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Anterior Petrosectomy With Intertentorial Approach

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BACKGROUND AND OBJECTIVES: The extradural anterior petrosal approach (EAPA) can present a challenge because it deals with critical structures in a narrow, confined corridor. It is associated with several potential approach-related risks including temporal lobe and venous injuries. Tentorial peeling has the potential to largely eliminate these risks during the approach and may offer more options for tailoring the dural opening to the anatomic region that one wants to expose.
METHODS: Anatomic dissections of five adult injected non–formalin-fixed cadaveric heads were performed. Anterior petrosectomy with intertentorial approach (APIA) through a tentorial peeling was completed. Step-by-step documentation of the cadaveric dissections and diagrammatic representations are presented along with an illustrative case.
RESULTS: Tentorial peeling separates the tentorium into a temporal tentorial leaf and posterior fossa tentorial leaf, adding a fourth dural layer to the three classic ones described during a standard EAPA. This opens out the intertentorial space and offers more options for tailoring the dural incisions specific to the pathology being treated. This represents a unique possibility to address brainstem or skull base pathology along the mid- and upper clivus with the ability to keep the entire temporal lobe and basal temporal veins covered by the temporal tentorial leaf. The APIA was successfully used for the resection of a large clival chordoma in the illustrative case.
CONCLUSION: APIA is an interesting modification to the classic EAPA to reduce the approach-related morbidity. The risk reduction achieved is by eliminating the exposure of the temporal lobe while maintaining the excellent access to the petroclival region. It also provides several options to tailor the durotomies based on the localization of the lesion.

KEY WORDS: Anterior petrosectomy, Kawase, Petroclival region, Tentorial peeling, Meckel's cave

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The extradural anterior petrosal approach (EAPA) was largely popularized by Kawase for resection of spheno-petroclival meningiomas[1] and clipping of aneurysms of the lower basilar artery.[2] EAPA offers access to the ventral pons, middle and upper clivus, and petroclival region. It also exposes the trigeminal nerve from the brainstem to the foramen ovale.[3]

ABBREVIATIONS: AE, arcuate eminence; **APIA,** anterior petrosectomy with intertentorial approach; **EAPA,** extradural anterior petrosal approach; **IPS,** inferior petrosal sinus; **LPZ,** lateral pontine zone; **MC,** Meckel's cave; **MMA,** middle meningeal artery; **PD,** posterior fossa dura; **PFTL,** posterior fossa tentorial leaf; **pICA,** petrosal internal carotid artery; **SCA,** superior cerebellar artery; **SPS,** superior petrosal sinus; **STZ,** supratrigeminal zone; **TD,** temporal dura; **TTL,** temporal tentorial leaf; **V3,** mandibular branch of trigeminal nerve.

Despite its benefits, this approach can present a formidable challenge because it deals with critical structures in a narrow, confined corridor. It is associated with several approach-related risks including temporal lobe and venous injuries, hearing impairment, facial nerve palsy, cerebrospinal fluid (CSF) fistula, and seizures.[3] One of the main concerns is the potential for retraction injury of the temporal lobe or vein of Labbé.[4,5] Recently, Vidal et al[6] described a technique of tentorial peeling in two cases of combined transpetrosal approach and showed that this technique has the potential to reduce the complications associated with the traditional combined petrosectomy. We recently published a cadaveric study illustrating in detail the procedure of tentorial peeling during the combined petrosal approach and identified potential landmarks for a safe, reproducible, and efficient procedure.[7] This variant, although it allows access to the petroclival region while minimizing manipulation of the temporal lobe, could have the potential disadvantage of partially reducing the exposure and/or surgical freedom because of less mobilization of the supratentorial structures. In the case of a combined petrosectomy, this potential disadvantage is partly compensated by the extensive removal of the petrous bone and the presence of multiple surgical windows. When considering tentorial peeling in the context of EAPA, concerns arise regarding the potential for further reduced surgical exposure, given the already limited surgical corridor obtained by this approach. In this study, we present a clinical case and a detailed cadaveric dissection demonstrating the technique of the anterior petrosectomy with intertentorial approach (APIA). We highlight the variation of dural openings made possible by this approach that allows it to be specifically tailored to the pathology being treated.

METHODS

We performed the dissections at the "neurosurgical education and training laboratory" (NET-Lab) at Lausanne University Hospital using five non–formalin-fixed heads injected with colored latex. Heads were fixed with a 3-pin head holder. An extended EAPA was performed using high-speed drill (Midas Rex; Medtronic) and microsurgical instruments. A rod lens endoscope system was also used to visualize deeper anatomic structures (Karl Storz GmbH, KG).

