobe is retracted superior and posterior with two self-retaining retractors.

Using the high-speed drill, the foramen ovale and the foramen rotundum are now unroofed to allow mobilization of the trigeminal complex. Beginning with the foramen rotundum, the nerve is unroofed to the take-off of the zygomatic branch. The bone separating the foramen rotundum and foramen ovale was reduced to expose periosteum covering the infratemporal fossa. The trigeminal third division is next liberated by complete unroofing of the nerve starting at the foramen ovale to the muscular branches to the temporalis muscle. The connective tissue sheaths of the second and third divisions of the trigeminal were freed from the bone of the floors of their respective foramina.

The internal auditory canal (IAC) is next skeletonized. This dissection is begun by identifying the greater superficial petrosal nerve (GSPN), exiting the facial hiatus, and running in the major petrosal groove and the arcuate eminence (AE). The intersection of imaginary lines drawn along the axes of these two structures is identified. The angle between these two lines is bisected, and drilling begins midway along the bisection axis from the intersection to the petrous ridge. The IAC is located along this bisection axis, what we call Brackmann's line, usually 3 to 4 mm deep to the middle fossa floor.[16] When IAC dura is exposed, the horizontal intrapetrous carotid is next exposed in the posterolateral (Glasscock's) triangle.[17] The artery is uncovered from the crossing of the tensor tympani muscle lateral to the trigeminal complex. With carotid and IAC exposure, the volume of bone between these two structures can be removed to expose posterior fossa dura without encountering any neural or vascular structures. Posterior fossa dura is exposed to the depth of the inferior petrosal sinus (Fig. 1).

The IAC is next skeletonized 270° by removing the wedge of bone between the bony labyrinth and the IAC. This wedge of bone is in what we term the postmeatal triangle, bounded by the geniculate ganglion, porus acousticus, and superior semicircular canal.[16] The IAC is unroofed completely to the geniculate ganglion (Fig. 2).

Total petrous apex resection and exposure of the foramen Lacerum are next performed. To do this, the trigeminal nerve is mobilized superior and anterior by dividing the connective tissue attachments between the carotid adventitia and the epineurium of the trigeminal ganglion. With the ganglion partially elevated, any remaining bone of the petrous apex is removed with the drill under direct vision (Fig. 2).

The dural incisions are next made to expose the petroclival area and sixth cranial nerve. From the arcuate eminence toward the porus trigeminus, the dura is incised above the superior petrosal sinus. This results in exposure of the superior surface of the tentorium. The porus trigeminus is then opened to liberate the nerve. A second horizontal incision is then made below the superior petrosal sinus, parallel to the superior incision. The superior

