

Operative surgical nuances of modified extradural temporopolar approach with mini-peeling of dura propria based on cadaveric anatomical study of lateral cavernous structures

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Abstract

Background: Extradural temporopolar approach (ETA) has been modified as less invasive manner and named as trans-superior orbital fissure (SOF) approach with mini-peeling technique. The present study discusses the operative nuances of this modified technique on the basis of cadaveric study of lateral cavernous structures.

Methods: In five consecutive cadaveric specimens, we performed an extradural anterior clinoidectomy with mini-peeling of the dura propria to expose the anterior clinoid process entirely. We also investigated the histological characteristics of the lateral cavernous sinus (CS) between the dura propria and periosteal dura at the SOF, foramen rotundum (FR), and foramen ovale (FO) levels, and of each trigeminal nerve division.

Results: Coronal histological examination of the lateral wall of the CS showed invagination of the dura propria and periosteal dura into the SOF. In contrast, no such invagination was observed at the levels of the FR and FO. This finding supports the technical rationale of the only skeletonization of the SOF for peeling of the dura propria but not FR. In addition, our modified ETA method needs only minimal dural incision between the SOF and FR where no cranial nerves are present.

Conclusion: Our technical modification of ETA may be recommended for surgical treatment of paraclinoid lesions to reduce the risk of intraoperative neurovascular injury.

Key Words: Anterior clinoidectomy, cavernous sinus, extradural temporopolar approach, paraclinoid lesion, skull base surgery

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INTRODUCTION

Extradural temporopolar approach (ETA), which requires peeling of dura propria of the temporal lobe dura mater from the lateral wall of the cavernous sinus (CS) and extradural anterior clinoidectomy (EAC), is a variant of the Dolenc's technique but focuses more on temporal lobe retraction over the dura mater and provides a surgical corridor to the central skull base via the opened CS.^[3,4] However, the original ETA requires the skeletonization of foramen rotundum (FR) as well

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as superior orbital fissure (SOF) and the dura propria incision at SOF to peel the dura propria from the lateral wall of the CS.^[3,4] The disadvantage of ETA is the risk of injuring the neurovascular structures passing through SOF during dissection.^[13]

In contrast, ETA was recently modified to provide less invasive but adequate exposure of the anterior clinoid process (ACP)^[1,9] and named as trans-SOF approach with mini-peeling technique.^[6] The modified ETA including mini-peeling technique has been applied to treat various tumors and aneurysms in the parasellar to interpeduncular region.^[7,8,11] The present study investigated the usefulness of this modified approach and operative techniques with special emphasis on the cadaveric anatomical findings of lateral cavernous structures.

MATERIALS AND METHODS

Surgical procedure of extradural anterior clinoidectomy with mini-peeling

EAC with mini-peeling of dura propria was performed as follows. A semi-coronal skin incision is performed followed by inter-fascial dissection. A standard frontotemporal craniotomy is performed up to the supra-orbital notch, and the temporal squama is rongeuired out until the floor of the middle cranial fossa is exposed. The lesser wing of the sphenoid bone is flattened until the meningo-orbital band (MOB) is fully exposed. The middle fossa dura is dissected until the SOF, and the FR are exposed [Figure 1a]. The roof of the SOF is skeletonized and opened to expose the junction between the dura propria of the temporal lobe

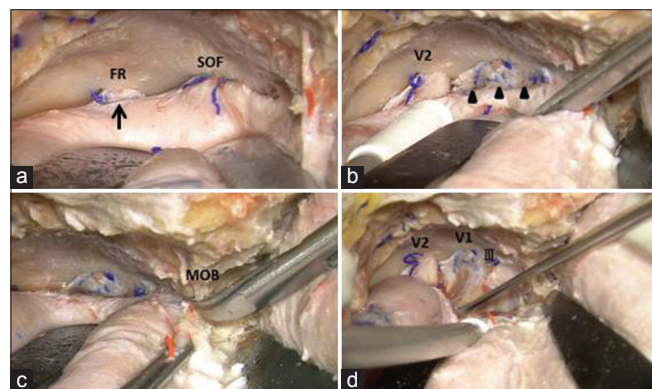


Figure 1: After standard frontotemporal craniotomy, the middle fossa dura is dissected until the foramen rotundum, and superior orbital fissure are exposed (a). Skeletonization of the foramen rotundum is not needed because this junction is naturally exposed at the foramen rotundum (a, arrow). The roof of the superior orbital fissure is skeletonized and opened to expose the junction between the dura propria of the temporal lobe and the periosteal dura (b, arrowheads). The bone around the meningo-orbital band is drilled and incised to a length of 4 mm (c). Peeling of the dura propria is started from the foramen rotundum to the lateral wall of the superior orbital fissure (d). V2: Second division of the trigeminal nerve

