

Cavernous sinus: anatomy, histology and terminology

Seno cavernoso: anatomía, histología y terminología

Luis Delgado-Reyes^{1,2}, Armando Pérez-Torres³, Oscar O. Gasca-González^{4,5*}, and Julio C. Pérez-Cruz^{2,4,6}

¹Servicio de Neurocirugía, Hospital Juárez de México; ²Departamento de Anatomía, Facultad de Medicina, Universidad Nacional Autónoma de México; ³Laboratorio de Filogenia del Sistema Inmune y Mucosas, Departamento de Biología Celular y Tisular, Facultad de Medicina, Universidad Nacional Autónoma de México; ⁴Facultad de Medicina, Universidad Nacional Autónoma de México; ⁵Clínica de Medicina Familiar Santa María, Instituto de Seguridad y Servicios Sociales para los Trabajadores del Estado; ⁶Laboratorio de Técnicas Anatómicas, Academia de Anatomía Humana, Escuela Superior de Medicina, Instituto Politécnico Nacional. Ciudad de México, México

Abstract

Background: Although the cavernous sinus (CS) has been studied since 1695, its anatomy and name are still under discussion. **Method:** Anatomy and histology of 40 CS from human cadavers were studied, included both from a newborn specimen. **Results:** Two walls limit the CS, an inferior medial one composed only of the dura's outer layer and a superior lateral one consisting of both dura's layers. Sinusoidal veins pass through the lateral wall of the CS as a transition between venous tributaries and the CS. An endothelial layer covers the inner surface of the CS and the outer surface of the internal carotid artery. The space within the CS shows trabeculae, which are rarer in adults compared to the newborn. The loss of trabeculae in the CS may be a natural process along with life. **Conclusions:** In conclusion, the CS is a real sinus, and the term "cavernous sinus" is appropriately applied.

Keywords: Cavernous sinus. Internal carotid artery. Venous sinus. Lateral sellar compartment. Parasellar venous pathway.

Resumen

Antecedentes: Si bien el seno cavernoso (SC) ha sido estudiado desde 1695, su anatomía y nombre aún están bajo discusión. **Métodos:** Se estudiaron la anatomía y la histología de 40 SC de cadáveres humanos, incluyendo los dos de un recién nacido. **Resultados:** El SC está limitado por dos paredes, una inferomedial compuesta solo por la capa más externa de la duramadre y otra superolateral compuesta por ambas capas de la duramadre. Hay venas sinusoidales que atraviesan la pared lateral del SC formando una transición entre venas tributarias y el SC. Una capa endotelial recubre la superficie interna del SC y la superficie externa de la arteria carótida interna. El espacio dentro del SC presenta trabéculas, las cuales son escasas en el adulto en comparación con el recién nacido. La pérdida de trabéculas en el SC puede ser un proceso natural a lo largo de la vida. **Conclusiones:** En conclusión, el SC es un verdadero seno, por lo que el término «seno cavernoso» se aplica de forma correcta.

Palabras clave: Seno cavernoso. Arteria carótida interna. Seno venoso. Compartimento lateral selar. Vía venosa paraselar.

*Correspondence:

Oscar O. Gasca-González

E-mail: oog1708@gmail.com

2444-0507/© 2021 Academia Mexicana de Cirugía. Published by Permanyer. This is an open access article under the terms of the CC BY-NC-ND license (<http://creativecommons.org/licenses/by-nc-nd/4.0/>).

Date of reception: 28-02-2021

Date of acceptance: 25-05-2021

DOI: 10.24875/CIRUE.M23000432

Cir Cir (Eng). 2023;91(1):91-96

Contents available at PubMed

www.cirurgiaycirujanos.com

Introduction

The dura mater is the outermost meningeal layer made up of 2 layers according to some authors. The outermost layer includes the periosteum or, as some authors call it, the endosteum. The inner layer includes the true dura mater, the dural or meningeal layer¹⁻⁵. However, other authors propose that only the outer layer should be considered the dura mater^{6,7}. Venous sinuses are spaces that contain and drain venous blood from the brain and pericranial structures. The two layers of the dura mater outline the venous sinuses, according to Carpenter¹. According to Barr⁶, the 2 layers outline true dura mater and the periosteum. In any case, a venous sinus can be intra- or extradural, considering that “sinus” means “cavity.”