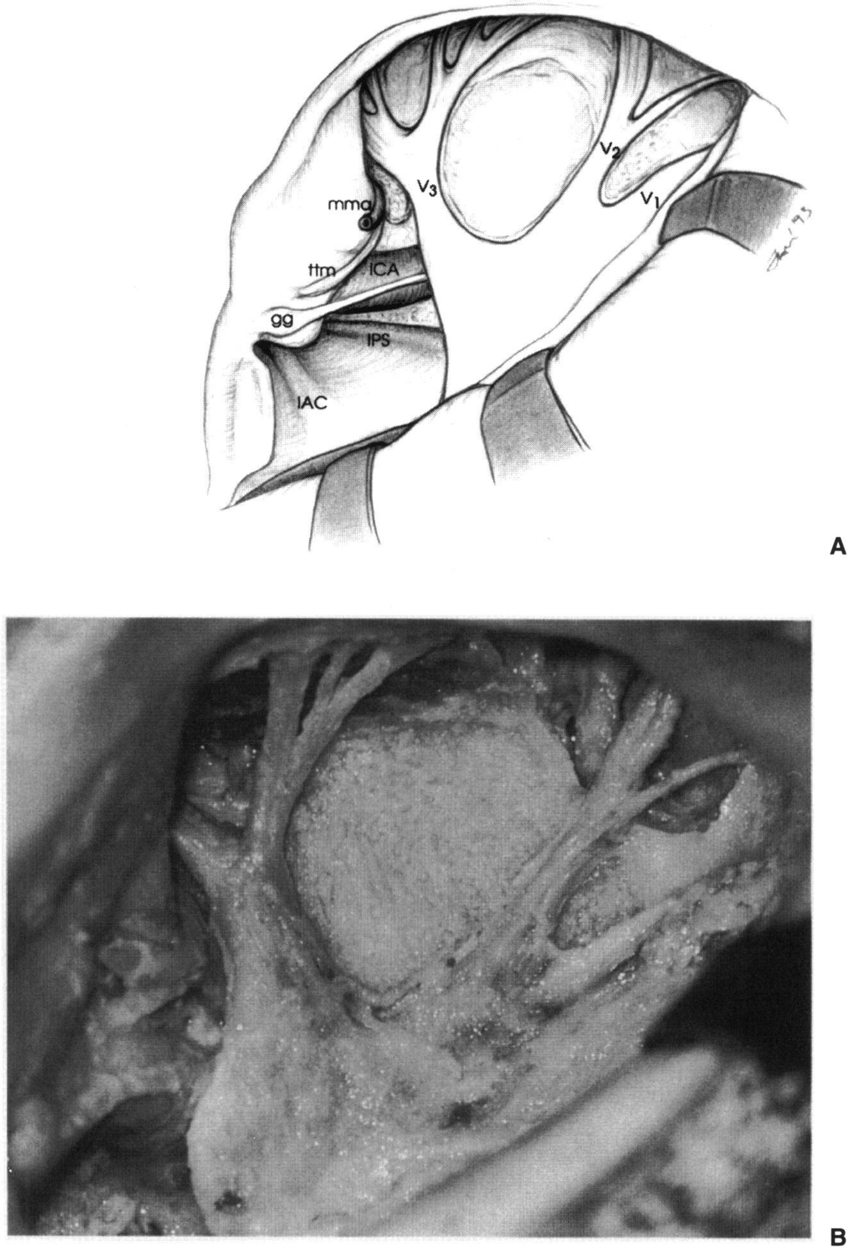


Figure 1. A: Illustration of initial extradural exposure via a left-sided approach. The second and third trigeminal divisions are exposed peripherally, and the petrous internal carotid has been uncovered. Bone between the internal auditory canal and the petrous apex has been removed down to the inferior petrosal sinus. gg: geniculate ganglion, IAC: internal auditory canal, ICA: internal carotid artery, IPS: inferior petrosal sinus, mma: middle meningeal artery, ttm: tensor tympani muscle, V_1, V_2, V_3: divisions of the trigeminal complex. B: Photo of injected cadaver dissection with peripheral dissection and liberation of the trigeminal second and third branches.

