




Original Article

Defining the limits of the anterior wall of the cavernous sinus through an endoscopic view: Cadaveric anatomical study

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ABSTRACT

Background: The anterior wall of the cavernous sinus (CS) represents an important landmark for endoscopic surgery that although mentioned before, no precise anatomical boundaries have been described. We describe the anatomical landmarks that delimit the anterior wall of the CS, emphasizing its importance as a reference for accessing the CS through endoscopic approaches.

Methods: Six adult cadaveric heads fixed with formaldehyde and injected with colored silicone were studied. In all the heads, an endonasal endoscopic approach to the sellar and parasellar regions was performed and the anatomy of the anterior wall of the CS was studied.

Results: Four consistent anatomical landmarks that mark the limits of the anterior wall of the CS were found in all the specimens: anterosuperiorly, the lateral opticocarotid recess; posterosuperiorly, the medial opticocarotid recess; anteroinferiorly, the inferior part of the maxillary strut; and posteroinferiorly, the superolateral angle of the clival recess.

Conclusion: It is of paramount importance to recognize the anatomical landmarks that define the limits of the anterior wall of the CS to achieve a safe access to this so complex region.

Keywords: Anterior wall, Boundaries, Cavernous sinus, Endoscopic, Skull base

INTRODUCTION

The cavernous sinus (CS) is a paired structure located on each side of the sella, pituitary gland, and sphenoid sinus, extending from the superior orbital fissure rostrally to the dorsum sellae caudally. It is defined as the dural envelope through which the cavernous segment of the internal carotid artery (ICA) courses, as well as venous outflow from the orbital, sphenoidal, and temporal regions.^[17] Classically, the external structure of the CS has been described as being formed by four walls of dura mater: the lateral, medial, superior, and the posterior walls.^[3] Although mentioned in some publications,^[6,7,20,21] a fifth wall, the anterior wall of the CS has not been described in detail and no precise anatomical limits and landmarks have been defined to precisely determine the extension of this much relevant structure.

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The aim of the present study is to describe the endoscopic anatomy of the anterior wall of the CS, delimit its anatomical borders, and highlight its importance as an anatomical reference for endoscopic approaches to the CS and surrounding areas.

MATERIALS AND METHODS

Six heads (12 sides) of adult cadavers fixed with formaldehyde and injected with colored silicone (red for arterial system and blue for venous system) were dissected. All the specimens were dissected bilaterally through an endonasal approach (medial to lateral dissection) using neurosurgical endoscopic instruments, including 4-mm diameter and 18 cm length 0° and 30° endoscopes coupled to a high-definition camera Image1 S H3-Link system (Karl Storz, Germany). A Midas Rex high-speed drill was used to remove bone tissue (Medtronic, USA). Two-handed binostril techniques were used. The configuration of the anterior wall of the CS, its relationship with nearby neurovascular structures, and its anatomical boundaries were studied. Measurements of distances between predefined anatomical landmarks were performed in all specimens (12 sides), obtained by direct measurement with a scientific divider, and then calculated using a slide caliper in unit of 0.1 mm. All measurements were made by a single investigator. Data were analyzed as continuous variables in STATA 17 software package (College Station, TX, StataCorp LLC) obtaining means, medians, standard deviations, and ranges. No ethics committee approval was sought or required to complete this study.

RESULTS

Surgical anatomy of the anterior wall of the CS

The anterior and inferior surfaces of the pituitary gland are covered by two layers of dura mater: the meningeal or inner layer, which adheres to the gland; and the periosteal or outer layer, which lies in contact with the sellar floor of the sphenoid bone. At the site where the sellar floor and the carotid sulcus transition, these dural layers split, the periosteal layer continues laterally to form the anterior wall of the CS, and the meningeal layer continues posteriorly at each side of the pituitary gland to form the medial wall of the CS.^[21] Therefore, the anterior and medial walls of the CS are single layered. According to the ICA segments described by Labib *et al.*,^[14] the medial wall of the CS is in close relation to the posterior portion and the anterior wall of the CS to the anterior portion of the parasellar segment of the ICA, which courses from the superomedial petrous apex to the proximal dural ring. Loose arachnoid-like adhesions were found between the ICA and the anterior wall of the CS, which were easily separated with gentle blunt dissection [Figure 1].