and the periosteal dura [Figure 1b]. Skeletonization of FR is not needed because this junction is naturally exposed at FR [Figure 1a, arrow]. The bone around MOB is drilled. The orbital apex is partially opened around the base of the ACP at the medial extent of SOF. The tip of the microscissors should be pointed at the dura propria junction at SOF and MOB is incised to a length of about 4 mm [Figure 1c]. The dura propria between SOF and FR is incised. Peeling of the dura propria is started from FR to the lateral wall of SOF [Figure 1d] and continued until the ACP is completely exposed epidurally [Figure 2a]. Care should be taken to maintain the sphenoparietal sinus (SPS) on the dura propria side and to stop the peeling at the point where SPS drains into CS to prevent postoperative problems with venous congestion. Before drilling of ACP, dissection of the inferolateral part of the ACP, where the fissural part of the oculomotor nerve passes, is needed to avoid oculomotor nerve injury. Drilling of ACP with a high-speed drill using cold saline irrigation is started from the lateral part of ACP [Figure 2b], and the optic canal is then opened partially in the medial part of ACP using a micro-punch to avoid heat injury, with thinning of the bone along the medial and anterior surfaces of the clinoid process. The core of ACP is hollowed like an egg shell with a small 2-mm diamond burr and dissected from the carotid-oculomotor membrane. After removal of ACP, the clinoid segment (C3) of the internal carotid artery (ICA) can be seen [Figure 2c]. The partially opened optic canal can be enlarged using a micro-punch, and the remainder of the optic strut between the opened clinoid space and optic canal can be removed with either a small diamond drill or micro-punch. Following these simple, safe, and adequate procedures, extradural exposure of ACP is fully accomplished without the risk of cranial nerve injury.

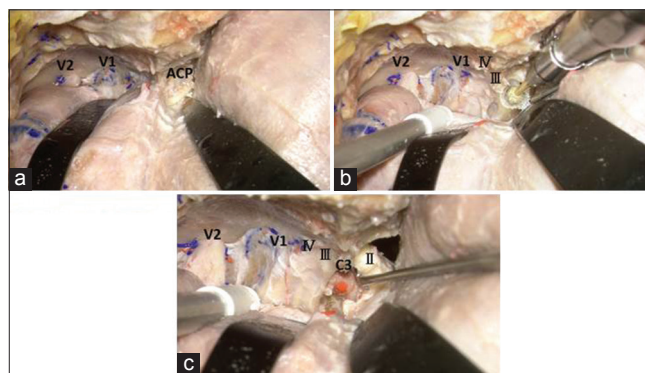


Figure 2: The dura propria is peeled from the lateral wall of the superior orbital fissure until the anterior clinoid process is exposed epidurally (a). Drilling of the anterior clinoid process with a high-speed drill using saline irrigation is started from the lateral part of the anterior clinoid process (b). After removal of the anterior clinoid process, the clinoid segment (C3) of the internal carotid artery can be seen (c). II: Optic nerve, III: Oculomotor nerve, IV: Trochlear nerve, V1: First division of the trigeminal nerve, V2: Second division of the trigeminal nerve

Cadaveric study

Specimen preparation

All cadavers were donated with written permission for anatomical study on the normal structures of the human body. The cadavers were initially fixed with a solution containing 3.3% formalin and 66% ethanol by perfusion through a femoral artery and underwent immersion fixation in the same fixative for several weeks. Cranial blood vessels were injected with colored silicone.

Cadaveric dissection

Two specimens were used for cadaveric dissection of ETA using a surgical microscope (Carl Zeiss Contravas; Zeiss, Inc., Montpelier, MD, USA) under $\times 4$ to $\times 40$ magnifications. All procedures were consistent with the clinical setting, and all observations were made from the surgeon's angle of view. All photographs illustrating anatomical structures are from the left side of the patient. Each head was fixed in a Mayfield head clamp and positioned for a standard approach. The bone dissections were performed with a Midas Rex drill (Midas Rex Institute, Fort Worth, TX, USA). The surgical technique of EAC with mini-peeling of the dura propria was performed and the anatomic features of the paraclinoid space were examined in stepwise dissections [Figures 1 and 2].

Histological investigation

Five specimens were used for histological examination of the spatial relationship of the dural layers of the lateral wall of CS. The CS region including the SOF, FR, and foramen ovale (FO) was removed *en bloc* [Figure 3a] and immersed for defatting in a solution containing 33% chloroform and 67% methanol, and then in 99% ethanol. The blocks were decalcified in a 9.5% EDTA solution for up to 3 months, dehydrated, and embedded in paraffin [Figure 3b]. Coronal sections of 6- μ m thickness were obtained using a sliding microtome, and then stained with Masson trichrome with necessary modifications to optimize the results for over-fixed material.