After petrosectomy was performed, the anatomic plane between the two tentorial layers, posterior fossa tentorial leaf (PFTL) and a temporal tentorial leaf (TTL), was identified and developed. The surgical technique and salient step were described in detail.

Institutional Review Board/ethics committee approval was not required for this study. The patient consented to the procedure and to the publication of the patient's image.

Surgical Technique

Steps 1, 2, and 3: Patient Position and Skin Incision, Craniotomy and Peeling of the Middle Fossa, and Anterior Petrosectomy

These steps do not differ from the standard technique for EAPA widely described in the literature[1,2] (Figure 1A).

Step 3: Tentorial Peeling

After anterior petrosectomy is completed, tentorial peeling can be performed. The meningeal dura of the middle fossa covers the petrous bone and forms the outermost layer of Meckel's cave (MC). MC consists of its own separate sleeve of posterior fossa meningeal dura, which is formed by a posterior fossa evagination into the middle fossa[8] that circumferentially invests the trigeminal root. This dura is continued as the undersurface of the tentorium. Superiorly, a characteristic layer of fibrous tissue covers the roof of the cave between the middle fossa dura and the MC sleeve of dura. This tissue is continuous with the tentorium and the posterior petroclinoid ligament.[9] This anatomic arrangement forms a potential cleavage plane between the temporal tentorial leaf (TTL) and the PFTL at the level of the Gasserian ganglion, just posterior to V3. This plane lies immediately above the superior petrosal sinus (SPS) and is developed in between the two tentorial layers by staying parallel and just superior to the SPS in an oblique anterior-posterior direction. The SPS is left confined by the dura and attached to the PFTL. The peeling is extended as far posterior as possible to improve the distribution of the forces applied onto the TTL and to increase the intertentorial operative corridor (Figures 1B and 2). The peeling can be extended all the way medially to the free edge of the tentorium where the two layers are fused. The trochlear nerve is safe during peeling because it courses in the subtentorial groove under the inferior surface of the PFTL and is not exposed by intertentorial peeling. It stays in this groove until it pierces the dura at the level of the petrous apex, entering the lateral cavernous sinus near the posterolateral margin of the oculomotor triangle.[10]

Step 4: Tailored Dural Opening

First Window (APIA 1)

The first surgical window (Figures 3A-3D and 4A and 4B) is created by opening the dura mater of the posterior fossa (Figures 1B and 4B). The dura is incised with a linear cut that extends from the SPS to the IPS, contained within the drilling area. In addition to opening the posterior fossa, it provides an early decompression by opening into the cisterns and releasing CSF. This dural incision is then extended in a T fashion through a cut parallel to the lower border of the SPS. This small window exposes the middle clivus, upper cerebellopontine angle cistern, and the lateral pontine zone or the peritrigeminal zone[11] (Figures 3A and 4C). The middle clivus, basilar artery, and CN VI (ascending the clivus to enter Dorello's canal) form the ventral and medial limits of the exposure, whereas the internal acoustic canal, CN VII, and CNVIII are located just beyond the dorsal and inferior limits. Cranially, exposure is bound by the trigeminal nerve, and Dandy's vein (superior petrosal vein) will commonly drain into the SPS at the dorsal and medial edge of the exposure. Unlike the standard technique, even for the narrow window given by this durotomy, the tentorial peeling allows for greater epidural retraction of the temporal lobe, providing more maneuvering space for surgical instruments and minimizing the risk of direct temporal lobe contusion.

Second Window (APIA 2)

To advance to the second surgical window, the dural opening of the posterior fossa is extended across the SPS to the PFTL (Figures 1B and 4B). The SPS, confined within the PFTL, is ligated and transected as anteriorly as possible, just posterior to V3. Once the posterior fossa incision is taken across the SPS, it is continued medially across the PFTL, just short of the tentorial free edge. Next, the incision across the PFTL can be extended anteriorly and posteriorly parallel to the free edge without crossing over into the TTL. The posterior limit of the incision can then be taken back across the SPS, and a rhomboid of posterior fossa and PFTL dura separated by ligated SPS can be removed to maximize the exposure of the second window. The superior petrosal vein must be sacrificed to make this last cut.