Defining the limits of the anterior wall of the CS

The standard endonasal endoscopic approach was performed as described elsewhere.^[8,9] To achieve maximal exposure of the anterior wall of the CS, a transpterygoid approach must be performed. This involves removal of the ascending process of the palatine bone, removal of the posterior wall of the maxillary sinus to expose the pterygopalatine fossa, and transposition of the pterygopalatine fossa contents to drill the base of the pterygoid process.^[19] This will allow to maximize the sphenoid sinus opening until the lateral recess of the sinus is exposed.^[22] At this point, four consistent anatomical landmarks that limit the anterior wall of the CS were identified in all specimens: anterosuperiorly, the lateral opticocarotid recess (LOCR); posterosuperiorly, the medial opticocarotid recess (MOCR); anteroinferiorly, the posteroinferior part of the maxillary strut; and posteroinferiorly, the superolateral angle of the clival recess. Thus, the borders of the anterior wall of the CS can be defined as detailed in Table 1 and Figure 2.

These anatomical landmarks and their intracranial relationship from a dorsolateral perspective possess significant surgical relevance. The LOCR corresponds to the

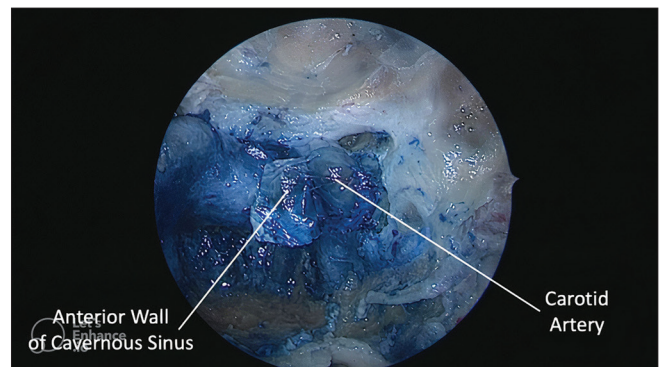


Figure 1: Endoscopic image showing the relationship of the anterior wall of the cavernous sinus with the parasellar segment of the internal carotid artery.

Table 1: Anatomical limits of the anterior wall of the CS through an endoscopic view.

Borders of the anterior wall of the CS

Superior	From the inferior aspect of the LOCR to the MOCR, through the proximal dural ring
Medial	From the MOCR to the superolateral angle of the clival recess, through the lateral border of the sella
Inferior	From the superolateral angle of the clival recess to the posteroinferior border of the maxillary strut
Lateral	From the posteroinferior border of the maxillary strut to the LOCR, following the posterior border of the maxillary strut until the superior orbital fissure

LOCR: Lateral opticocarotid recess, MOCR: Medial opticocarotid recess, CS: Cavernous sinus

optic strut base, which divides the optic canal superomedially from the superior orbital fissure inferolaterally, and forms the anterosuperior limit of the anterior wall of the CS.^[16] The MOCR is a teardrop-shaped osseous depression formed at the convergence point of the optic canal, carotid sulcus, CS, superior aspect of the sella, and anterior cranial base, located at each side of the tuberculum recess, and forms the posterosuperior limit of the anterior wall of the CS. Although not corresponding exactly with the middle clinoid process, this osseous prominence provides a useful and surgically relevant landmark.^[15] The maxillary nerve does not course inside the dural envelope of the CS, thus, its superior border, at the posterior aspect of the maxillary strut, which divides the superior orbital fissure superiorly from the foramen rotundum inferiorly, marks the anteroinferior limit.^[10] Finally, the superolateral angle of the clival recess,