RESULTS

Coronal histological sections of the lateral wall of CS showed that the two dural layers (dura propria and periosteal dura) were separate at the levels of SOF [Figure 3c], FR [Figure 3d], and FO [Figure 3e]. The junction between the dura propria, which transits to the cranial nerve perineurium, and the periosteal dura was invaginated under SOF by about 1 mm [Figure 3c] at the level of the SOF. In contrast, no such invagination was observed at the levels of the FR [Figure 3d] and FO [Figure 3e]. This histological study confirms the necessity of skeletonization of the SOF, but not FR. Also, once the junction in SOF is surgically exposed, the

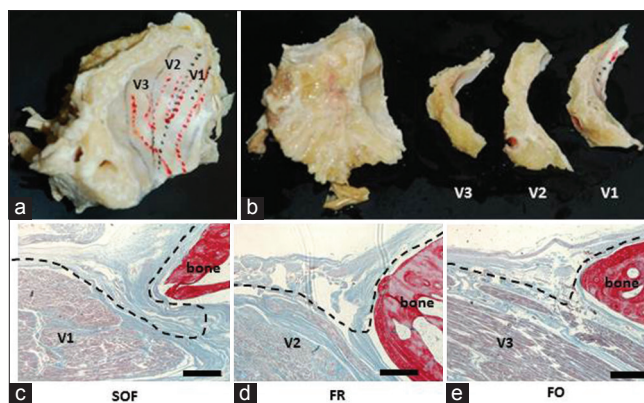


Figure 3: Cavernous sinus region including the superior orbital fissure, foramen rotundum, and foramen ovale was removed en bloc (a), and embedded in paraffin (b). The dura propria, which consists of the cranial nerve perineurium, is invaginated at the level of the superior orbital fissure (c). In contrast, no such invagination was observed at the levels of the foramen rotundum (d) and foramen ovale (e). Black broken line shows the layer of the peeling. V1: First division of the trigeminal nerve, V2: Second division of the trigeminal nerve, V3: Third division of the trigeminal nerve. Scale bars = 500 μ m

dura propria incision can be limited to the dura propria between SOF and FR where no neurovascular structures exist.

DISCUSSION

Removal of ACP^[2,10] is one of the essential skull base techniques to treat paraclinoid lesions. Anterior clinoidectomy can be performed through the intradural approach or extradural approach.^[3-5,12] EAC through the trans-CS approach requires peeling of the lateral wall of the CS to entirely expose ACP for drilling.^[3,4] This extradural procedure has been refined by minimizing the area of peeling in the lateral wall of the CS including the anterior part of the CS.^[1,6,9] Compared to previous extradural surgical procedures, this modified EAC is very advantageous, which can provide an extensive exposure of the ACP with simple and safe handling. In these extradural procedures, SOF was uncovered, and the peeling of the dura propria was started from FR to the medial side of the SOF. In the present study, examination of coronal histological sections of the lateral wall of the CS showed that the junction between the two dural layers, dura propria and periosteal dura, were invaginated under the level of the SOF. In contrast, no such invagination of the periosteal dura was present at the levels of the FR and FO. Therefore, skeletonization of FR is not needed. On the other hand, SOF skeletonization is mandatory just before peeling of the dura propria at SOF level to confirm the precise layers to dissect. In addition, the peeling of the dura propria should be started from the FR to easily confirm the inter-reticular layer.

Our schematic illustration of the dura propria of the temporal lobe and other anatomical structures is based on our cadaveric study and surgical experience [Figure 4]. The junction between the dura propria and the periosteal dura was invaginated by about 1 mm at the SOF. The original Dolenc's procedure requires dural incision at the SOF [Figure 4a, blue broken line] and carries the risk of injury to the cranial nerves. Our method requires skeletonization of SOF to expose this junction and needs only minimal dural incision between SOF and FR where no cranial nerves are present [Figure 4b, blue broken line]. The dura propria mini-peeling from SOF to the anterior part of CS can be performed from these junctions until the ACP is totally exposed epidurally [Figure 4c]. Figure 5 also shows the operative procedures of EAC via the trans-SOF approach followed by modified ETA. Figure 5a shows the tip of the micro-scissors pointing to the exposed dura propria junction at the skeletonized SOF during cutting of the MOB. The dura propria incision can be limited to the dura propria between SOF and FR where no neurovascular structures exist [Figure 5a, black broken line]. After dura propria incision between SOF and FR, the dura propria should be carefully peeled from the SOF to preserve the SPS on the peeled dura propria, which appears whitish [Figure 5b] until the ACP is entirely exposed. Before drilling, the inferolateral part of the ACP should be dissected because the extradural part of the oculomotor nerve passes there [Figure 5b, arrow]. After removal of the ACP, the optic canal should be opened using a micro-punch. The optic strut between the C3 of the ICA and optic sheath is removed if necessary.