The term “cavernous sinus” (CS) was first coined by Winslow bak in 1732^{8,9}, and has been studied since 1695. However, there is still no consensus on its anatomy, histology, and terminology. The CS is a paired space, lateral to the sella turcica, located on the intracranial surface of the sphenoid and temporal bones. The internal carotid artery (ICA) runs through it, while the oculomotor and trochlear cranial nerves are found inside its lateral wall, as well as the ophthalmic and maxillary branches of the trigeminal nerve. The abducens cranial and sympathetic nerves run medial to the lateral wall inside the CS^{2-5,9-14}.

There is controversy on the location of the CS with respect to the dura mater; an extradural space for some authors^{6,10,11,15-21}, an intradural space for others^{3,9,22-27}.

Several reports on the interior anatomy of the CS describe it as a trabeculated space filled with blood^{8,9,14,24}, while others describe it as a space where a venous plexus surrounding the ICA is located^{2,10,15,28-30}. It is precisely because of this duality of concepts, that the term “cavernous sinus” has become a topic of discussion. Some authors maintain the concept of CS^{2-4,9,13,14,22,23,31,32}, while others prefer to call it lateral sellar compartment or parasellar venous pathway¹⁰. However, many of these observations were done in dissections under stereoscopic microscopy, and only a few were histological observations. Therefore, we decided to study the anatomy of the CS using both stereoscopic microscopy and histological sections.

Method

This was a cross-sectional, observational, and descriptive study of 40 cavernous sinuses from 19 adult

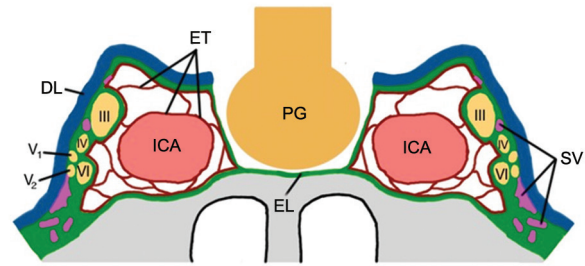


Figure 1. Internal anatomy of the cavernous sinus (coronal section). DL: dural layer; EL: endosteal layer; ET: endothelium; ICA: internal carotid artery; III, oculomotor nerve; IV, trochlear nerve; PG: pituitary gland; SV: sinusoidal veins; V₁: ophthalmic branch of the trigeminal nerve; V₂: maxillary branch of the trigeminal nerve; VI: abducens nerve.

human cadavers and 1 newborn whose cause of death was not cerebral. From the adult cadavers, blocks from the parasellar and sellar regions were obtained that were fixed in a 10% formaldehyde solution after being injected with liquid acetate colored with red paint through the common carotid arteries and internal jugular veins. The two cavernous sinuses of each specimen were dissected under microscopic vision, and then, paraffin sections stained with hematoxylin-eosin were obtained from each CS. The newborn's cavernous sinuses were fixed with a 1.5% glutaraldehyde solution to obtain semi-thin araldite sections stained with toluidine blue after being washed with a sodium cacodylate buffer solution (pH 7.2) through the common carotid arteries.

Results

We found that the CS superolateral wall is a thick wall made by both layers of the dura mater (Figs. 1 and 2). We saw venous channels in the lateral wall ending inside the CS, through which the afferent veins drain; these venous channels separate the two layers of the lateral wall. These channels are similar to those in the superior longitudinal sinus, those that Testut and Latarjet²⁴ referred to as sinusoidal veins (Figs. 3 and 4)²⁴.