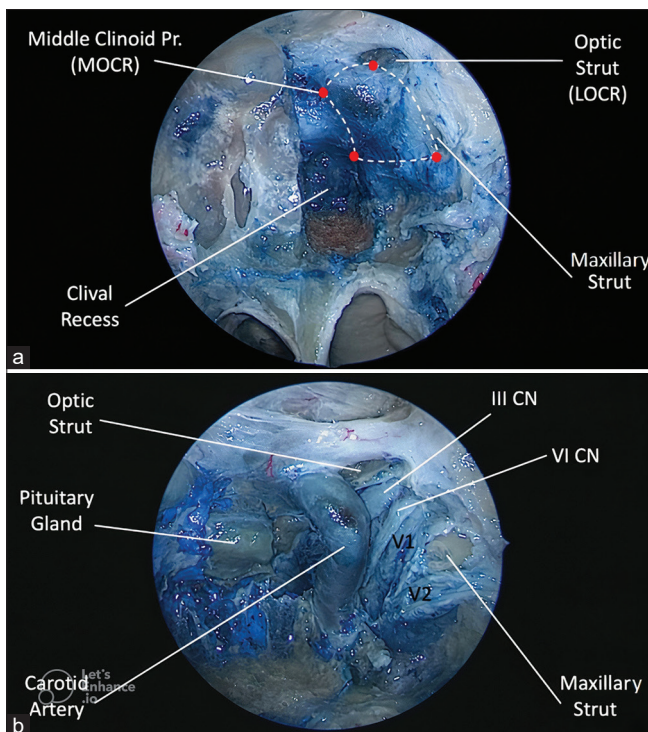


Figure 2: Endoscopic view of the left anterior wall of the cavernous sinus (CS). (a) The bone overlying the pituitary gland and the internal carotid artery (ICA) has been removed in the left side. The limits of the anterior wall are defined as follows: anterosuperiorly, by the lateral opticocarotid recess; posterosuperiorly, by the medial opticocarotid recess; anteroinferiorly, by the posteroinferior margin of the maxillary strut; and posteroinferiorly, by the superolateral angle of the clival recess. (b) The single layer of dura covering the anterior wall has been removed and the neurovascular contents of the CS are exposed, including the parasellar segment of the ICA, and the medial margins of III CN, VI CN, V1, and V2. III CN: Oculomotor nerve, VI CN: Abducens nerve, LOCR: Lateral opticocarotid recess, MOCR: Medial opticocarotid recess, V1: Ophthalmic nerve, V2: maxillary nerve.

which marks the transition between the sellar floor and the paraclival carotid, corresponds to the posteroinferior limit.^[11] In all of the specimens, a sellar configuration of the sphenoid sinus was found, posing no major challenge to identify this landmark; however, it is worth mentioning that in the case of presellar or conchal sinuses, a thorough and more careful dissection should be performed.

Four intervals were defined: distance A-B (from the LOCR to the MOCR); distance B-C (from the MOCR to the superolateral angle of the clival recess); C-D (from the superolateral angle of the clival recess to the posteroinferior margin of the maxillary strut); and D-A (from the posteroinferior margin of the maxillary strut to the LOCR) [Figure 3]. The following mean measurements were obtained: A-B, 17.25 mm (13–20 mm); B-C, 18.08 mm (17–19 mm); C-D, 34.25 mm (32–37 mm); and D-A, 18 mm (15–20 mm) [Table 2].

DISCUSSION

A proper understanding of the dural layers that form both the anterior and medial walls of the CS is of paramount importance. Although the concept of “anterior wall of the CS” has been previously mentioned in some publications, the exact anatomical landmarks that define this region have not been described before.^[2,6,21]

Previously, the descriptions of the medial wall of the CS were made by visualizing it through transcranial approaches, which made it impossible to speak of an anterior wall of the CS, but now, with endoscopic endonasal approaches that project a direct vision of the CS from another perspective, it is possible to precisely describe the anterior wall of the CS

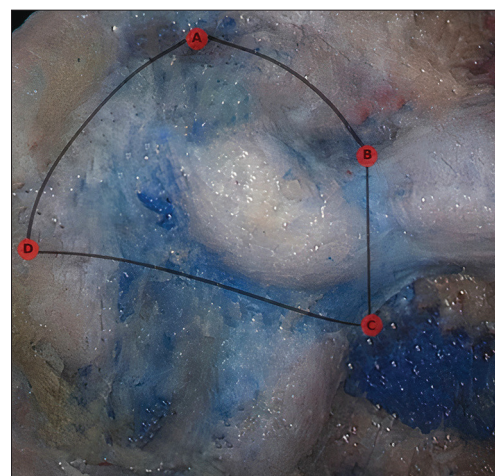


Figure 3: Endoscopic view of the right anterior wall of the cavernous sinus. (A) Lateral opticocarotid recess. (B) Medial opticocarotid recess. (C) Superolateral angle of the clival recess. (D) Posteroinferior margin of the maxillary strut.

in addition to the concept of the sphenoid segment of the medial wall.