Compared with the first window, this second window expands exposure cranially to include the supratrigeminal zone[11] (Figures 3B and 4D). The posterior parallel cut, once the superior petrosal vein is cut, exposes the posterolateral surface of the pons, dorsal to the emergence of the trigeminal nerve, completing 360-degree exposure of the root entry point of the trigeminal nerve. The middle clivus (medial to MC) and the insertion of the tentorium's free edge at the petrous apex form the ventral limits, whereas the middle cerebellar peduncle is the dorsal anatomic limit. MC and the latero-mesencephalic segment of the superior cerebellar artery at the level of the lower half of the ambient cistern form the cranial limits, and the free edge of the tentorium is the medial limit.

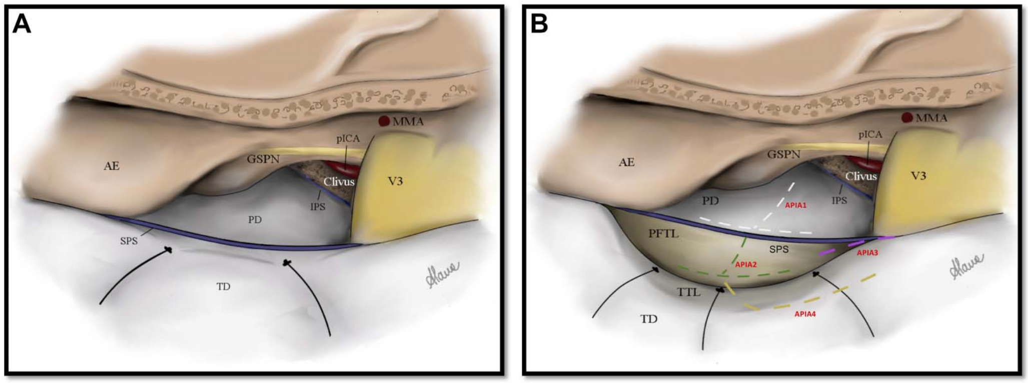

FIGURE 1. *Schematic drawing representing the surgeon's view after completing anterior petrosectomy* **A**, *with and* **B**, *without tentorium peeling.* **B**, *The drawing highlights the variation of dural opening (APIA 1-4) made possible by this approach that allows it to be specifically tailored to the patient and pathology being treated. AE, Arcuate eminence; APIA, anterior petrosectomy with intertentorial approach; GSPN, greater superficial petrosal nerve; IPS, inferior petrosal sinus; MMA, middle meningeal artery; PD, posterior fossa dura; PFTL, posterior fossa tentorial leaf; pICA, petrosal internal carotid artery; SPS, superior petrosal sinus; TD, temporal dura; TTL, temporal tentorial leaf; V3, mandibular branch of trigeminal nerve.*

Third Window (APIA 3)

The cut of the PFTL can further be extended at the level of MC to open the porus trigeminus (Figures 1B and 4B). This cut enlarges the previous window and allows greater exposure of the upper portion of the middle clivus, especially at the level of the petrosal apex and the confluence of the IPS and SPS. This cut exposes MC (Figure 5A) and facilitates transposition of the trigeminal nerve cranially or caudally so that the prepontine cistern can be better visualized (Figure 5B). The cranial limit of the third window is marked by the insertion of the free edge of the tentorium to the petrosal apex at the level of the confluence of the sinuses (Figures 3C and 5A).

Fourth Window (APIA 4)

The surgical window is further widened by sectioning the free edge of the tentorium. This cut is made after verifying the transition point of the trochlear nerve from its cisternal segment to its tentorial segment. In general, the trochlear nerve first becomes subtentorial (enters the tentorial groove and abuts the undersurface of the PFTL) at the level of the posterior border of the cerebral peduncle, generally 2 cm posterior to the external auditory meatus.[10,12] A small incision of the TTL, very close to the free edge, can be made to visualize the tentorial incisura and the trochlear nerve in the cistern. Thus, the free edge of the tentorium can be

