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Clinical Article

Meningeal Layers Around Anterior Clinoid Process as a Delicate Area in Extradural Anterior Clinoidectomy : Anatomical and Clinical Study

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Objective : Removal of the anterior clinoid process (ACP) is an essential process in the surgery of giant or complex aneurysms located near the proximal internal carotid artery or the distal basilar artery. An extradural clinoidectomy must be performed within the limits of the meningeal layers surrounding the ACP to prevent morbid complications. To identify the safest method of extradural exposure of the ACP, anatomical studies were done on cadaver heads.

Methods : Anatomical dissections for extradural exposure of the ACP were performed on both sides of seven cadavers. Before dividing the frontotemporal dural fold (FTDF), we measured its length from the superomedial apex attached to the periorbita to the posterolateral apex which connects to the anterosuperior end of the cavernous sinus.

Results : The average length of the FTDF on cadaver dissections was 7 mm on the right side and 7.14 mm on the left side. Cranial nerves were usually exposed when cutting FTDF more than 7 mm of the FTDF.

Conclusion : The most delicate area in an extradural anterior clinoidectomy is the junction of the FTDF and the anterior triangular apex of the cavernous sinus. The FTDF must be cut from the anterior side of the triangle at the periorbital side rather than from the dural side. The length of the FTDF incision must not exceed 7 mm to avoid cranial nerve injury.

Key Words : Extradural clinoidectomy · Frontotemporal dural fold · Superior orbital fissure · Anatomical study.

INTRODUCTION

Anterior clinoidectomy is an important technique in the surgery of aneurysms at the proximal internal carotid artery (ICA) or distal basilar artery as well as for cavernous sinus tumor surgery[5,14,19,21]. By enlarging the carotico-oculomotor triangle window, the removal of the anterior clinoid process (ACP), enhances access to such locations, making aneurysm clipping easier, and aggressive tumor removal possible[20]. However, it is a technically challenging procedure because of the deep location of the ACP and the presence of surrounding eloquent structures[4]. Extradural anterior clinoidectomy is more difficult than an intradural technique because it is more extensive and requires precise knowledge of the anatomical background of the ACP and surrounding neurovascular structures.

Dolenc[7,9-11] proposed the division of the frontotemporal dural fold (FTDF) between the periorbita and the dura of the temporal fossa as a method to increase the extradural exposure of the ACP. Exposure and removal of the ACP must be performed within the limits of the meningeal layers surrounding it to avoid morbidities such as ophthalmoplegia. This cadaveric study provides anatomical details of the meningeal layers around the ACP, and some useful measurements that allow the safe separation of the FTDF, by elevating the temporal fossa dura from the superi-

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or orbital fissure (SOF) we were able to clinically evaluate the appropriate length of the FTDF incision to expose of the ACP.

MATERIALS AND METHODS

Cadaveric materials

Anatomical dissections were done for extradural anterior clinoidectomy on seven cadaveric formalin-fixed heads injected with colored silicone. Both sides of the seven heads were prepared and each head was fixed in a Mayfield headholder and positioned for a standard pterional approach. We performed a stepwise extradural exposure of the ACP using an operative microscope, as recommended by Dolenc[9,10].

Anatomic dissections

As in a routine pterional craniotomy[23], a linear curved incision was made, the temporalis muscle was reflected inferiorly, and a frontotemporal craniotomy with flattening of the sphenoid ridge was performed with a high-speed drill.

The dura of the anterior and middle fossa was dissected from the cranial base to expose the FTDF medially and the bony SOF inferolaterally. The frontal dura covering, the lesser wing of the sphenoid bone was dissected until the FTDF inhibited further exposure of the ACP. The sphenoid ridge was removed to open the lateral end of the SOF. The posterior one-third of the orbital roof together with the optic canal was removed. The ACP was partially drilled away and the FTDF beyond the bony SOF, attached to the periorbita was exposed. Then, the foramen rotundum and foramen ovale were drilled and V2 and V3 were exposed for identification of the anterior margin of the cavernous sinus. The greater sphenoid wing was exposed from the foramen ovale laterally to the junction with the lesser wing medially and was partially removed with a small rongeur or drill. This exposed the FTDF, and the SOF-dura and periorbita-dura junctions at the anterior junction of the lateral wall of the cavernous sinus (Fig. 1). The FTDF was resected and the outer dura layer of the lateral wall of the cavernous sinus was carefully peeled away from the inner layer (Fig. 2). The peeling was performed from the foramen ovale along the anterior part of the lateral wall of the cavernous sinus superomedially. The entire dimension of the ACP was fully exposed and the dura surrounding it were carefully examined.