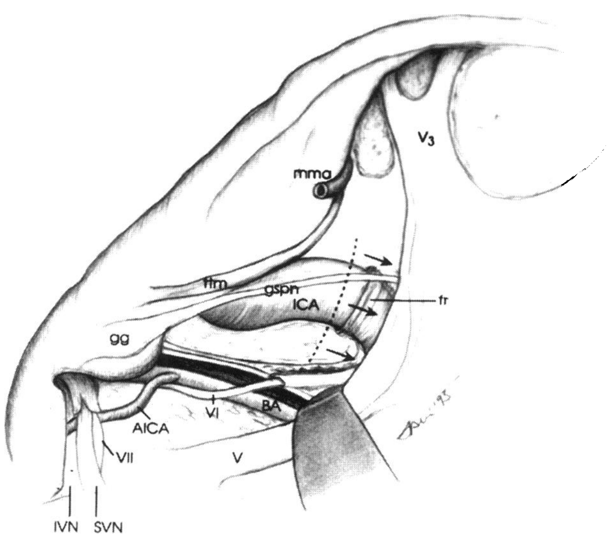


Figure 2. With the trigeminal retracted medially, the internal carotid artery is exposed as it enters the cavernous sinus, piercing the posterolateral fibrous ring. The trigeminal could be medially retracted an average of 9.1 mm with liberation of the trigeminal second and third divisions (arrows). The posterior fossa dura has been opened to reveal the sixth nerve (VI) from the posterior fossa to its entrance into Dorello's canal. AICA: anterior inferior cerebellar artery, BA: basilar artery, fr: posterolateral fibrous ring, gg: geniculate ganglion, gspn: greater superficial petrosal nerve, ICA: internal carotid artery, IVN: inferior vestibular nerve, mma: middle meningeal artery, SVN: superior vestibular nerve, ttm: tensor tympani muscle, V_3: mandibular division, V: trigeminal root, VI: abducens nerve, VII: facial nerve.

petrosal sinus is then ligated where it crosses over the trigeminal nerve. The tentorium is incised in the sagittal plane to the incisural edge, behind the dural entrance of the fourth cranial nerve. The tentorium is then retracted posterior and superior with the temporal lobe. The dura over the IAC is then opened longitudinally to expose the facial and superior vestibular nerves. The posterior fossa dura is then incised along the medial and lateral margins of exposure. The flap of posterior fossa dura is then removed by incising along the edge of the inferior petrosal sinus from lateral to medial. Before this step, the intradural compartment was always inspected to locate the entrance of the sixth nerve into Dorello's foramen, uniformly found directly inferior to the porus trigeminus (Fig. 3).

Beginning at Dorello's foramen, the sixth nerve is exposed in Dorello's canal toward the carotid artery. To fully expose the carotid artery to the meningohypophyseal trunk (C4-5 junction), the fibrous ring surrounding the carotid at the foramen Lacerum is divided to completely free the trigeminal complex from this structure and to open the cavernous sinus. For enhanced exposure, the third division of the trigeminal is cut at the foramen ovale region. The trigeminal complex is then translocated superior and anterior, providing full exposure of the posterior cavernous sinus region (Fig. 4).

RESULTS

Anatomical Observations

Arterial Relationships

As the intrapetrous carotid artery (C_6 segment) enters the cavernous sinus, it was found to penetrate the outer cavernous membrane just inferior to the lateral margin of the trigeminal complex. The artery is surrounded by a thickened adventitial band that was connected to the outer cavernous membrane, continuous with the trigeminal connective tissue capsule above and the periosteum below. This fibrous ring was distinguishable in all dissections. The intrapetrous carotid artery was also observed to be surrounded by a thin venous plexus for a variable distance in all cases. This plexus in some specimens extended to the region of the genu of the intrapetrous carotid artery. The extent of bony covering of the artery in the middle fossa was variable. In the majority of specimens, thin bone covered the carotid until the artery passed under the Gasserian ganglion at the foramen Lacerum. Several specimens had some exposed petrous carotid in the middle fossa floor, an observation in agreement with previous studies.[17] The dorsal meningeal branch of the meningohypophyseal trunk was the most frequently observed artery passing through the posterior cavernous sinus, usually in close apposition to the sixth cranial nerve as it crossed the interval between Gruber's ligament and the carotid artery (Fig. 3).