However, a clarification of these two concepts is mandatory and particularly useful in endonasal endoscopic surgery. According to Yasuda *et al.*,^[23] the medial wall of the CS consists of two parts: the sellar portion which separates the pituitary fossa from the CS; and the sphenoidal portion which is formed by the dura lining the carotid sulcus adherent to the body of the sphenoid bone. It is important to recall that both the medial and anterior walls are single layered, with the former being covered by the meningeal layer and the latter by the periosteal layer that splits from the lateral border of the sella. From the endonasal endoscopic point of view, that sphenoidal portion of the medial wall of the CS (i.e., the anterior wall) deserves special consideration as it serves as a direct access to the CS. It should be noted that profound venous bleeding should be expected when opening the dura located in this region, and exhaustive hemostasis must be sought before proceeding with sinus exploration.

Through a dorsolateral perspective, the anterior border of the medial wall of the CS has been classically described as being attached to the margins of the superior orbital fissure,^[17] and no further attempts to make a thorough description of this structure have been found. With the development and refining of neuroendoscopic techniques, the anterior wall of the CS has become a fundamental anatomical structure which is traversed in a wide variety of surgical procedures. Fernandez-Miranda *et al.*^[6] reported a series of 12 patients (six chordomas, five petroclival meningiomas, and one epidermoid tumor) in which an interdural pituitary transposition with posterior clinoidectomy was performed to reach the retrosellar and interpeduncular areas. Zhang *et al.*^[24] describe a series of 14 patients (eight pituitary adenomas, three meningiomas, two squamous cell carcinomas, and one chondrosarcoma) in which a direct trans cavernous approach was performed for resection of intracavernous lesions, whether with a primary origin in the sinus or sellar lesions with parasellar extension. In these cases, the importance of a correct identification of the anterior wall lies on a safe access to the CS, allowing for a wider maneuverability for further dissection.

Defining the borders of the anterior wall of the CS might improve the understanding of the extension of certain tumors that secondarily involve this structure. For instance, in cases of pituitary adenomas with important CS invasion, the limits of the anterior wall of the CS may guide the extent of the approach to achieve a complete resection, assuming that the tumor is located entirely within the CS.

Another potential application of the correct identification of the anterior wall of the CS is illustrated by Fernandez-Miranda *et al.*,^[7] who described the dural opening through the lateral aspect of this wall to adequately expose the lateral

compartment of the CS and providing a direct access to the inferior compartment. This overcomes the limitation of the position of the ICA when trying to access the lateral compartment of the CS through a conventional transcavernous approach medial to the ICA [Figure 4]. Therefore, by exploring the limits of the anterior wall of the CS, multiple compartments within the CS can be entered safely.

To enhance the understanding of the lateral border of the anterior wall of the CS, the anatomical landmarks can be extrapolated to the findings that are seen through dorsolateral microsurgical approaches to the CS and other transcavernous approaches. From a dorsolateral perspective, the anterior border of the CS has been described to attach to the superior orbital fissure, while the inferior border is described to course at the inferior border of the ophthalmic nerve.^[17] Consequently, the maxillary nerve is not considered to be part of the CS. In our study, we confirmed that removing the anterior wall of the CS does not expose the maxillary nerve. However, it does provide access to the inferior-most portion of the CS even below the ophthalmic nerve. Therefore, the dura that lies just posterior to the maxillary strut provides

Table 2: Measurements of the limits of the anterior wall of the CS.

	Mean (mm)	S.D.	Median (mm)	Min (mm)	Max (mm)
Distance A-B	17.25	2.34	17.5	13	20
Distance B-C	18.08	0.79	18	17	19
Distance C-D	34.25	1.54	34.5	32	37
Distance D-A	18	1.53	18	15	20

CS: Cavernous sinus, S.D.: Standard deviation. As depicted in Figure 3: A: lateral opticocarotid recess; B: medial opticocarotid recess; C: superolateral angle of the clival recess; D: posteroinferior margin of the maxillary strut.