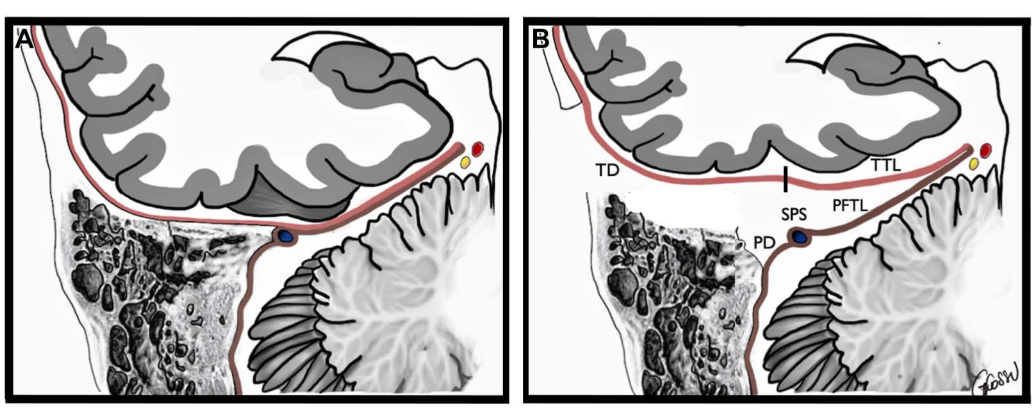

FIGURE 2. *Schematic drawing illustrating tentorial peeling and the most important anatomic landmarks. Coronal view* **A**, *before and* **B**, *after anterior petrosectomy and peeling have been performed. The plane between the TTL (pink line) and the PFTL (brown line) is developed just superior to the SPS.* **A** *and* **B**, *were used with permission from Giammattei, L., Starnoni, D., Ronconi, D. et al, "Tentorial peeling during combined petrosal approach: a cadaveric dissection." Acta Neurochirurgica. 164, 2833-2839, 2022, Springer Nature. DOI: https://doi.org/10.1007/s00701-022-05370-z. PFTL, posterior fossa tentorial leaf; PD, presigmoid dura, SPS, superior petrosal sinus; TD, temporal dura; TTL, temporal tentorial leaf.*