The inferomedial wall is thinner than the lateral one and is only made up of the outer layer of the dura mater that represents the periosteum or endosteum of the base of the skull. This layer surrounds the structures inside the CS lateral wall (oculomotor and trochlear cranial nerves, ophthalmic branches, and maxillary branches of the trigeminal nerves). We also found that the endosteum surrounds the abducens

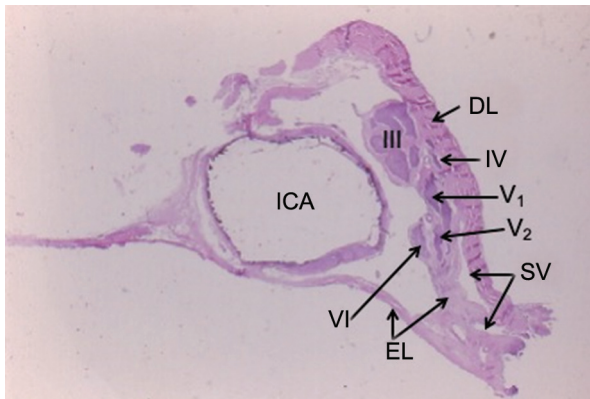


Figure 2. Microscopic image of the cavernous sinus. Coronal section of a paraffin block stained with hematoxylin-eosin. DL: dural layer; EL: endosteal layer; ICA: internal carotid artery; III: oculomotor nerve; IV: trochlear nerve; SV: sinusoidal veins; V₁: ophthalmic branch of the trigeminal nerve; V₂: maxillary branch of the trigeminal nerve; VI: abducens nerve.

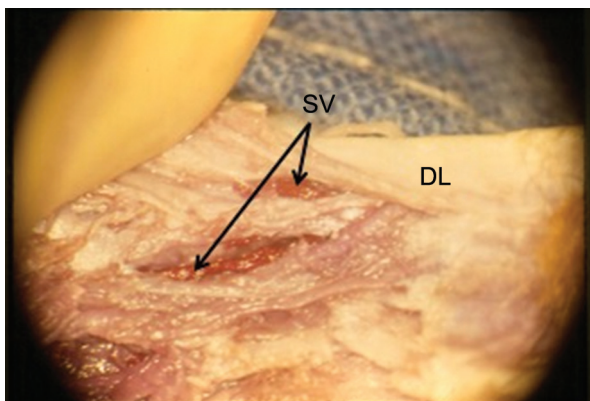


Figure 3. Dissection of the cavernous sinus lateral wall, longitudinally traversed by the sinusoidal veins. DL: dural layer; SV: sinusoidal veins.

cranial and sympathetic nerves that run medial to the CS lateral wall (Fig. 5).

The cavernous portion of the ICA runs inside the CS. There are multiple irregular trabeculae between the walls of the CS and the ICA. A layer of modified endothelium covers the inner surface of the CS and reflects to cover the tunica adventitia of the ICA. This arrangement resembles the visceral peritoneum (Fig. 6).

The newborn's CSs showed more trabeculae than the adults' CSs.

Discussion

Our results are consistent with those proposed by Carpenter¹, Loveren et al.², Campero et al.³, and



Figure 4. Microscopic image of the cavernous sinus (close-up of figure 2). Coronal section of a paraffin block stained with hematoxylin-eosin. ET: endothelium; SV: sinusoidal veins.

Boardman et al.¹⁴, that the dura mater is made up of two layers. It is well known that some venous sinuses are limited by the two layers of the dura mater, as it is the case of the superior longitudinal sinus, or solely by the dural layer (the case of the inferior longitudinal sinus).

We found that the CS is a unique structure divided by trabeculae, not a venous plexus with multiple veins. This is consistent with the descriptions given by authors such as Harris and Rhoton⁹, among others^{8,14,24}, but in contrast with what other authors have described^{2,10,15,28-30}. Given this finding, we consider the use of the term "cavernous sinus" is the proper term to use (Fig. 7). However, Hashimoto et al.⁴ argue that both concepts are not mutually exclusive and that based on the different variations in the development of the CS, it can be arranged as a sinusoidal venous space with trabeculae or as a venous plexus with multiple veins.

