



Neuroanatomical Study

Surgical anatomy of the dural walls of the cavernous sinus

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ABSTRACT

The external structure of each cavernous sinus (CS) is made of four dural walls. The aim of this study was to describe the anatomy of the dural walls of the CS. We studied 42 adult cadaveric heads, fixed with formalin and injected with coloured silicon. The main findings were: (i) the lateral wall of the CS has two layers – the external, which is thick and pearly grey, and the internal, which is semi-transparent and containing the cranial nerves (CNs); (ii) the medial wall of the CS has two areas – sellar and sphenoidal, both made up of one dural layer only; and (iii) the superior wall of the CS is formed by three triangles – oculomotor, clinoid and carotid – CN III may be found in a cisternal space of the oculomotor triangle; and (iv) the posterior wall of the CS is made up of two dural layers – meningeal dura and periostic dura – and this wall is close to the vertical segment of CN VI.

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1. Introduction

The cavernous sinuses (CS) are paired structures on both sides of the sella turcica, pituitary gland and sphenoid sinus.¹ The CS extends from the superior orbital fissure to the dorsum sellae, being the inferior limit of the upper border of the maxillary nerve.

The external structure of each CS is made of four walls of dura mater: the lateral, medial, superior (also called the roof of the CS), and the posterior wall. Within those walls is venous blood flow, the internal carotid artery with its branches, as well as cranial nerve VI (CN), the sympathetic plexus and adipose tissue (Fig. 1).

2. Materials and methods

The heads of 42 adult cadavers, fixed with formalin and injected with coloured silicon, were studied. In 40 of the 42 heads, the skull vault and the encephalon was removed to expose the cranial base. Twenty heads (40 CS), were studied from the outside toward the centre and 20 were studied from the top downwards. Both remaining heads (4 CS) were bisected sagittally using a high-speed electric saw (Fleetwood Food Equipment; Philadelphia, PA, USA), and the dissections proceeded medially to laterally. A Carl Zeiss surgical microscope (OPMI-1 Lab) (Oberkochen, Germany), 3× to 25× magnification, was used. A Midas Rex high-speed drill was used to remove bone tissue (Legend GoldTouch, Medtronic; Minneapolis, MN, USA).

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3. Results

3.1. Lateral wall of the cavernous sinus

The lateral wall of the CS is made of two dural layers, the outer layer (meningeal dura), and the inner one (periostic dura) (Fig. 2). Both dural layers of the lateral wall continue laterally with the dura covering the floor of the middle fossa, medially with the dura of the superior wall of the CS, anteriorly with the dura covering the concavity of the greater wing of the sphenoid bone, and posteriorly with the tentorium. The external layer is thicker with a pearly grey colour, while the internal layer is thin, transparent and containing CN III, IV and V on their way through the CS to the superior orbital fissure. There is a cleavage plane between both dural layers; which is important surgically because it permits access to the inner layer of the lateral wall without entering the venous compartment of the CS, and also allows exposure of the CN.

The limits of the lateral wall of the CS are: (i) superiorly – the anterior petroclinoid ligament; (ii) inferiorly – the superior border of the maxillary nerve; (iii) anteriorly – the superior orbital fissure; and (iv) posteriorly – an imaginary line that lies flush with the plane of the dorsum sellae.

3.2. Medial wall of the cavernous sinus

The medial wall of the CS, the only wall which cannot be observed in the skull base, is also the only wall made of only one single dural layer (Fig. 3). This dural layer makes not only the medial limit of the CS, but also the lateral limit of the pituitary fossa. The medial wall of the CS exhibits two areas: the sellar and the sphenoidal parts.² The sellar area is nothing but the dural