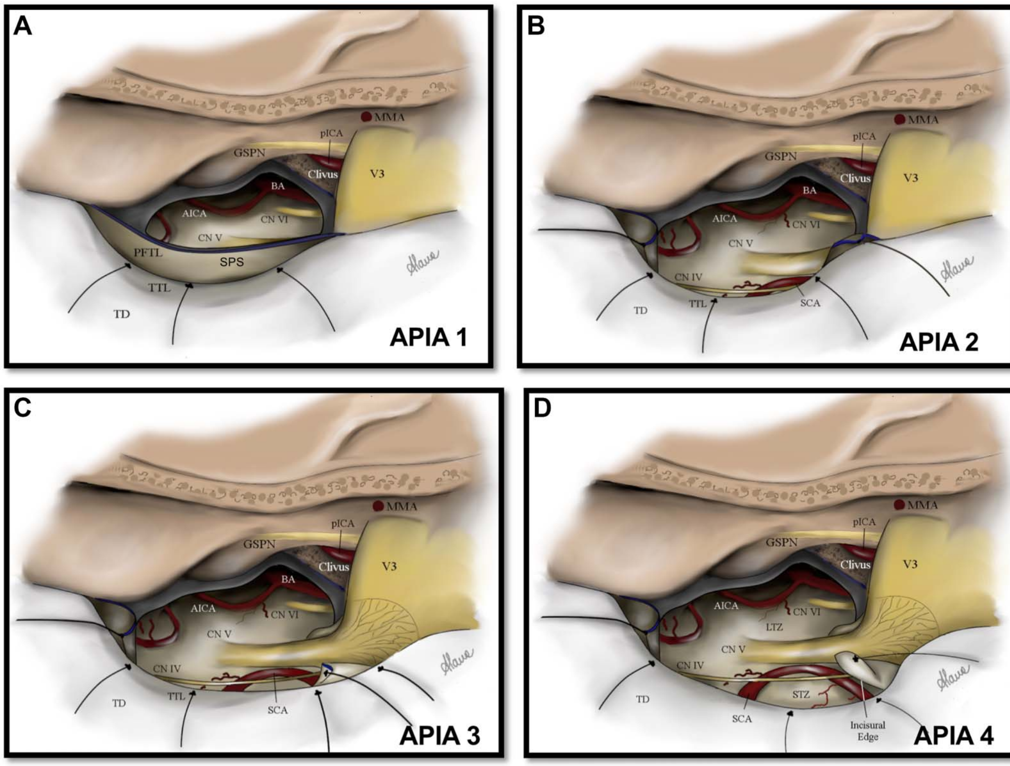

FIGURE 3. **A**, *Schematic drawing representing the surgeon's view obtained after APIA 1 dural cut.* **B**, *View obtained with APIA 1 + 2 dural cuts.* **C**, *View obtained with APIA 1 + 2+3 dural cuts where Meckel's Cave has been opened.* **D**, *View obtained with APIA 1 + 2+3 + 4 dural cuts. AE, arcuate eminence; APIA, anterior petrosectomy with intertentorial approach; GSPN, greater superficial petrosal nerve; IPS, inferior petrosal sinus; MMA, middle meningeal artery; PD, posterior fossa dura; PFTL, posterior fossa tentorial leaf; pICA, petrosal internal carotid artery; SPS, superior petrosal sinus; TD, temporal dura; TTL, temporal tentorial leaf; V3, mandibular branch of trigeminal nerve.*

cut immediately posterior to it, connecting incisions in the PFTL and TTL. This cut is subsequently extended anteriorly and posteriorly along the most medial border of the TTL, parallel to the free edge (1B, 3B, 4C). Anteriorly, once the insertion point of the tentorium to the petrosal apex is visualized, the dural cut is stopped a few millimeters short of this point, curved anteromedially, and continued across the basal temporal dura parallel to the anterior petroclinoidal fold in the direction of the anterior clinoid.

The surgical window provided by this cut is centered on the exit of the oculomotor nerve from the cerebral peduncle. It exposes the lateral surface of the midbrain including two safe brainstem entry zones: the anterior mesencephalic zone and the lateral mesencephalic sulcus,[11] as well as the upper clivus, posterior clinoid, and dorsum sella along the skull base (Figures 3D and 5C and 5D). The trochlear nerve and the anterior end of the tentorial attachment to the petrous ridge form the caudal limits, whereas the parahippocampal gyrus is located along the cranial edge. The dorsum sellae forms the ventral limit, whereas the lateral surface of the midbrain and the ambient cistern comprise the dorsal boundary.

Clinical Case

A 32-year-old male was referred to our neurosurgical clinic with a diagnosis of a large petroclival intradural lesion, extending inferiorly to the level of the prepontine cistern and the internal acoustic meatus and superiorly to the level of the interpeduncular cistern and the upper margin of the dorsum sella with significant compression of the pons (Video). The radiological features of the lesion were compatible with a chordoma (Figure 6A and 6B). Surgery was performed using an APIA 1–3, including opening of the porus trigeminus without the section of the tentorial incisure (see Video). This approach allowed a large exposure of the upper and middle clivus from the internal acoustic canal to the dorsum sellae without exposing the supratentorial brain. Postoperatively, the patient developed transient, mild CN VI palsy and a facial hypoesthesia because of cranial nerve manipulation, both recovered within the first 2 weeks after surgery. Audiometry showed normal hearing function. MRI showed a near total resection with a small residual tumor at the level of the uppermost margin of the dorsum sellae dura (Figure 6C and 6D). MRI showed no signal changes in the temporal lobe in T2 and flair sequences.

DISCUSSION

EAPA is a challenging approach that deals with critical structures in a narrow operative corridor. Concerns about the