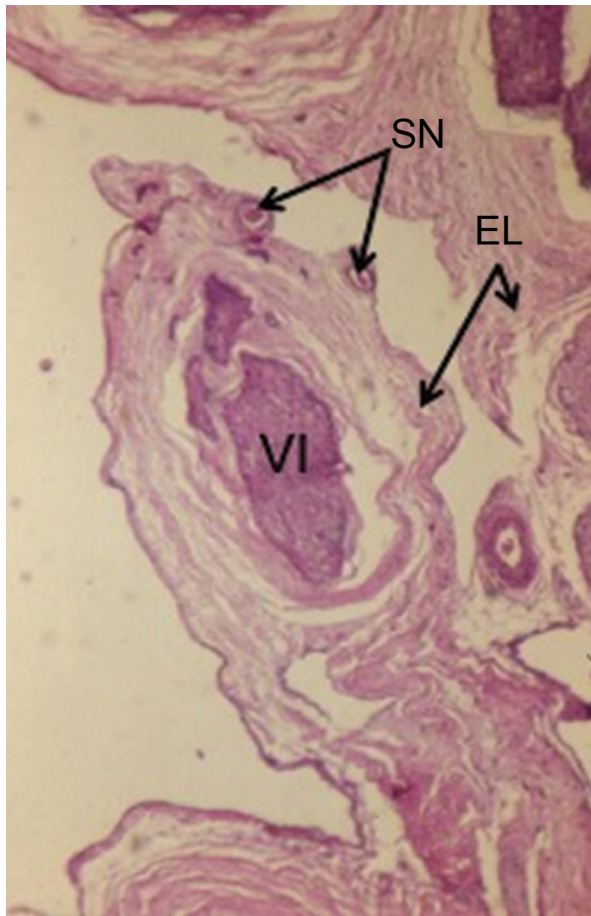


Figure 5. Microscopic image of the cavernous sinus (close-up to the abducens nerve). Coronal section of a paraffin block stained with hematoxylin-eosin. EL, endosteal layer; SN, sympathetic nerves; VI, abducens nerve.

We agree with the authors who propose that the CS is limited by two walls, an inferomedial and a superolateral one. The inner and outer layers of the dura mater create the lateral wall, which also makes up the roof of the CS^{3,14}.

Although it has been described that the abducens cranial and sympathetic nerves run medial to the lateral wall. Inside the CS, these observations have mostly been made through microscopic dissections³ or imaging rather than histological studies¹⁶. In the present study, it has been demonstrated that these nerves are surrounded by lateral wall endosteum (Figs. 2 and 5). These observations are consistent with what Hashimoto et al.⁴ have reported during the embryonic development of the CS.

Our observations prove that the inferomedial wall is thinner and made up of only the outer layer of the dura

mater, which reinforces the notion proposed by Camp-ero et al.³, who also suggested that this wall creates, simultaneously, the hypophyseal fossa lateral wall.

The CS lateral wall is a structure that, according to some authors, is of dual embryonic origin: on the one hand, the inner wall, actually limiting the CS, originates from extracranial structures and drains venous blood through the superior ophthalmic vein, the only afferent before birth. On the other hand, based on this theory, the outer layer of the CS lateral wall would have a different embryonic origin from a primitive tentorial sinus that originally, before the 8th week of gestation, drains blood from the superficial middle cerebral vein (SMCV). According to this theory, the formation of the CS lateral wall involves the fusion of both systems, the CS itself and the primitive tentorial sinus^{31,34,35}. These two structures would fuse and, depending on the degree of fusion, would give rise to 3 types of SMCV drainage into the CS: 1) persistence of the primitive tentorial sinus in adults, known as the paracavernous sinus, which receives the SMCV; 2) the formation of a venous sinus inside the CS lateral wall, the laterocavernous sinus, which also receives blood from the SMCV and may or may not have secondary connections to the CS, and 3) direct drainage of the SMCV into the CS^{31,35,36}. According to Gailloud et al.³¹, the first pattern is the most common of them all, while the third one is the least common, although the most reported of all. In this regard, our findings of venous structures within the lateral wall suggest the presence of sinusoidal veins draining directly into the CS and receiving blood from the CS afferent veins. We consider that, since the observations made by Gailloud et al.³¹ were angiographic, the pattern found in our study can be easily mistaken with the second and third patterns described by Gailloud et al.³¹ and other authors³⁶.

The findings that the endothelium that covers the CS inner surface reflects to cover the outer layer of the tunica adventitia of the ICA are not described in the literature we have looked into¹⁻³⁶.

The presence of fewer trabeculae in the newborn's CSs compared to adults' CSs suggests the possible disappearance of trabeculae throughout life. These findings are consistent with what Hashimoto et al.⁴ have reported, who found less venous spaces during fetal development.