Venous Relationships

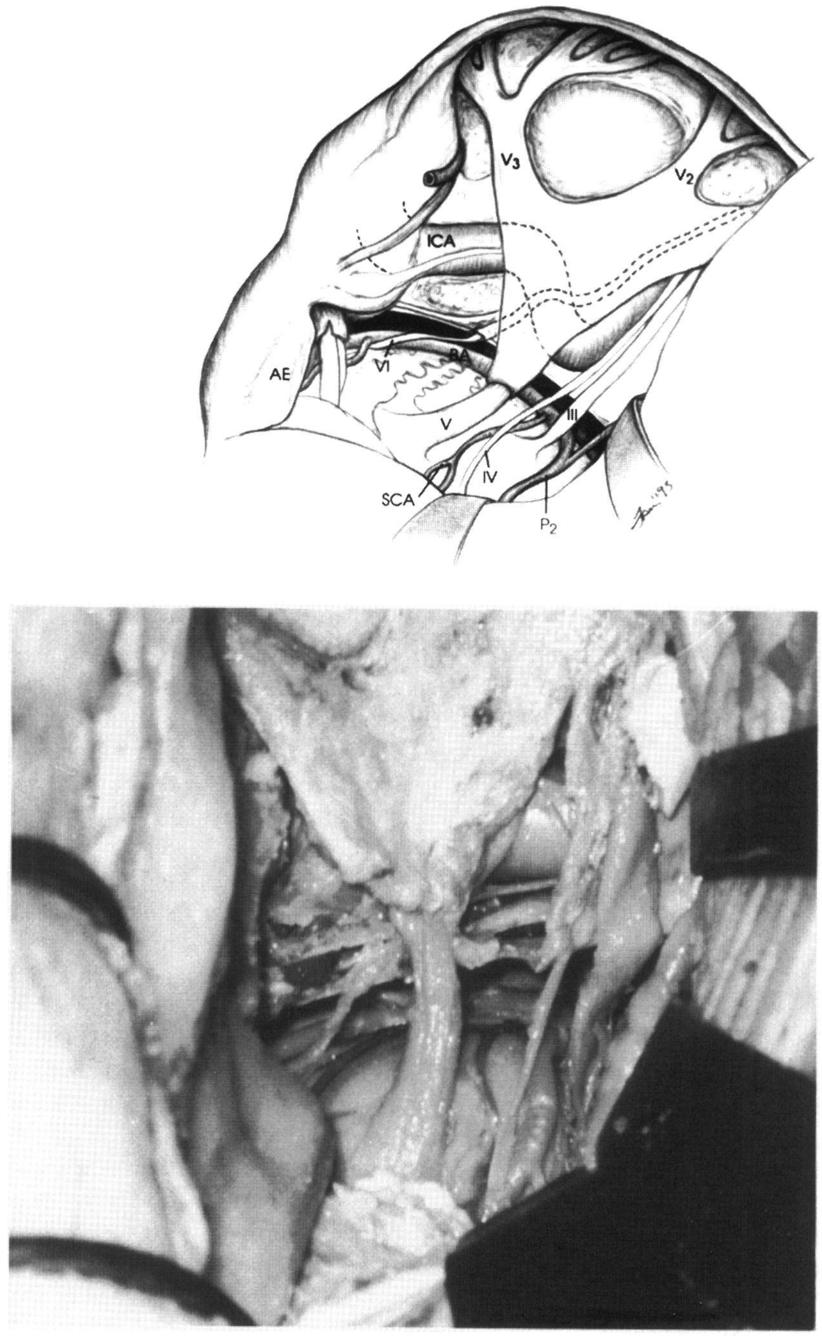
The venous connections of the posterior cavernous sinus were uniformly in agreement with previous descriptions.[1] The only observation worthy of note was the uniform presence of a sphenoidal emissary foramen medial to the foramen ovale, as described by Rhoton, which has connection to the pterygoid venous plexus.[1] The caliber of this venous channel showed a high degree of variability, in some specimens being as large as the trigeminal third division (Fig. 1).