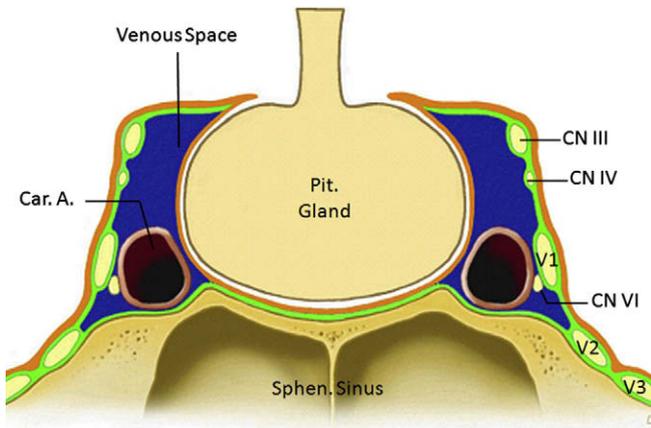


Fig. 1. Diagram of a coronal section through the cavernous sinus showing the meningeal layer (orange) and the periostic layer (green). A = artery, Car. = carotid, CN = cranial nerve, Pit. = pituitary, Sphen. = sphenoid.

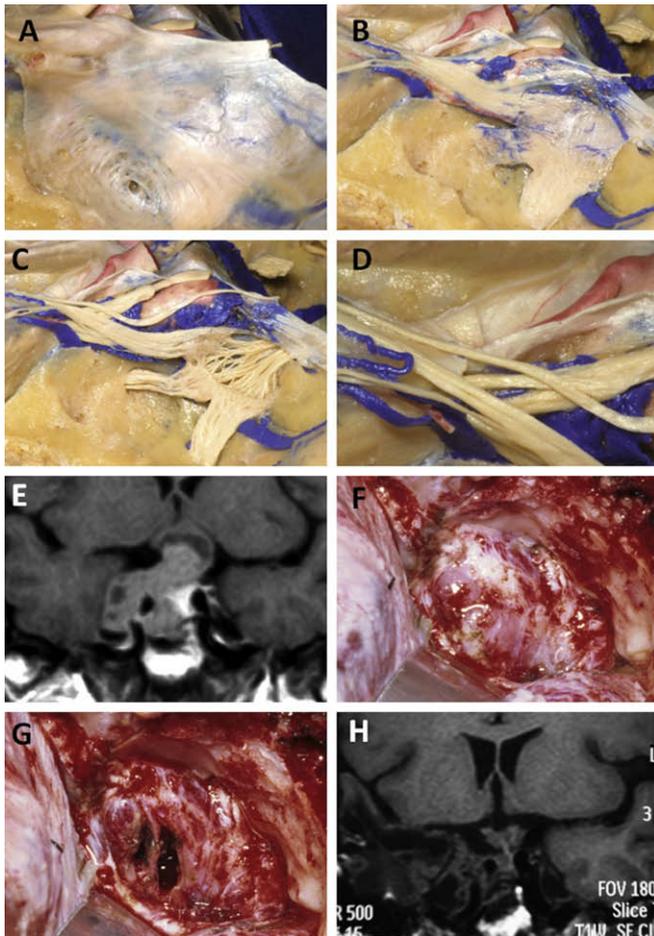


Fig. 2. (A–D) Photographs of the stepwise dissection of a lateral wall of the cavernous sinus (CS) of a formalin-fixed adult cadaverous head, injected with blue silicon (left side) showing: (A) the outer layer (meningeal layer); (B) the inner layer with cranial nerves (CN); (C) the already dissected inner layer with CN; and (D) an enlarged view of the superior orbital fissure. (E–H) Pituitary macroadenoma with extension into the right CS showing: (E) preoperative coronal T1-weighted non-enhanced MRI; (F) surgical view of the extradural approach before opening the inner layer of the lateral wall of the CS; (G) surgical view after tumor resection; and (H) postoperative coronal T1-weighted non-enhanced MRI, after an extradural approach.