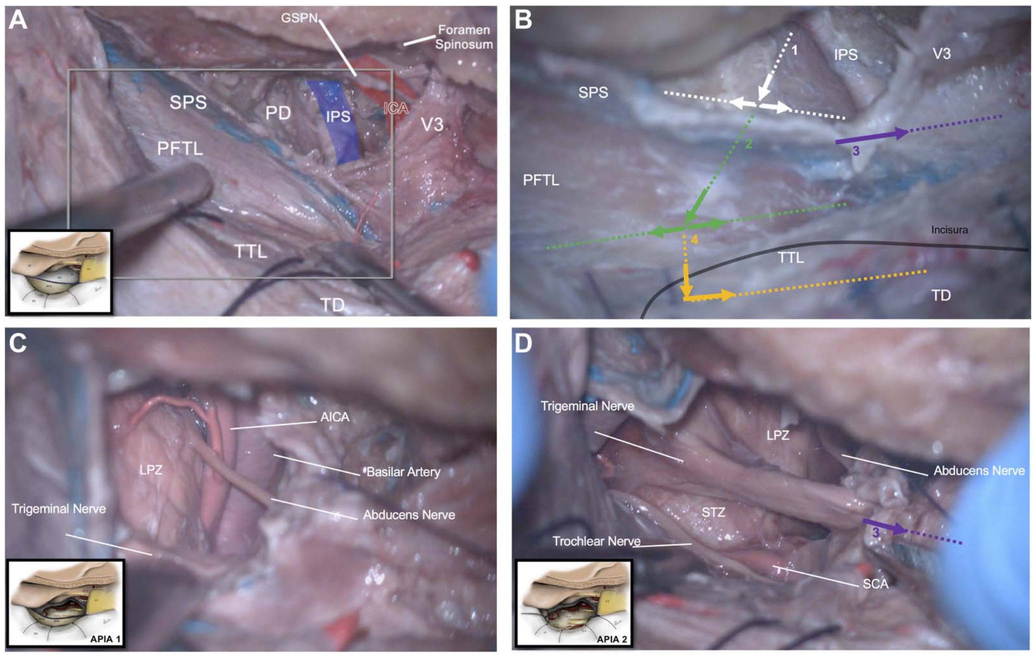

FIGURE 4. **A**, *Surgeon's view after completion of an anterior petrosectomy and tentorial peeling.* **B**, *Magnified view of Kawase's triangle with tentorial peeling, showing the APIA dural cuts 1–4.* **C**, *View obtained after APIA 1 dural cut.* **D**, *View obtained with APIA 1 + 2 dural cuts. AICA, anterior inferior cerebellar artery; APIA, anterior petrosectomy with intertentorial approach; GSPN, greater superficial petrosal nerve; ICA, internal carotid artery; IPS, inferior petrosal sinus; LPZ, lateral pontine zone; PD, posterior fossa dura, PFTL, posterior fossa tentorial leaf; SCA, superior cerebellar artery; SPS, superior petrosal sinus; STZ, supratrigeminal zone; TD, temporal dura; TTL, temporal tentorial leaf; V3, mandibular branch of trigeminal nerve.*

approach-related morbidity have been raised, especially the risk of iatrogenic injury to the temporal lobe and vein of Labbé.[3-5,13,14] Giammattei et al[3] reported that 6.1% of patients show postoperative temporal lobe abnormalities (two contusions and one case of temporal lobe swelling). To mitigate this risk, Vidal et al[6] first introduced the concept of peeling the tentorium for access. The goal of this technique is to reduce the harmful effects of brain manipulation by leaving the brain covered by dura as much as possible as an extra layer of protection. We also recently published a cadaveric study illustrating in detail the procedure in a stepwise manner following the combined petrosal approach.[7]

Compared with the standard EAPA, APIA offers more options for tailoring the cut of the tentorium and posterior fossa dura to the anatomic region that one wants to expose. As shown in our cadaveric dissection, tentorial peeling adds a new dural layer to the three classic ones described during a standard EAPA. The cut of the posterior fossa dura combined with the cut of the PFTL, without sectioning the free edge, allows exposure of the entire subtentorial region, including the entire lateral surface of the pons and the lower half of the ambient cistern. All these can be achieved without any exposure of the temporal lobe or any of the intradural supratentorial space. This exposure can be further expanded with the opening of the MC.

These different surgical windows also allow access to specific entry zones of the anterolateral brainstem with no or minimal exposure of supratentorial structures. In this way, intraparenchymal lesions located at the level of the brain stem, such as cavernomas or gliomas, can be approached by the most direct surgical window. The same principle can be applied to aneurysms of the posterior circulation located along the anterolateral surface of the brainstem, choosing the surgical window that best exposes the lesion and provides proximal control.

In the case of petroclival lesions with extension to the upper clivus and dorsum sellae or with extension to the upper part of the ambiens and interpeduncular cistern, the free edge of the tentorium can be cut to reach the TTL (APIA 4). This configuration allows an exposure that resembles the classic EAPA, but the exposure of the supratentorial brain tissue is limited to only the most medial surface of the parahippocampal gyrus, while keeping the fusiform and lateral neocortical gyri completely covered by dura, thereby reducing the morbidity of classical transpetrosal approaches.[3,15] Because the basal temporal lobe is held in place by the TTL, the resultant brain shift after CSF drainage is minimized, a fact that could influence intraoperative navigation when needed.

