Anatomical study of the superior orbital fissure as seen during a pterional approach

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Object. The superior orbital fissure (SOF) is an important landmark in the neurosurgical pterional approach, but the anatomical features of the SOF and the procedures necessary to fully expose it and its contents have not been detailed. Although the pterional approach is commonly used during skull base or vascular surgery by neurosurgeons who may already be familiar with its nuances and anatomical relationships to the SOF, this knowledge may also be useful to the wider neurosurgical community. The authors describe the spatial relationships of the contents of the SOF and suggest a specific sequence of steps for exposing the SOF region in a pterional approach.

Methods. Using standard microsurgical equipment and instruments, the authors performed 20 pterional approaches in 10 embalmed cadaver heads in which the vascular systems had been injected with colored material.

Five sequential steps were delineated for approaching and dissecting the SOF and its contents: 1) drilling the sphenoideal ridge, anterior clinoidal process, and part of the greater and lesser wings of the sphenoid; 2) resecting the dural bridge; 3) detaching the hemispheric dura mater, thereby exposing the anterior portion of the cavernous sinus and the neural component entering the SOF; 4) identifying and dissecting the extraanular structures; and 5) opening the anulus of Zinn and identifying its neural constituents.

Conclusions. Knowing the 3D relationships of the contents of the SOF encountered in the pterional approach enables safe neurosurgical access to the area. The proposed sequence of steps allows a controlled exposure of the SOF and surrounding areas. Untethering the frontotemporal lobe by transecting the dural bridge connecting the dura to the periorbita allows good exposure of the basal frontotemporal lobes, both intra- and extradurally, and reduces brain retraction.

KEY WORDS • cavernous sinus • orbit • superior orbital fissure • microsurgical anatomy • pterional approach
Results

Five sequential surgical steps were used to approach and dissect the SOF, and are detailed below.

Bone Stage

The first step of the dissection consists of an anterior clinoidectomy, executed after a standard pterional flap is formed. The neurovascular structures of the SOF are exposed and mobilized by drilling the sphenoidal ridge, unroofing the ON, and removing the anterior clinoidal process and part of the greater and lesser wings of the sphenoid. At this point, the microscope is angled toward the most lateral aspect of the SOF, encountering the periorbital continuation of the intracranial dura mater, the dural bridge.

Dural Bridge Resection

The dural bridge is located on the lateral side of the SOF, between the greater and lesser wings of the sphenoidal bone. It is very short (usually 2–3 mm) and contains a small bridging vessel, the orbitomeningeal artery, that needs to be transected (Fig. 2). This vessel was present in all our specimens, and in eight, it was more than half the size of the middle meningeal artery. Sometimes the border between the dural bridge and the nerves crossing the lateral portion of the SOF is not easily identifiable. Therefore, careful retraction of the dura while resecting the dural bridge is advised so that once separated from the bridge, the dura can provide a well-defined cleavage plane between itself and the cranial nerves of the anterior portion of the cavernous sinus, and entry into the lateral aspect of the SOF can be controlled to avoid risks to its neural structures (Fig. 3). Resecting the dural bridge allows further detachment of the dura from the surrounding structures and enables extradural exposure of the anterior portion of the cavernous sinus and the third and fourth cranial nerves as well as the first division of the fifth cranial nerve (Fig. 4).

Identifying and Dissecting Extraanular Structures

The extraanular structures are the trochlear, lacrimal, and frontal nerves, and the SOV, which provides the main venous drainage from the orbit to the cavernous sinus. The lacrimal nerve is the most lateral nerve in the SOF, and therefore is the first nerve encountered by the surgeon during a pterional approach. The frontal nerve is immediately medial to the lacrimal nerve, and the fourth cranial nerve is inferior and medial to the frontal nerve (Fig. 6). The SOV is located inferomedially to the lacrimal nerve. Because these structures need to be carefully mobilized to access the most medial (and deeper, from the pterional perspective)
structures of the SOF, an incision is made just lateral to the lacrimal nerve and continued forward into the periorbita approximately 3 to 4 mm. This incision allows the surgeon access to the area containing the nerves, allowing further identification and dissection of these nerves that will need to be gently retracted to expose the deeper intraanular structures (Fig. 7).

Opening the Anulus of Zinn and Exposing the Intraanular Structures

The anulus of Zinn is an important anatomical landmark in the SOF. It is a fibrous ring at the orbital apex in front of the upper half of the medial part of the SOF, and is attached to the lateral margin of the fissure near the junction of its lateral and medial parts. Four rectus muscles arise from the anulus and form a cone around the neural and vascular structures passing through the anulus. The intraanular structures are the nasociliary nerve, the third and sixth cranial nerves, sympathetic nerve fibers, the ciliary root, and the inferior ophthalmic vein.

The next step in exposing the SOF is to open the anulus of Zinn and identify the neural components that cross it, which are the nasociliary nerve and the sixth cranial nerve, the two branches of the third cranial nerve, and the sympathetic nerve fibers. An incision is made in the anulus along the medial aspect of the nasociliary nerve, which lies outside the anulus. Once the nasociliary nerve has been exposed inside the anulus, the sixth cranial nerve located me-
dially to the nasociliary nerve can be identified. The third cranial nerve and its superior and inferior divisions are located deep and medial to the nasociliary nerve and the sixth cranial nerve. Between the sixth cranial nerve laterally and the inferior oculomotor division medially is the sensory root of the ciliary ganglion (Fig. 8). Deep in the surgical field, just medial and inferior to the third cranial nerve, lies the ophthalmic artery (Fig. 9).