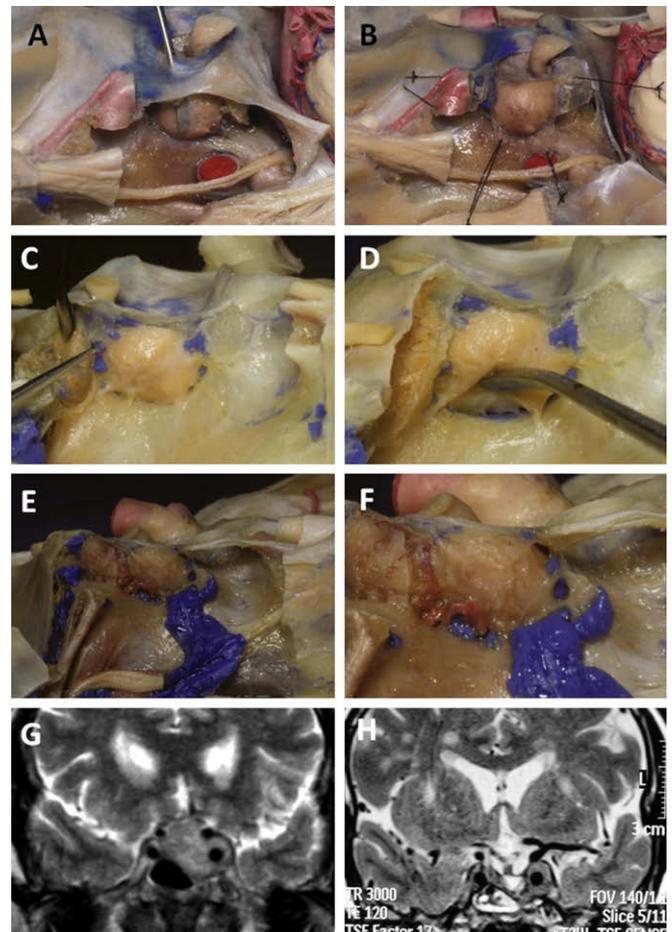


Fig. 3. (A–F) Photographs of the medial wall of the cavernous sinus (CS) showing: (A) a microdissector placed between the pituitary gland and the medial wall of the CS; (B) the opened medial wall of the CS (sellar part); (C) the medial wall of the CS; (D) a microdissector elevating the pituitary gland; and (E) the medial wall of the CS, enlarged in (F). (G) Preoperative coronal T2-weighted MRI showing a pituitary macroadenoma with extension into the left CS; and (H) postoperative coronal T2-weighted MRI, after an endonasal trans-sphenoidal approach, showing tumor resection up to the medial wall of the left CS.

membrane between the pituitary gland and the venous space of the CS, and the sphenoid area is made by the dural membrane adherent to the body of the sphenoid bone, precisely to the carotid sulcus.

The limits of the medial wall of the CS are: (i) superiorly – where the medial wall joins the superior wall of the CS; (ii) inferiorly – an imaginary line starting at the level of the foramen rotundum, passing through the inferior border of the carotid sulcus and lingula of the sphenoid bone, finally ending at the level of the upper portion of the petroclival fissure; (iii) anteriorly – an imaginary line going from the optic pillar to the foramen rotundum, passing through the medial end of the superior orbital fissure; and (iv) posteriorly – an imaginary line starting in the posterior clinoid process and reaching the superior end of the petroclival fissure.

The pituitary gland, with 6 sides, is surrounded by a very thin and transparent membrane, the pituitary capsule, firmly adherent to the gland itself. Outside this membrane, the pituitary gland is surrounded by dura. The lateral side is the only portion of the pituitary gland covered just by one dural layer.