Abducens Nerve Relationships

The sixth cranial nerve entered Dorello's foramen at a fairly uniform distance, averaging 11.6 mm ± 1.9 (range = 10 to 15 mm), directly inferior from the porus trigeminus through this viewing angle. After entering Dorello's foramen, the sixth nerve was observed to be covered by a sleeve of dura propria for a variable distance towards the cavernous carotid artery. The nerve, covered by the dural sleeve, travelled between the leaves of the dura for a variable distance before entering a space containing venous plexus with connection to the posterior cavernous sinus. This dural sleeve, separable from the epineurium, is contiguous with the connective tissue covering the trigeminal complex above and the periosteal layer below, that is, the outer cavernous membrane. The length of sixth nerve exposed measuring from Dorello's foramen to the point at which the nerve crosses the carotid artery averaged 12.3 mm ± 2.5 (6 to 16 mm). The distance from Dorello's foramen to the porus acousticus averaged 16.3 mm ± 1.8 (14 to 20 mm) (Fig. 2).

Trigeminal Nerve Relationships

Relevant anatomic relationships of the trigeminal complex concerned two main facets. The first was defining the precise characteristics of the connections of the nerve's connective tissue sheath to the outer cavernous membrane. Importantly, as described above, the connective tissue sheath has attachment to the outer cavernous membrane lateral and inferior, and to the fibrous ring around the carotid artery entering the sinus. Full mobilization of the nerve required detachment of this connection. The connective tissue sheath was also found to be adherent to the dura propria at the porus trigeminus, which requires separation of this attachment when freeing the nerve at this anchoring point. The second major facet observed was the distance along the second and third branches to the first major branching point from their respective foraminal entrances. This distance was felt to represent the minimum of extradural bone removal necessary to completely unroof these branches and maximize their mobilization. The motor branches to the temporalis muscle are the first branches of V_3, and were found to be an average of 5.4 mm ± 1.1 (4 to 7 mm) from the lip of the foramen ovale. Similarly, the zygomatic branch of V_2 was found to exit the nerve an average of 10.4 mm ± 2.5 (6 to 13 mm) distal to the foramen rotundum (Fig. 1).



A

B

Figure 3. A: Illustration of the full exposure afforded by incising the tentorium and retracting the temporal lobe more posteriorly. This exposure requires dissection of the lateral and superior cavernous triangles. The fourth (IV) and third (III) cranial nerves are exposed medial to the trigeminal root, as well as the superior cerebellar (SCA) and posterior cerebral (P_2) arteries. B: Corresponding cadaver dissection of the full exposure of the region with dissection of the lateral and superior cavernous triangles.

Morphometric Analysis

Morphometric relationships were determined both prior to and after the extradural bone removal was performed. The predrilling measurements are summarized in Table 1. Most important are the relationships between the structures identified on the floor of the middle fossa that provide the landmarks for the resection of the petrous pyramid.

Table 2 contains the measurements between structures identified after the extradural bone removal was complete. Important relationships that outline the operative corridor through this approach to the posterior cav-

Table 1. Extradural Middle Fossa Morphometric Relationships Prior to Drilling

	Distance (mm)	*± Std. Dev.*	*Range*
GSPN @ V_3 to porus trigeminus	12.6	1.1	10–14
Porus trigeminus to AE	24.2	3.5	17–29
AE to geniculate ganglion	14.6	3.0	12–21
GSPN @ V_3 to geniculate ganglion	15.2	0.9	14–17
GSPN @ V_3 to foramen ovale	6.2	0.8	5–8
GSPN @ V_3 to foramen rotundum	19.1	2.0	15–22

Table 2. Morphometric Relationships Between Key Structures After Bone Removal

	Distance (mm)	± Std. Dev.	Range
GSPN @ V_3 to Dorello's foramen	15.4	1.8	13–19
porus trigeminus to Dorello's foramen	11.6	1.9	10–15
Porus acousticus to geniculate ganglion	15.1	1.9	12–18
Porus acousticus to Dorello's foramen	16.3	1.8	14–20
Foramen ovale to 1st branch	5.4	1.1	4–7
Foramen rotundum to 1st branch	10.4	2.5	6–13
Length intracavernous carotid exposed	13.0	3.1	9–19
Dorello's foramen to foramen Lacerum	10.7	2.0	6–14

ernous region are given by the distances from Dorello's foramen to the porus trigeminus, 11.6 mm ± 1.9 (10 to 15 mm), and to the GSPN-V_3 junction, 15.4 mm ± 1.8 (13 to 19 mm). The third side of this triangular corridor is provided by the length of intracavernous carotid artery exposed, averaging 13.0 mm ± 3.1 (7 to 20 mm).