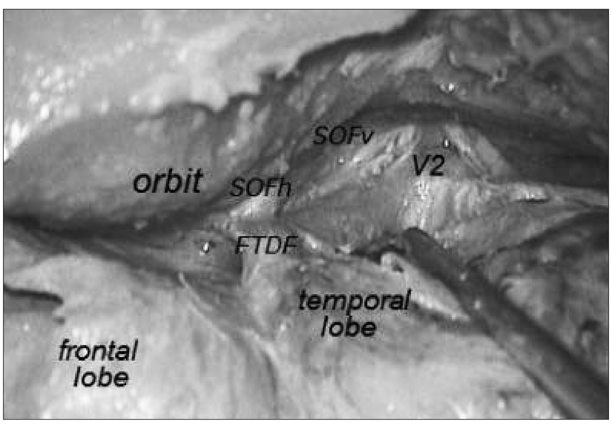

Fig. 1. Surgical anatomy of the right anterior clinoid process and surrounding neurovascular structures. SOFh : horizontal limb of the superior orbital fissure, SOFv : vertical limb of the superior orbital fissure, V2 : maxillary branch of the trigeminal nerve, FTDF : frontotemporal dural fold.

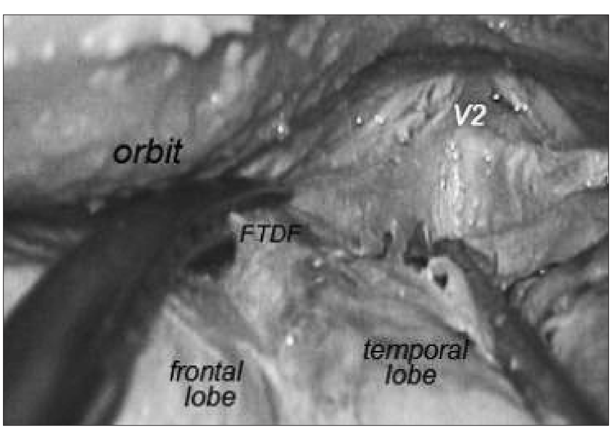

Fig. 2. To avoid injuring the cranial nerves, the horizontal meningeal limb of the superior orbital fissure must be cut in a direction parallel to the anterior clinoid process, not perpendicular to it, and from the anterior side of the triangle at the periorbital side rather than from the dural side. FTDF : frontotemporal dural fold, V2 : maxillary branch of trigeminal nerve.

Measurement of the FTDF

The lateral border of the SOF can be divided into upper and lower segments by a triangular-shaped bony prominence[21]. The structures beyond the bony SOF can be classified into two portions when sectioning the FTDF along the edges of the SOF. The neural portion, which is composed of the III, IV, V1, and VI cranial nerves and surrounded by connective tissue, extends into the posterior orbit. The meningeal portion, namely the FTDF, is composed of the extension of the outer layer formed by the temporal fossa dura and the extension of superior surface dura of the ACP covered by the dura of the frontal base. We have defined the vertical neural and the horizontal meningeal limbs of the SOF - (the SOFv and SOFh, respectively) based on their appearance and structural contents (Fig. 3). Dividing the FTDF, along the edges of the SOF reveals a cleavage plane between the temporal fossa dura and the inner layer of the lateral wall of the cavernous sinus[12,15]. Before separating the FTDF on the cadaveric heads, we measured the length of the SOFh as well as the length of the FTDF from the superiomedial apex to the periorbita to the posteriolateral apex which meets the outer most margin of the anterosuperior cavernous sinus (Fig. 4).

RESULTS

The SOFh on the right side was 8 mm long in two cadavers, 7 mm long in four cadavers, and 6 mm long in one cadaver; on the left side, it was and 8 mm long in one cadaver, 7 mm long in five cadavers, and 6 mm long in one cadaver. The average length of the SOFh was 7 mm on the right side and 7.14 mm on the left side (Table 1). When we cut an approximately 7 mm long incision in the FTDF, cranial nerves were usually exposed. However, in one specimen, a 6 mm incision exposed the cranial nerves on both sides. We suggest that the safety margin to cut the FTDF may be 5 mm.