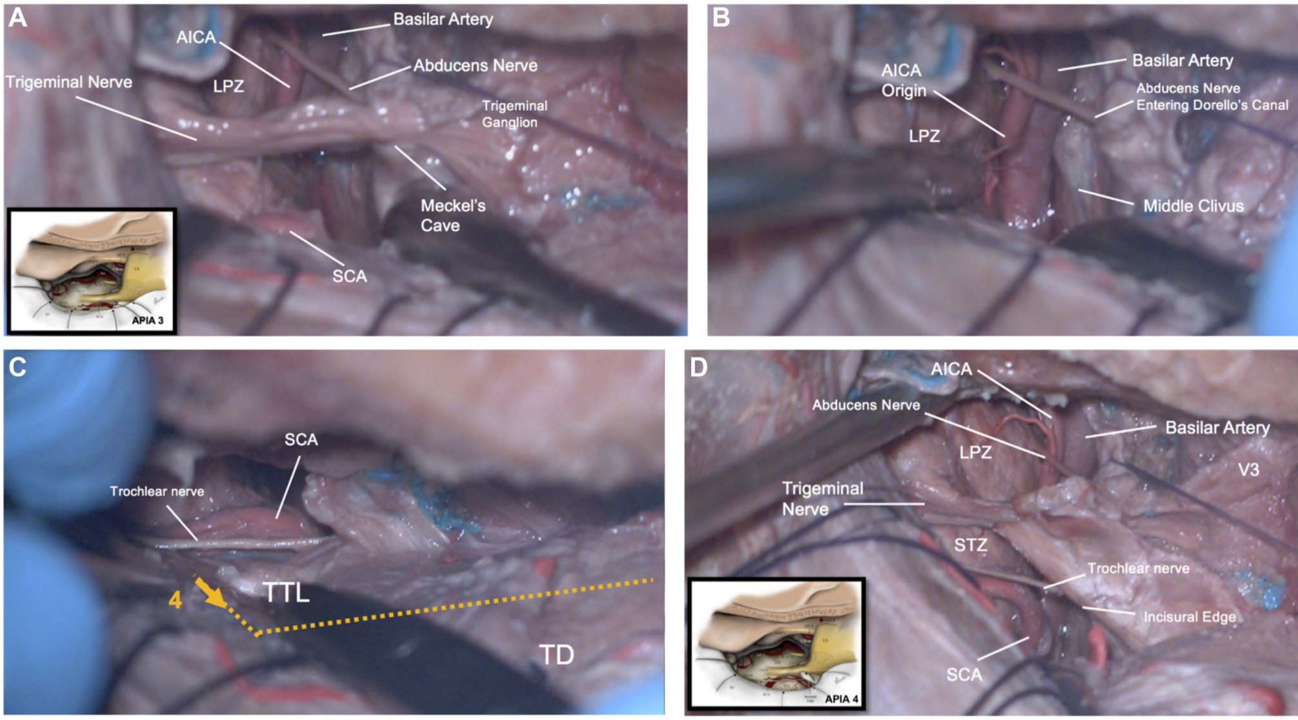

FIGURE 5. **A**, *Meckel's cave has been opened after the APIA 3 cut, allowing transposition of the fifth cranial nerve.* **B**, *Transposing the fifth nerve superiorly improves exposure of the basilar trunk and middle clivus.* **C**, *APIA 4 cut is made by crossing across the PFTL and incisura, into the TTL, and then advancing anteriorly into the temporal dura posterior and superior to the cavernous sinus.* **D**, *Operative view obtained after all four APIA cuts have been completed. The temporal lobe is completely covered with dura. AICA, anterior inferior cerebellar artery; APIA, anterior petrosectomy with intertentorial approach; LPZ, lateral pontine zone; SCA, superior cerebellar artery; STZ, supratrigeminal zone; TD, temporal dura; TTL, temporal tentorial leaf; V3, mandibular branch of trigeminal nerve.*

Understanding the meningeal architecture of the cavernous sinus, MC, and tentorium is essential for a safe implementation of this technique. Inadequate understanding of this anatomy can easily lead to a violation of the numerous neurovascular structures involved in these regions. The architectural relationship among the dura-arachnoid of MC, trigeminal ganglion, and the trigeminal nerve roots is complex, unclear, and controversial in the literature.[9,16-20]

In their study, Janjua et al[9] showed that at MC, a distinct intermediate fibrous layer reinforces the meningeal dura overlying the MC in the middle cranial fossa. This characteristic layer of fibrous tissue, covering the superior surface of the cave, laid underneath the middle fossa dura and was continuous with the tentorium and the posterior petroclinoid ligament. This fibrous layer, just above MC, can be exploited to find the natural plane between the two layers of the tentorium without risking transgression into the natural plane between the perineum of V3 and the PFTL. Disruption of this natural plane can cause inadvertent entry into the SPS, which remains totally confined within the dural envelope of the PFTL.