DISCUSSION

The cavernous sinus has been described by Harris and Rhoton as being divided into four distinct venous spaces.[1] The posterior portion of the cavernous sinus is composed of the lateral and posterior-superior venous spaces. The trigeminal complex largely forms the roof of this region, with the apical petrous pyramid constituting the floor. The intracavernous carotid artery's C_5 and C_4 segments (according to Fisher's classification) form an anterior and lateral boundary to this space.[2] Posteriorly, the petroclival dura ascending to the tentorial edge forms the back wall. This region is often involved in neoplastic processes of the petroclival and sellar areas, as well as intrinsic tumors of the cavernous sinus. Surgical access to the region is affected through several different approaches, each with their own particular strengths and weaknesses. While in our experience the frontotemporal, middle fossa transpetrosal, and posterior combined petrosal strategies have been largely satisfactory in most cases, exposure of the posterior cavernous region has been hampered due to an immobile Gasserian ganglion and difficulty in fully exposing the petrocavernous abducens nerve (Fig. 1).

Access via a frontotemporal exposure has been advantageous for exposing the anteromedial portion of the cavernous sinus.[4,18] Utilizing the posteroinferior cavernous triangle (delimited by the porus trigeminus, posterior clinoid, and foramen of Dorello), the inferior portion of the posterior cavernous region may be accessed intradurally.[18,19] Processes with lateral extension under the trigeminal complex may not be well exposed without intradural mobilization and elevation of the trigeminal complex and the sixth nerve laterally. This maneuver usually requires increased temporal lobe retraction and sacrifice of the temporal tip bridging veins to provide the necessary working space. In some cases, a subtemporal exposure is additionally required to free the lateral aspect of the trigeminal complex. Also, lateral mobilization of the nerve, if overly aggressive, puts stress on V_1, V_2, and the sixth nerve, frequently resulting in postoperative dysesthesias and diplopia.

Exposing the posterior cavernous sinus through a posterior combined petrosal approach does provide exposure of the region, at the expense, however, of a deep surgical field that requires working in between the cranial nerves spanning the cerebellopontine angle.[7–10,12] This long reach also puts the surgeon at a disadvantage when trying to control cavernous sinus bleeding. Combining the posterior petrosal route with some dissection of the medial petrous pyramid from the middle fossa trajectory shortens this operative distance.[10] However, full exposure of the posterior cavernous sinus through this combined petrosal strategy is still obstructed without mobilization of the trigeminal nerve and extensive petrous apex removal. Such extensive petrous apex removal through this strategy has largely been done via a transcochlear approach.[11,12]

Extradural subtemporal exposure of the region provides the shortest working distance to the posterior cavernous sinus. The dangers of excessive retractor pressure placed on the inferior temporal lobe are compensated for by extradural bone removal, as done in several different approaches.[13,14,16,20] Utilizing an anterior middle fossa transpetrosal approach, lateral extensions of processes involving the posterior cavernous sinus can be accessed. This approach provides good exposure of the medial cerebellopontine angle from the internal auditory canal to the foramen of Dorello. The lateral portion of the posterior cavernous sinus can be partially accessed with this technique. However, the trigeminal complex still presents an obstruction unless mobilized, which requires elevation of the temporal dura from the third division and ganglion, and releasing the nerve at the porus trigeminus and foramen ovale. To gain a wider operative corridor, the petrous apex needs to be totally resected and the cavernous sinus opened laterally (Fig. 2).