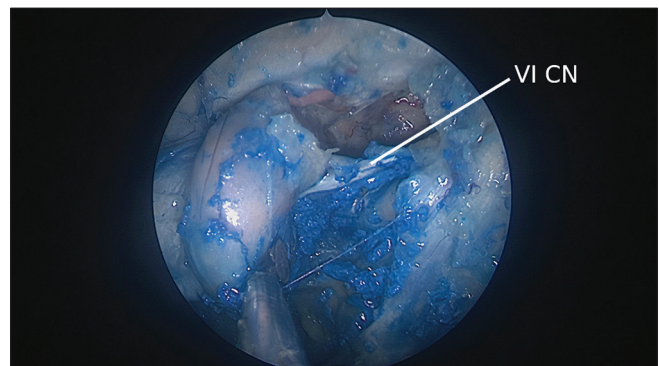


Figure 4: Dural opening of the lateral portion of the anterior wall of the CS allows for access to the lateral compartment of the cavernous sinus (CS). The internal carotid artery is being retracted medially and the VI CN can be seen as it enters the posterior wall of the CS. VI CN: Abducens nerve, CS: Cavernous sinus, ICA: Internal carotid artery.

access to the lateral compartment of the CS. The relevance of this distinction may be extrapolated to the description of the contents of the anteromedial middle fossa triangle,^[5] which has been used to achieve hemostasis of the CS.^[11]

The identification of the lateral border of the anterior wall of the CS may also be useful for other nontumoral pathologies such as encephaloceles and CSF leaks. In these cases, the defect can be found anterior to this structure, thus guiding the extent of bone removal for an adequate exposure in the lateral recess of the sphenoid.^[12,18] On the other hand, other endoscopic approaches, such as through the quadrangular space to access Meckel's cave lesions, do not require the opening of the CS. The quadrangular space is bounded medially by the paraclival ICA, inferiorly by the petrous ICA, laterally by V2, and superiorly by the sixth cranial nerve.^[13] By understanding the borders of the anterior wall of the CS, the quadrangular space can be entered without opening or dissecting the CS to identify these landmarks, thus stressing the importance of its accurate identification before the dural opening is performed [Figure 5].

It is important to note that the anatomy herein described should not be expected to be similar in cases of tumors extending to the CS. A tumor presenting cavernous invasion may bulge the anterior wall of the CS and significantly distort its usual appearance. Furthermore, these lesions may also displace the intracavernous structures depending on the origin and growth pattern of the tumor. For this reason, adjuvant tools (i.e., image-guidance systems, intraoperative Doppler, and recently, intraoperative ICG)^[4] are encouraged to locate the anatomical landmarks that bound the anterior wall of the CS as well as the structures that course through the CS, such as the ICA. This will allow a safe opening of this wall, providing access to different compartments of the CS.

We consider that a precise anatomical description and the definition of the endoscopic limits for the anterior wall of the

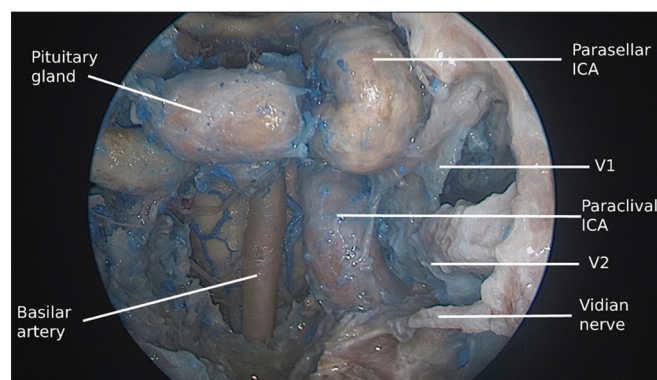


Figure 5: The quadrangular area is located below the inferior border of the anterior wall of the cavernous sinus (CS), allowing for a direct access to Meckel's cave without traversing the CS. ICA: internal carotid artery; V1: ophthalmic branch; V2: maxillary branch.

CS are of paramount importance for the neurosurgeon as this provides a simple yet helpful landmark to guide a safe access to the CS and to other surrounding areas.

CONCLUSION

The anterior wall of the CS represents the most rostral access door to the CS and its contents through endoscopic approaches. It is necessary to describe its limits and adopt a uniform anatomical language to properly understand this so complex area.

Declaration of patient consent

Patient's consent not required as there are no patients in this study.

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Nil.

Conflicts of interest

There are no conflicts of interest.

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