Conclusions

The CS is a true venous sinus made up by two walls, an inferomedial one consisting only of the

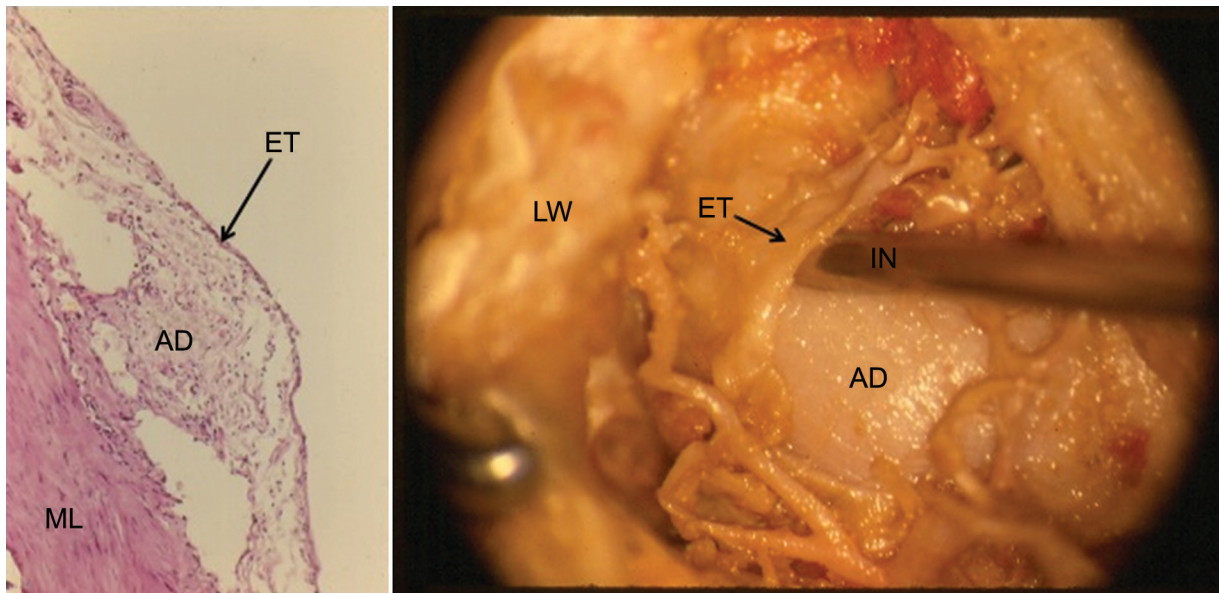


Figure 6. External surface of the internal carotid artery (ICA) covered by a thin layer of modified endothelium. **A:** microscopic image of the cavernous sinus (CS) (close-up to the ICA). **B:** dissection of the CS lateral wall (the ICA tunica adventitia is separated from the endothelium using an insulin needle). AD: adventitia of the ICA; ET: endothelium; IN: insulin needle; LW: cavernous sinus lateral wall; ML: muscular layer of the ICA.

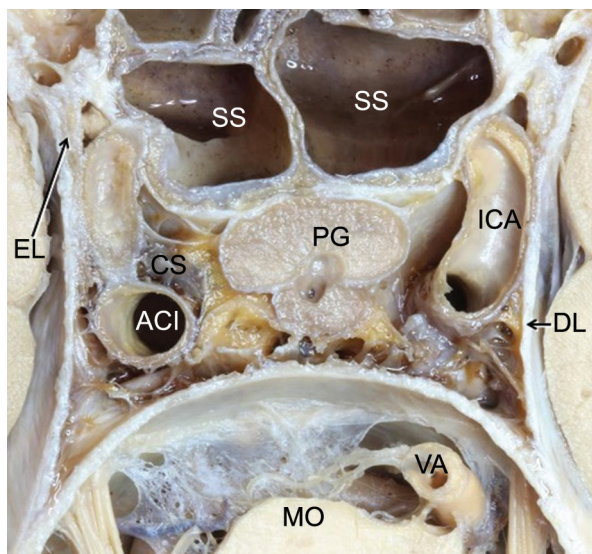


Figure 7. Cross-section of a block of the sellar and parasellar regions. CS: cavity of the cavernous sinus showing the internal trabeculae; DL: dural layer; EL: endosteal layer; ICA: internal carotid artery; MO: medulla oblongata; PG: pituitary gland; SS: sphenoidal sinuses; VA: vertebral artery.