3.3. Superior wall of the cavernous sinus

The superior wall of the CS, also called the roof of the CS, is the dural area above the CS contents, between the upper extremities of

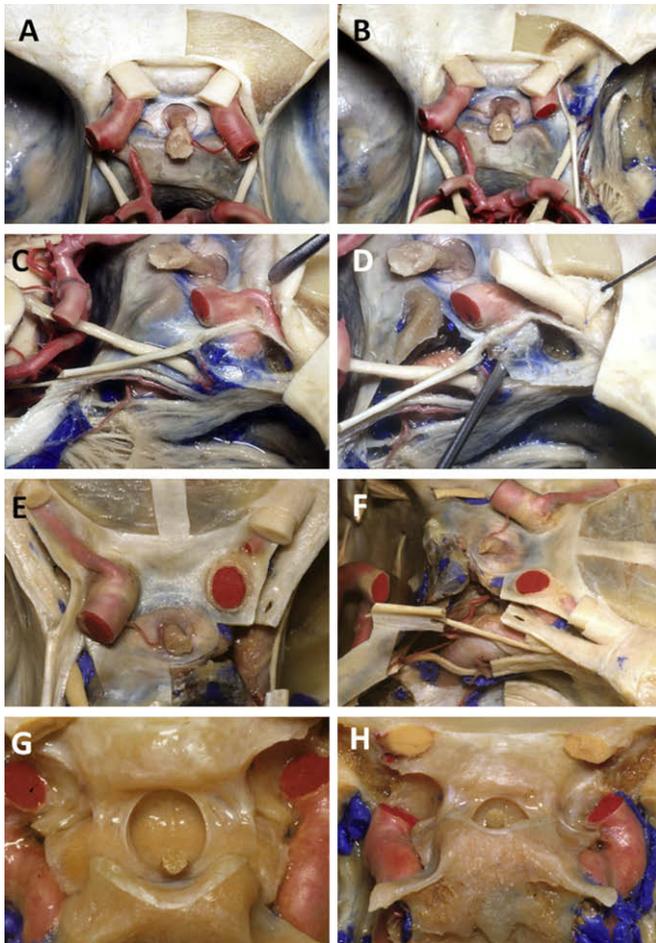


Fig. 4. Photographs of the superior wall of the cavernous sinus (CS) showing: (A) superior view before resection of the anterior clinoid process; (B) superior view after resection of the anterior clinoid process; (C) lateral view of a right CS – the anterior clinoid process removed to expose the clinoid segment of the internal carotid artery; (D) a microdissector placed between the carotid artery and the carotid collar; (E, F) superior and lateral views, respectively – the internal carotid artery has been cut at the level of the distal dural ring; (G, H) a wide opening of the diaphragm sellae and lateral extension of the pituitary gland over the internal carotid artery.

the lateral and medial walls (Fig. 4). The superior wall shows greater anatomical complexity. It is formed by three triangles: clinoid, oculomotor, and carotid triangles. The medial areas of the carotid and oculomotor triangles are continuous with the diaphragma sellae. The superior wall of the CS, just as the lateral and posterior walls, is made by two dural layers: meningeal and periosteal dura. It is difficult to define the limits of the superior wall, so, to fully expose this wall, it is necessary to remove the anterior clinoid process, achieving exposure of the clinoid segment of the internal carotid artery.

The roof of the CS therefore has the shape of a trapezium, with the base to the lateral side. The limits of the superior wall are: (i) medially – the lateral limit of the diaphragma sellae; (ii) laterally – the anterior petroclinoid ligament and also the lateral border of the anterior clinoid process; (iii) anteriorly – an imaginary line passing through the base of the anterior clinoid process; and (iv) posteriorly – the posterior petroclinoid ligament.

There is a minute arachnoid cystern, the so-called cystern of the oculomotor nerve, which accompanies CN III in the roof of the CS.³ Such a cystern expands from the point where the nerve perforates the dura of the roof of the CS to the area below the tip of the anterior clinoid process (Fig. 5). For that anatomical reason, CN III is not