DISCUSSION

Removal of the ACP[5,14,19], is an important process in the surgery of giant or complex aneurysms at the proximal ICA or the distal basilar artery as well as in cavernous sinus tumor surgery to exposure the ICA and optic nerve with less need for brain retraction. An extradural anterior clinoidectomy increases the surgical exposure of the carotico-oculomotor triangle almost two-folds. Enlargement of this window facilitates the management of parasellar aneurysms and tumors[20]. However, an extradural anterior clinoidectomy is technically challenging; it is more extensive than the intradural procedure and requires a clear understanding of the anatomical background of the ACP and its surrounding neurovascular structures.

The anatomy of the ACP and surrounding structures has been studied extensively[3-5,7,13,14,16,20,24]. The ACP is located at the medial end of the lesser wing of the sphenoid bone and forms the lateral wall of the intracranial end of the optic canal. Its average length is 7.7 mm and its average width is 4 mm[16]. A normal ACP is usually composed of a thin shell of cortical and inner trabecular bone. It may contain air cells that communicate with the paranasal sinuses. The incidence of ACP pneumatization ranges from 4 to 29.3%[1,17].

The subperiosteal resection of the ACP creates an anatomical space, the clinoid space[6,14,16,24], which is limited superiorly and laterally by the dura that covers the superior and lateral aspects of the ACP. Its medial aspect is formed by the optic nerve sheath. The inferior root of the lesser sphenoid wing, the optic strut, is located just below the optic nerve. This bony ridge extends from the base of the ACP to the body of the sphenoid bone. The optic strut ranges from 3 to 7 mm in diameter and varies in shape from round to oval. The clinoid segment of the ICA runs along the posterior margin of the optic strut and is covered by a thin periosteal membrane[12].

Recent reports proposed a more extensive elevation of the temporal fossa dura from the SOF to increase its exposure before removal of the ACP[4,18]. The SOF is a narrow bony cleft through which the orbit communicates with the cavernous sinus in the middle cranial fossa. The bony SOF can be defined by three borders, the superior, medial and lateral. The lateral border is formed from the superior edge of the greater wing of the sphenoid and can be divided into upper and lower segments by a triangular shaped bony prominence[21]. At the SOF, the dura covering the middle fossa and cavernous sinus blends into the periorbita of the orbital apex and the lateral edge of the annular

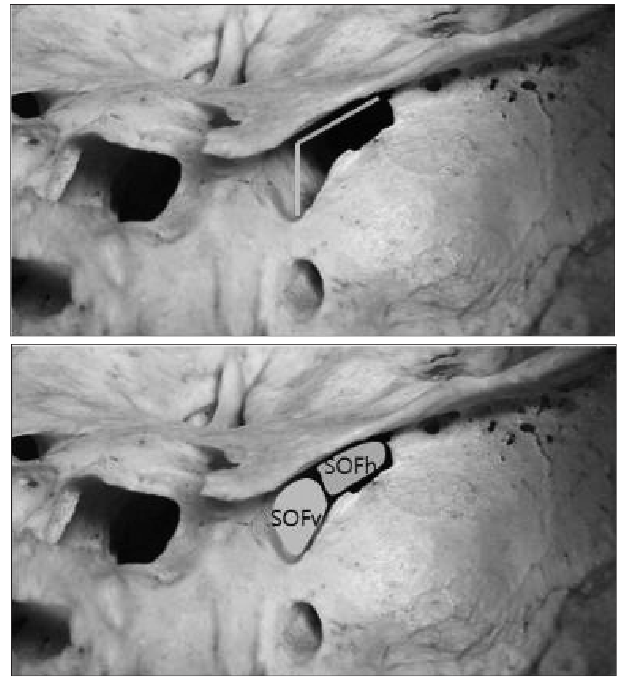

Fig. 3. Photographs showing the posterior view of the superior orbital fissure. The vertical neural limb (SOFv) and horizontal meningeal limb of the superior orbital fissure (SOFh) are schematically demonstrated.