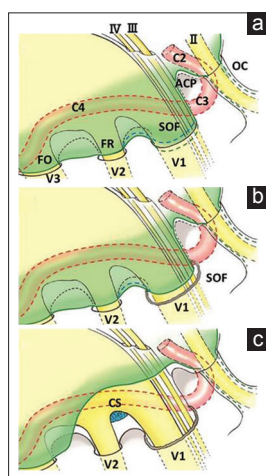


Figure 4: Schematic illustration of the dura propria of the temporal lobe and other anatomical structures. The junction between the dura propria and the periosteal dura was invaginated at the superior orbital fissure (a, blue broken line). Our method needs only minimal dural incision between the superior orbital fissure and foramen rotundum where no cranial nerves are present (b, blue broken line). The dura propria peeling can be performed until the anterior clinoid process is totally exposed epidurally (c). OC: Optic canal, II: Optic nerve, III: Oculomotor nerve, IV: Trochlear nerve

This approach allows extradural early localization and exposure of the optic nerve. The exposed optic nerve can be followed from the optic canal proximally toward any tumor in an intradural location, which allows the surgeon to recognize the exact location of the optic nerve early in the surgical procedure. Thereafter, CS is exposed in Dolenc's anteromedial triangle and Mullan's anterolateral triangle [Figure 5c and d]. After the completion of the extradural procedures, incisions of the falciform ligament, distal dural ring, and tentorium are followed and finally the temporal lobe is retracted over the dura mater to accomplish the modified ETA [Figure 5c and d]. The modified ETA with mini-peeling of the dura propria can provide a fully operative field for management of the paraclinoid aneurysms and/or parasellar tumor removal.

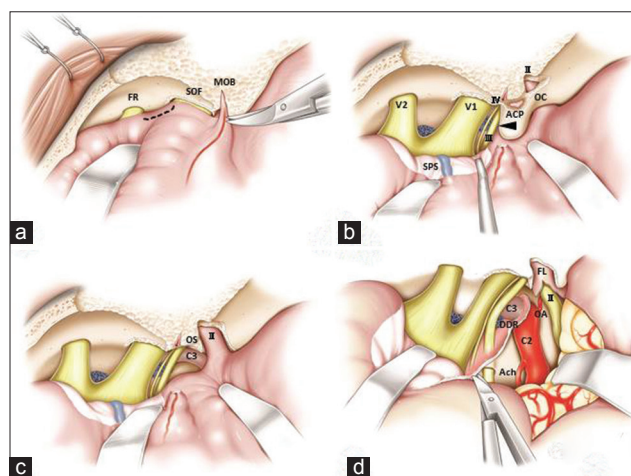


Figure 5: Schematic illustration of the operative techniques of extradural anterior clinoidectomy with mini-peeling of the dura propria followed by extradural temporopolar approach. During cutting of the meningo-orbital band, the tip of the micro-scissors is pointed to the exposed dura propria junction at the skeletonized superior orbital fissure (a). The dura propria incision can be limited to the dura propria between superior orbital fissure and foramen rotundum where no neurovascular structures exist (a, black broken line). The dura propria should be carefully peeled from the superior orbital fissure to preserve the sphenoparietal sinus on the peeled dura propria, which appears whitish until the anterior clinoid process is entirely exposed (b). Before drilling, the inferolateral part of the anterior clinoid process should be dissected because the extradural part of the oculomotor nerve passes there (b, arrow). After removal of the anterior clinoid process, the optic canal should be opened using a micro-punch. The clinoid segment (C3) of the internal carotid artery can be seen and the optic strut between the C3 and optic sheath is removed if necessary (c). Final operative view of the extradural temporopolar approach (d) suggests that incision of the falciform ligament and distal dural ring facilitates mobilization of the optic nerve and internal carotid artery, which contributes to a wide operative field in the infraoptic and subchiasmatic spaces without intraoperative neurovascular injury. OC: Optic canal, OS: Optic strut, II: Optic nerve, III: Oculomotor nerve, IV: Trochlear nerve, V1: First division of the trigeminal nerve, V2: Second division of the trigeminal nerve, SPS: Sphenoparietal sinus, DDR: Distal dural ring, FL: Falciform ligament, OA: Ophthalmic artery, Ach: Anterior choroidal artery

CONCLUSION

EAC requires extensive knowledge of the detailed anatomical structure of the SOF, MOB, and walls of the CS. On the basis of current cadaveric study of lateral cavernous structures, our modified extradural method requires skeletonization of SOF to expose interteticular layer and needs only minimal dural incision between SOF and FR where no cranial nerves are present. We recommend its less invasive, safe, and useful technique to entirely expose the ACP followed by modified ETA.

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Conflicts of interest

There are no conflicts of interest.

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