On the other hand, Youssef et al[21] failed to find evidence of this structure, and Sabanci et al[17] further argued that the level of cessation of this dural layer along the Gasserian ganglion may vary between individuals. In cases where the dissection plane is not clear or evident at the level of MC, the peeling can start in the posterior part of the tentorium where it is thicker, just a few millimeters above the SPS. Moreover, tentorial peeling may disrupt normal venous flow that may occur through alternate tentorial drainage routes (spenobasal or sphenopetrosal), and therefore, an accurate preoperative analysis of the venous anatomy is imperative.[13,14]

The surgeon must also meticulously localize the position of the fourth cranial nerve, which, in the case of large tumors of the skull base, could be moved superiorly. Another important point to consider is the case in which there is a significant calcification of the tentorium, especially in the case of a meningioma with a large tentorial implantation, which would make it difficult or impossible to identify the two tentorial layers.

CONCLUSION

APIA is an important technical addition to the classical EAPA, designed with a view to eliminate iatrogenic injury to temporal

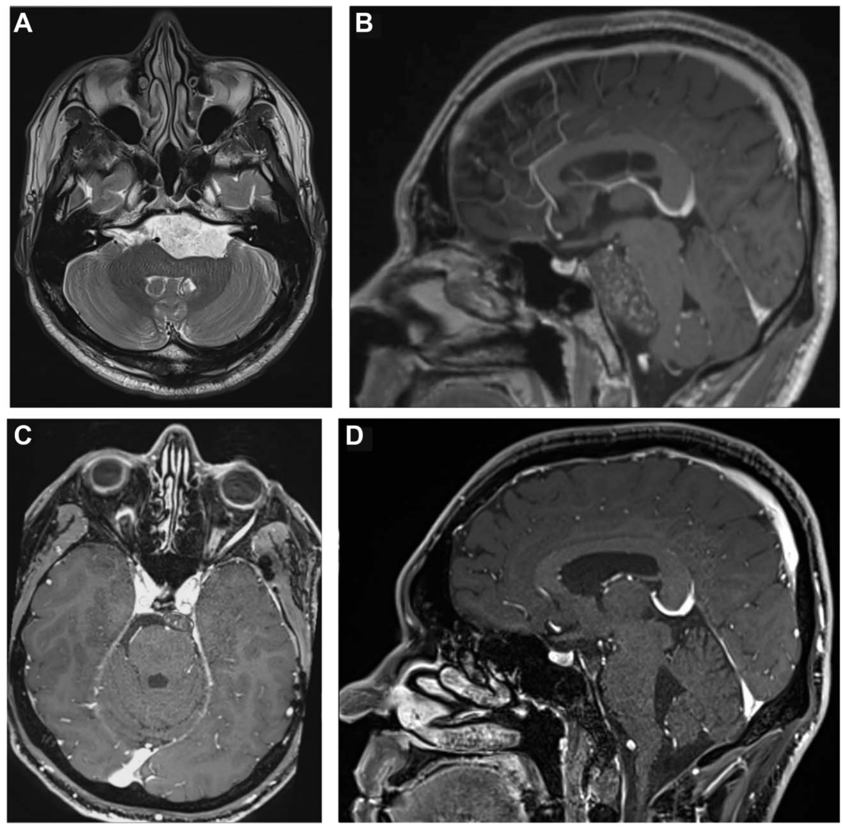

FIGURE 6. **A**, *Preoperative axial T2-weighted and* **B**, *sagittal gadolinium–enhanced magnetic resonance imaging showing a large petroclival intradural lesion, extending inferiorly to the level of the prepontine cistern and the internal acoustic meatus and superiorly to the level of the interpeduncular cistern and the upper margin of the dorsum sella with significant compression of the pons.* **C**, *Postoperative axial and* **D**, *sagittal gadolinium–enhanced magnetic resonance imaging showing a near total resection with a small residual tumor at the level of the uppermost margin of the dorsum sellae dura.*

lobe and venous drainage. It has the potential to reduce the approach-related morbidity of this surgery while being able to provide adequate access to the petroclival region.

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VIDEO. This video shows the different steps of the anterior petrosal intertentorial approach (APIA) for resection of a petroclival chordoma. Surgery was performed using an APIA 1–3, including opening of the porus trigeminus without the section of the tentorial incisura. This approach allowed a large exposure of the upper and middle clivus from the internal acoustic canal to the dorsum sellae without exposing the supratentorial brain.