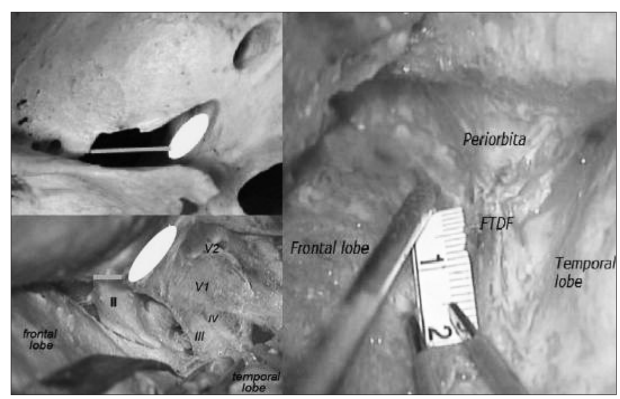

Fig. 4. Photographs showing the relationship between the superior orbital fissure and neural structures on surgical position. The III, IV, V1 and V2 cranial nerves pass through the vertical neural limb of the superior orbital fissure (ellipse). The frontotemporal dural fold (FTDF) is within the horizontal meningeal limb of the superior orbital fissure (full line). The actual measurements are visible.

Table 1. Lengths of the frontotemporal dural folds of cadaveric formalin-fixed heads

Cadaveric number	Right side (mm)	Left side (mm)
1	7	7
2	8	7
3	7	6
4	7	8
5	6	7
6	7	7
7	8	7
Average	7.14	7.00

tendon of Zinn. At this level, the outer and inner layers of the lateral wall of the cavernous sinus separate from one another[15]. The inner layer extends the perineurium of the cranial nerves at the lower segment of the lateral border of the SOF and the outer layer is formed by the temporal fossa dura in the cavernous orbital region[12]. The frontal and temporal dura also fuse together along the inferior margin of the lesser wing at the upper segment. This fold of dura, the FTDF, covers and hides most of the ACP.

The structures beyond the bony SOF can be classified into the neural and meningeal portions. The neural portion is composed of the III, IV, V1 and VI cranial nerves and surrounding connective tissues, and extends the cranial nerves into the posterior orbit. The meningeal portion, which represents the FTDF, is composed of only dura, including the extension of the outer layer formed by the temporal fossa dura and the extension of the superior surface of the ACP covered by the dura of the frontal base. Because of the SOF's triangular-shaped bony appearance and structural components, we have defined two portions, the SOFv and the SOFh. To prevent morbid complications, resection of the SOF should occur only within the SOFh.

Recent reports have described the division of the FTDF to increase the exposure of the ACP and thus facilitate extradural anterior clinoidectomy[4,12,18]. Dolenc[8,10] used a backward-curved pair of scissors to divide the FTDF and avoid injury of the SOF contents, although an inexperienced surgeon attempting this procedure may be unclear about the length and direction of the recommended cut. Our cadaveric study, suggests that the cut, which should not exceed 7 mm to avoid the exposure of cranial nerves and reduce the possibility of cranial nerve palsy, should be made within the SOFh, and should be performed partially scissors. When dividing the FTDF to fully expose the entire ACP, the sleeve should not be pulled but should be peeled away from the cranial nerve. To avoid cranial nerve injury, the SOFh must be cut in a direction parallel to the ACP, not perpendicular to it, and from the anterior side of the triangle at the periorbital side rather than from the dural side. In addition, the procedure must be combined with the peeling of the outer dural layer of the lateral wall of the cavernous sinus to meet the posterior triangular apex of the FTDF. Adherence to these strategic points should allow even an inexperienced surgeon safely perform the procedure.

Bayassi[2] performed a cadaveric dissection and measured the length of the FTDF by fully exposing the anatomy around the ACP, without considering surgical issues. In contrast, we exposed the FTDF through a pterional approach using an extradural anterior clinoidectomy and measured the length of the FTDF incision until the exposure of the cranial nerves. Therefore, our study correlates favorably with the surgical procedure. Bayassi[21] also reported one specimen with an FTDF length of 5.4 mm, although the average lengths of each side were 8.4 and 8.3 mm. Taking into consideration these anatomical measurements and our surgical data, we suggest that the lengh of the FTDF incision not exceed 5 mm to reduce the risk of cranial nerve exposure[13]. However, because our study was focused on the clinical division of the FTDF during a surgical procedure. Actual length of the FTDF may be less accurate than one based on a full exposure of the relevant anatomy.

CONCLUSION

Anterior clinoidectomy is an important technique in the microsurgery of parasellar pathologies and the division of the FTDF is the crucial step in this procedure. In our study, the average length of the FTDF was 7 mm on the right side and 7.14 mm on the left side. Therefore, the length of an incision in the FTDF during extradural anterior clinoidectomy must not exceed 7 mm to avoid the exposure of cranial nerves.

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