outer layer of the dura mater, and a superolateral one including both layers of the dura mater. Inside the CS lateral wall, there are sinusoidal veins showing the transition between the CS afferent veins and

the CS itself. Both the inner surface of the CS walls and the outer surface of the ICA are covered by an endothelial layer. It is possible that, in time, the loss of trabeculae inside the CS is just a natural process.

Funding

None whatsoever.

Conflicts of interest

None reported.

Ethical disclosures

Protection of human subjects and animals in research. The authors declare that the procedures followed were in accordance with the regulations of the relevant clinical research ethics committee and with those of the Code of Ethics of the World Medical Association (Declaration of Helsinki).

Patients' data protection. The authors declare that no patient data appear in this article.

Right to privacy and informed consent. The authors declare that no patient data appear in this article.

References

- Parent A. Carpenter's Human neuroanatomy. 9th ed. Baltimore: Williams & Wilkins; 2006.
- Kawase T, van Loveren H, Keller JT, Tew JM. Meningeal architecture of the cavernous sinus: clinical and surgical implications. *Neurosurgery*. 1996;39:527-34;discussion 534-6.
- Campero A, Campero AA, Martins C, Yasuda A, Rhoton AL Jr. Surgical anatomy of the dural walls of the cavernous sinus. *J Clin Neurosci*. 2010;17:746-50.
- Hashimoto M, Yokota A, Yamada H, Okudera T. Development of the cavernous sinus in the fetal period: a morphological study. *Neurol Med Chir (Tokyo)*. 2000;40:140-50.
- Klinger DR, Flores BC, Lewis JJ, Barnett SL. The treatment of cavernous sinus meningiomas: evolution of a modern approach. *Neurosurg Focus*. 2013;35:E8.
- Kiernan JA, Rajakumar N, Barr's The human nervous system: an anatomical viewpoint. 10th ed. Philadelphia: Lippincott Williams & Wilkins; 2014.
- Rogers R, Epker BN. Carotid-cavernous sinus fistula accompanying mid-facial fractures: report of case. *J Oral Surg*. 1972;30:429-32.
- Bedford MA. The "cavernous" sinus. *Br J Ophthalmol*. 1966;50:41-6.
- Harris FS, Rhoton AL. Anatomy of the cavernous sinus. A microsurgical study. *J Neurosurg*. 1976;45:169-80.
- Taptas JN. The so-called cavernous sinus: a review of the controversy and its implications for neurosurgeons. *Neurosurgery*. 1982;11:712-7.
- Cavallo LM, Cappabianca P, Galzio R, Iaconetta G, de Divitiis E, Tschabitscher M. Endoscopic transnasal approach to the cavernous sinus versus transcranial route: anatomic study. *Neurosurgery*. 2005;56(2 Suppl):379-89;discussion 379-89.
- Isolan G, de Oliveira E, Mattos JP. Microsurgical anatomy of the arterial compartment of the cavernous sinus: analysis of 24 cavernous sinus. *Isolan Arq Neuropsiquiatr*. 2005;63:259-64.
- Dolenc VV. Surgery of vascular lesions of the cavernous sinus. *Clin Neurosurg*. 1990;36:240-55.
- Boardman JF, Rothfus WE, Dulai HS. Lesions and pseudolesions of the cavernous sinus and petrous apex. *Otolaryngol Clin North Am*. 2008;41:195-213.
- Parkinson D. Surgical anatomy of the lateral sellar compartment (cavernous sinus). *Clin Neurosurg*. 1990;36:219-39.
- Kehrli P, Maillot C, Wolff MJ. The venous system of the lateral sellar compartment (cavernous sinus): an histological and embryological study. *Neurol Res*. 1996;18:387-93.