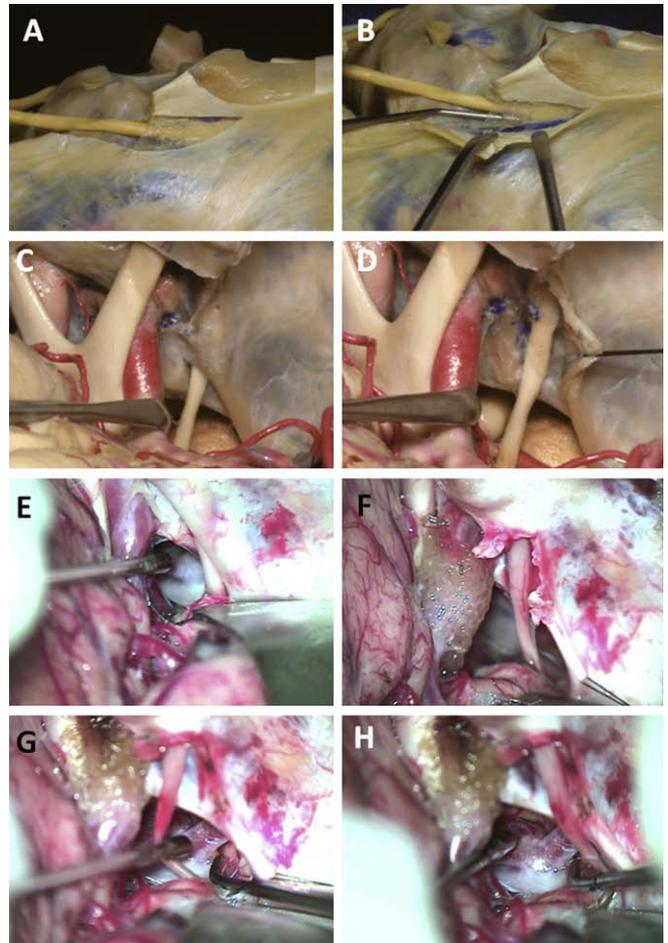


Fig. 5. Photographs showing (A, B) the oculomotor cystern; (C, D) the opening of the roof of the oculomotor cystern; (E–H) intraoperative photographs showing the opening of the roof of the oculomotor cystern to mobilize cranial nerve III, achieving good exposure of the interpeduncular cystern.

within the CS in the roof of the CS, but the oculomotor nerve is bathed by cerebrospinal fluid inside a cystern of its own.

The diaphragma sellae is a dural structure composed of two layers. Both layers continue anteriorly with the dura mater re-covering the planum sphenoidale and the anterior cranial fossa; posteriorly it extends as the dura covering the dorsum sellae and clivus. The diaphragma sellae extends from the tuberculum sellae to the dorsum sellae. Laterally the diaphragma sellae are limited by where the medial wall of the CS joins the superior wall. In the centre of the diaphragm there is an opening for the pituitary stalk with certain variations in its diameter.⁴ When the diameter measured is bigger than usual, there is more pituitary tissue in direct contact with the chiasmatic cystern.

3.4. Posterior wall of the cavernous sinus

The posterior wall of the CS is part of the dural covering of the clivus (Fig. 6). This posterior wall is made of two dural layers (meningeal and periosteal dura). The posterior wall, then, continues anteriorly with the dura of the oculomotor triangle, medially with the posterior wall of the basilar sinus and laterally with dura mater covering the posterior wall of the petrous bone.

The limits of the posterior wall are: (i) superiorly – a line passing through the posterior petroclinoid ligament, from the apex of the petrous bone to the posterior clinoid process; (ii) inferiorly – a line crossing the superior portion of the petroclival fissure;

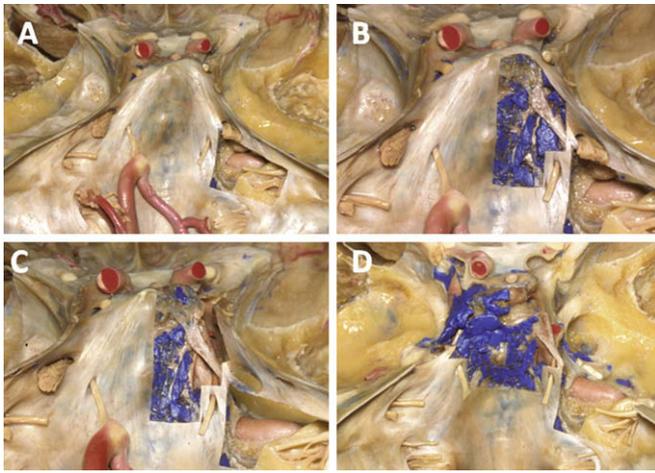


Fig. 6. Photographs (A–D) showing stepwise dissection of the posterior wall of the cavernous sinus.