Appropriate manipulation of the microscope allows visualization of the posterior section of the contents of the orbit. Further removal of the orbital roof and incision of the periorbita fully exposes the orbit, which is entered from the SOF portal as well as the orbital roof (Fig. 10). Throughout the dissection of the SOF, variously developed venous structures are encountered, which represent the drainage of the SOV and inferior ophthalmic vein into the veins of the cavernous sinus.

**Discussion**

The anatomy of the SOF is well described in most anatomy textbooks. Exploration of the SOF in recent studies has focused primarily on determining the surgical anatomy of different approaches to the orbit through the orbital roof and making craniometric measurements. Although the pterional approach is one of the most fundamental and widely used neurosurgical approaches, and the SOF and its contents are within the extradural pterional field of vision, little information is available on the surgical anatomy of the SOF during a pterional approach. The foundations of the current pterional approach can be traced to Wagner at the end of the nineteenth century, and Yaşargil refined and popularized the approach in the microneurosurgical era.

The SOF is a complex anatomical structure at the junction of two areas of surgical complexity, the anterior cavernous sinus and orbital apex. Consistent with all skull base anatomical junctions, the SOF has an intricate anatomy, containing multiple neurovascular structures whose anatomical relationships change as they pass from one compartment to another within a very confined space. The results of our study suggest that a simple pterional approach in combination with an anterior clinoidectomy, unroofing of the ON canal, and extensive removal of the lesser and greater sphenoidal wings leads to excellent extradural visualization of the contents of the SOF and its related topography (such as the anterior cavernous sinus and orbital apex).

As other investigators have done, we describe the exposure of the components of the SOF beginning with the anterior cavernous sinus. However, if operative circumstances require a different starting point, a thorough knowledge of the neural topography of the region will enable safe and effective choices. If dissection requires beginning further back on the superolateral wall of the cavernous sinus due to the pathological involvement of the anterior cavernous sinus area, the veins of the cavernous sinus do not need to be disturbed, because the third and fourth cranial nerves and the first division of the fifth cranial nerve can be identified in between the two layers of the superolateral wall of the sinus. Alternatively, beginning dissection by incising the posterior periorbita is more dangerous and requires knowledge of the extraanular nerves located just beneath the periorbita, which are not always visible through it.

For these reasons, we emphasize the importance of iden-

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Fig. 6. Photograph showing the identification of the extraanular structures. II = ON.

Fig. 7. Photograph demonstrating the gentle retraction of the extraanular structures to allow exposure of the anulus of Zinn and the nerves passing through it.

Fig. 8. Photograph showing the exposure of the nasociliary nerve after the initial opening of the anulus of Zinn. Asterisk indicates the nasociliary nerve; double asterisk, a remnant of the anulus of Zinn.
tifying the nerves in the anterior cavernous sinus when feasible. The ophthalmic nerve lies in the superolateral part of the anterior cavernous sinus, dividing into its lacrimal, frontal, and nasociliary branches 2 to 3 mm prior to the SOF. The lacrimal and frontal nerves are in close apposition as they enter the most lateral section of the SOF, and the fourth cranial nerve lies medially to them. Once these extraanular structures are identified and partially mobilized, they can be gently retracted, and the nasociliary nerve can be visualized as it enters the anulus of Zinn. Making a 2- to 3-mm incision medial to the nasociliary nerve and parallel to its long axis permits it to be mobilized, allows the identification of the third cranial nerve and its two branches medial to the nasociliary nerve, and facilitates the identification of the sixth cranial nerve.

Partial or extensive dissection of the SOF components may be valuable not only when approaching a pathology involving the fissure itself, but also for extra- and intradural pathology of the sellar–parasellar area. Although execution of all the steps described is necessary only when the pathology is considered completely resectable and crosses the orbit and anterior cavernous sinus, a detailed anatomical knowledge of the 3D relationships of the SOF components encountered is invaluable to all neurosurgeons using a pterional approach. Simple maneuvers made possible by a detailed knowledge of the anatomical construct described may be significantly helpful during a routine pterional approach.

We have found that transecting the dural bridge consistently leads to untethering the frontotemporal lobe from the SOF. This extradural untethering is particularly helpful because it increases the operative space between the frontal and temporal lobes, allowing a more basal exposure, both

Fig. 9. Photographs demonstrating the extensive opening of the anulus of Zinn to allow identification of the intraanular structures. III = inferior branch of the oculomotor nerve; III* = superior branch of the oculomotor nerve; asterisk indicates the nasociliary nerve; double asterisk, the ophthalmic artery.

Fig. 10. Photographs revealing a full exposure of the contents of the orbit after removal of the orbital roof and opening of the periorbita. Asterisk indicates the nasociliary nerve.
extra- and intradurally, with limited retraction of the brain. This basal exposure is achieved using a rather simple and routine neurosurgical approach and may be helpful in a routine pterional approach. With experience this dural bridge resection may be performed quickly and expeditiously. We have now incorporated this dural bridge resection in all our pterional approaches.

Conclusions

Controlled surgical exposure of the SOF and surrounding areas during a pterional approach is facilitated by an accurate knowledge of the 3D relationships of the neurovascular structures in the area, and the proposed series of surgical steps will allow safe exposure of this region. The extradural untethering of the frontotemporal dura by transecting the dural bridge connecting the dura to the periorbita is particularly helpful in achieving a more basal exposure of the basal frontotemporal lobe intra- and extradurally with minimal retraction of the brain.

References


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