- Kehrli P, Ali MM, Maillot C, Fortman J, Misra M, Dujovny M. Comparative microanatomy of the lateral wall of the 'cavernous sinus' in humans and the olive baboon. *Neurol Res*. 1997;19:571-6.
- Kehrli P, Ali M, Reis M Jr, Maillot C, Dietemann JL, Dujovny M, et al. Anatomy and embryology of the lateral sellar compartment (cavernous sinus) medial wall. *Neurol Res*. 1998;20:585-92.
- Yokoyama S, Hirano H, Moroki K, Goto M, Imamura S, Kuratsu JI. Are nonfunctioning pituitary adenomas extending into the cavernous sinus aggressive and/or invasive? *Neurosurgery*. 2001;49:857-62;discussion 862-3.
- Dietemann JL, Kehrli P, Maillot C, Diniz R, Reis M Jr, Neugroschl C, et al. Is there a dural wall between the cavernous sinus and the pituitary fossa? Anatomical and MRI findings. *Neuroradiology*. 1998;40:627-30.
- Songtao Q, Yuntao L, Jun P, Chuanping H, Xiaofeng S. Membranous layers of the pituitary gland: histological anatomic study and related clinical issues. *Neurosurgery*. 2009;64(3 Suppl):1-9;discussion 9-10.
- Moreira MB. Physiological importance of the conjugation of the internal carotid artery and cavernous sinus. *Med Hypotheses*. 1998;50:389-91.
- van Overbeeke JJ, Jansen JJ, Tulleken CA. The cavernous sinus syndrome. An anatomical and clinical study. *Clin Neurol Neurosurg*. 1988;90:311-9.
- Testut L, Latarjet A. *Tratado de anatomía humana*. Barcelona: Salvat; 1985.
- Yasuda A, Campero A, Martins C, Rhoton AL Jr, de Oliveira E, Ribas GC. Microsurgical anatomy and approaches to the cavernous sinus. *Neurosurgery*. 2008;62(6 Suppl 3):1240-63.
- Marinkovic S, Gibo H, Vucevic R, Petrovic P. Anatomy of the cavernous sinus region. *J Clin Neurosci*. 2001;8(Suppl 1):78-81.
- Tobenias-Dujardin AC, Duparc F, Ali N, Laquerriere A, Muller JM, Freger P. Embryology of the internal carotid artery dural crossing: apropos of a continuous series of 48 specimens. *Tobenias Surg Radiol Anat*. 2005;27:495-501.
- Bonnet P. [Cavernous sinus and cavernous sinus syndrome]. *J Med Lyon*. 1955;36:593-606.
- Hamby WB. Carotid-cavernous fistula (pulsating exophthalmos). *GP*. 1968;37:92-4.
- Papadakis N, Lukl ND. The cavernous sinus. 44th Ann Meet Am Assoc Neurosurg Surg. San Francisco, California; 1976.
- Gailloud P, San Millán Ruiz D, Muster M, Murphy KJ, Fasel JH, Rüfenacht DA. Angiographic anatomy of the laterocavernous sinus. *AJNR Am J Neuroradiol*. 2000;21:1923-9.
- Dalgıç A, Boyacı S, Aksoy K. Anatomical study of the cavernous sinus emphasizing operative approaches. *Turk Neurosurg*. 2010;20:186-204.
- Keller HM, Imhof HG, Valavanis A. Persistent cervical intersegmental artery as a cause of recurrence of a traumatic carotid-cavernous fistula: case report, with emphasis on Doppler ultrasound diagnosis. *Neurosurgery*. 1982;10:492-8.
- Hakuba A, Ohata K, Nakanishi N, Bae HG, Branco Soares S. Developmental anatomy of the cavernous sinus. En: Hakuba A, editor. *Surgery of the intracranial venous system*. New York: Springer; 1996. 26-35.
- Knosp E, Müller G, Perneczky A. Anatomical remarks on the fetal cavernous sinus and on the veins of the middle cranial fossa. En: Dolenc VV, editor. *The cavernous sinus: a multidisciplinary approach to vascular and tumorous lesions*. New York: Springer; 1987. 104-16.
- San Millán Ruiz D, Gailloud P, de Miquel Miquel MA, Muster M, Dolenc VV, Rüfenacht DA, et al. Laterocavernous sinus. *Anat Rec*. 1999;254:7-12.