(iii) medially – a line passing through the lateral edge of the dorsum sellae; and (iv) laterally – a line just medial to the entry opening of Meckel's cave.

4. Discussion

Numerous papers have been written on the anatomy and surgery of the CS.^{1–26} However, until recently, aspects of CS anatomy remained not well understood and few details were known about the dural walls of the CS. Parkinson,^{13–17} Dolenc,^{8,9} Umansky and Nathan and Umansky et al.^{23–25} are associated with progress in understanding both the anatomy and surgery of the CS. Until Umansky and Nathan's publication in 1982,²³ the dural structure of the CS lateral wall and its relationship to CN III, IV, and V was not clearly understood.

There are two ways of approaching the CS:²⁶ intradural, with access to the CS via its dural roof; and extradural, with access to the CS through its lateral wall, after surgically separating the two dural layers and identifying CN III, IV, and V.

Several controversies exist regarding anatomy of the CS medial wall. Some authors have reported absence of a medial wall,^{27,28} others suggested there were anatomical defects in the wall.^{29,30} Oldfield suggested that the medial wall of the CS is perforated by several veins.⁹ We observed that the dural tissue was fully intact in the medial wall, without perforations.²

The pituitary gland is surrounded by: two dural layers and by bony tissue on its anterior, inferior and posterior aspects; two dural layers on its superior aspect; and just one dural layer on its lateral aspect. Thus, the weakest area around the pituitary gland is its lateral aspect, an anatomical fact that might explain the lateral growth of some pituitary adenomas towards the CS.

Of the anatomy of the four walls of the CS, the details of the superior wall are the hardest to interpret. Some authors consider that the roof of the CS can be divided into two triangles, whereas others, three. We find it easier to interpret the anatomy of the superior wall if it is divided into three areas or triangles. The oculomotor triangle is the surgical area for gaining access to the interior of the CS, as well as the location of the CN III cistern. Thus, it is possible to open the cistern, and to free and mobilise CN III, without opening the CS itself.³

The diaphragma sellae is made up of two dural layers with a variably sized central opening for the passage of the pituitary stalk.⁴ Of the structures surrounding the pituitary gland that might act as a tumour “barrier”, the only area that shows anatomical

variation is the central opening. A very small aperture would render upward growth of a tumour virtually impossible, but lateral expansion into the weaker CS interior through the medial wall, is conceivable. However, in others with a wider diaphragmatic opening, upwards tumoral expansion might be possible because the diaphragma sellae would lack the usual membranous barrier.⁴

5. Conclusions

- 1) The lateral wall of the CS has two layers; the external is thick and pearly grey, and the internal is semi-transparent and contains the CN; thus the layers can be surgically separated to expose the III, IV and ophthalmic CN.
- 2) The medial wall of the CS has two areas, sellar and sphenoidal, both of which are made up of one dural layer only. The sellar portion is the safe lateral limit during a trans-sphenoidal approach to the sellae; it is also the weakest part of the pituitary gland's cover, thereby allowing lateral tumoral growth into the CS.
- 3) The superior wall of the CS is formed by three triangles: oculomotor, clinoid and carotid triangles. CN III is located in a cisternal space in the oculomotor triangle, and this cistern can be opened to mobilise the nerve without opening the CS.
- 4) The posterior wall of the CS is made up of two dural layers: meningeal and periostic. This wall is close to the vertical segment of CN VI, from the point of its dural perforation to where it changes direction at the level of Dorello's canal.

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