Exposure of the posterior cavernous region has been described via an intradural subtemporal approach by Hirsh and Sekhar.[20] This subtemporal, transcavernous, anterior transpetrosal approach includes temporomandibular joint disruption, occasional resection of the anterior 4 cm of the inferior temporal gyrus, interruption and reanastomosis of the fourth cranial nerve, intradural posterolateral cavernous sinus dissection, and intradural

A B

Figure 4. A: Dividing the third division of the trigeminal nerve results in complete rotation and translocation of the trigeminal complex to fully expose the intracavernous carotid artery to the C_4–C_5 junction. B: Magnified view of corresponding cadaver dissection showing detail of the sixth cranial nerve as it enters the posterior cavernous sinus. Of note is the sheath of dura propria surrounding the nerve as it enters Dorello's foramen. Also, blue silicone material can still be seen in the space surrounding the nerve in this region as it passes between the periosteal dural layer and dura propria. This venous space communicates with the posterior cavernous sinus.

drilling of the petrous apex. Their approach provides wide exposure of the region through intradural petrous apex resection. Essentially, defining the necessary maneuvers to total petrous apex resection through an extradural route, achieving an equivalent exposure of the posterior cavernous region, was the purpose of our study. In general, we have preferred to take advantage of the benefits of performing removal of bone at the skull base extradurally whenever possible. In the laboratory we have found this approach has several advantages, and have subsequently applied the strategy clinically (Fig. 2).

First, temporal lobe retraction takes place under the protection of the overlying dura throughout the procedure. The temporal lobe would not be exposed until later, if exposure above the tentorium becomes necessary. An additional advantage to this extradural temporal lobe re-

Figure 5. Lateral reflection of the trigeminal root exposes the sixth nerve as it crosses the carotid artery without cutting V_3 at the foramen ovale. This requires dissection of the lateral cavernous triangle. The dorsal meningeal branch of the meningohypophyseal trunk is seen in close relation to the nerve in Dorello's canal.

traction is the elimination of any possible need to interrupt the venous drainage of the lobe via ligation of the temporal tip bridging veins to the sphenoparietal sinus. Also, retraction pressure on the posterior inferior temporal lobe and the vein of Labbé is limited by the tethering of the dura at the posterior petrous ridge, preventing excessive elevation of that portion of the lobe. Second, extradural bone resection in the middle fossa involves exposure of the intrapetrous carotid artery at an early stage, identifying its location to maintain orientation and avoid inadvertent damage to the vessel with the drill. Exposure of the intrapetrous carotid artery also helps in locating the cochlea, as it is adjacent to the genu of the artery, under the geniculate ganglion. In our clinical experience, dural elevation from the middle fossa floor has not resulted in damage to the greater superficial petrosal nerve, facial nerve, or geniculate ganglion when done from the posterior to anterior direction, and when recognizing the dissection plane between the temporal dura and the connective tissue covering of the major petrosal groove, protecting the nerve. Third, the resection of the petrous apex occurs exclusively extradurally. This maintains a protective dural barrier throughout the procedure between the drill and the subarachnoid space, the fourth, sixth, and third cranial nerves, and intradural arterial and venous structures. Mobilization of the trigeminal complex allows total resection of the apex to proceed under direct vision. Elevation of the complex provides a significant increase in the operative corridor to the region in the cadaver studies. Division of the mandibular branch at the foramen ovale after opening the lateral cavernous sinus provided a maximum of exposure and could be done clinically, if necessary (Fig. 4).

Several anatomic observations made during the course of this study have clinical implications. Without liberation of the second and third divisions of the trigeminal nerve from their bony canals, the nerve could be reflected medially an average of 4.8 mm. This medial reflection was increased by 4 mm when the second and third divisions were mobilized. The length of nerve that was released from the bony canal equalled the distance to the first branch of each division. Measurements taken should provide some guideline for the clinical case, as it is not possible to visualize these nerves exiting the main trunk without opening the periosteal layer separating the bone from the infratemporal and pterygoid fossae.

The length of sixth nerve exposed in its course though Dorello's canal was quite variable in the specimens we examined, despite a fairly uniform location of Dorello's foramen in relation to both the porus trigeminus and porus acousticus. The nerve is covered by a sheath of dura propria upon entering Dorello's foramen. This dural tube was observed to continue for several millimeters, then blend with the epineurium after the nerve enters a space between dural layers filled by venous plexus. This peri-abducens venous plexus connects to the cavernous sinus venous plexus in the region of Gruber's ligament. In some specimens, difficulty was encountered in complete dissection of the abducens nerve from the posterior fossa to the cavernous sinus. This dissection was complicated by the nerve running for a variable distance between the dura propria and the periosteal dural layer along the petrous pyramid, in one case as far as 8 mm, before entering the space where the nerve is covered by venous plexus. In most specimens, however, the distance between the dural entrance of the sixth nerve and its entrance into this space filled with venous plexus was short, no more than 1 or 2 mm. Our observations were in accord with Umansky's definitive work on Dorello's canal (Figs. 3, 4).[3,21]

The length of intracavernous carotid artery that may be exposed through this strategy was fairly long, averaging around 12 mm. When added to the 10 mm of intrapetrous carotid (C_6) uncovered through the middle fossa bone dissection, this represents a long segment of carotid artery that is accessible.

The entrance of the carotid artery into the cavernous sinus at the foramen Lacerum was critically studied in the course of our dissections. The outer cavernous membrane is penetrated by the artery at the foramen Lacerum, and a thickening of the membrane forms a fibrous ring around the vessel. This ring was contiguous inferiorly with the periosteal lining of the cavernous sinus. Superior connections were to the connective tissue covering on the underside of the trigeminal complex. The fibrous ring was fairly wide, typically covering 2 to 3 mm of the vessel. The outer cavernous membrane between the trigeminal complex and the artery was sharply opened without the need to open this fibrous ring of tissue, allowing elevation of the trigeminal nerve. This fibrous ring is analogous to the fibrous band covering the artery's exit from the cavernous sinus piercing the carotico-oculomotor membrane.

Venous plexus from the cavernous sinus extended for a variable distance in many specimens over the intrapetrous carotid artery (C_6), in some specimens extending to the genu region, near the orifice of the carotid canal. This has technical implications for exposure of the intrapetrous carotid artery, in that venous bleeding from the cavernous sinus can occur during exposure of this segment of the artery in the middle fossa. Drilling technique should incorporate preservation of the thin membrane covering the venous plexus and the adventitial covering of the vessel.

CONCLUSIONS

Exposure of the posterior cavernous sinus can be accomplished through utilization of an extradural subtemporal approach that includes several key surgical maneuvers. Liberation of the peripheral branches of the second and third divisions of the trigeminal nerve extradurally via extensive unroofing of the foramen rotundum and foramen ovale results in allowing at least 5 mm of added anteromedial reflection of the trigeminal complex. Liberation of the trigeminal nerve at the porus trigeminus adds even more exposure through anterior and superior transposition. Mobilization of the trigeminal complex results in the ability to extradurally remove the petrous apex under direct vision, while minimizing temporal lobe retraction and preserving its venous drainage. Petrous pyramid removal via this method results in resection from the internal auditory canal anteriorly to the apex and inferiorly to the clivus. Opening of the foramen Lacerum through radical removal of the petrous apex and dividing the posterolateral fibrous ring surrounding the cavernous carotid artery result in full exposure of the artery from the intrapetrous genu to the meningohypophyseal trunk. The sixth cranial nerve is fully exposed from the posterior fossa through its entrance into Dorello's canal, to the point where it crosses the carotid artery. This surgical strategy benefits from the advantages of extradural bone removal and is easily combined with existing skull base approaches to affect improved exposure of the posterior cavernous sinus and petroclival region.

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