ARAŞTIRMA / ORIGINAL ARTICLE

Gülhane Tıp Dergisi 2010; 52: 162-166

Radiological and anatomical evaluation of the cranial nerves running lateral wall of the cavernous sinus

Yalçın Kırıcı (*), Cenk Kılıç (*), Murat Kocaoğlu (**), Hasan Ozan (*)

SUMMARY

The cavernous sinus is a clinically important structure. Injuries of the cranial nerves running lateral wall of the cavernous sinus may occur during surgery of this region. The descriptions of the sinus and its contents show great variation. To demonstrate the route of cranial nerves within the cavernous sinus with magnetic resonance imaging is useful. In this study the dimension and shape of the cavernous sinuses and courses of the nerves on its lateral wall were investigated radiologically and anatomically. In addition, the trabeculated venous space of the sinus was studied. Fifty magnetic resonance images with normal pituitary gland were chosen for radiological study, and 10 fetal and 5 adult cadavers were used for anatomical study. Asymmetric cavernous sinuses were encountered during magnetic resonance imaging. Differences in the courses of the cranial nerves on the lateral wall of this sinus were identified. The width of the sinus was identified in fetuses and adults. To know the anatomy of the cavernous sinus's related structures will provide a great benefit in minimizing the rate of complications which may occur during the resection of tumors of the cavernous sinus and the hypophysis, or other surgical procedures at this region.

Key words: *Cavernous sinus, maxillary nerve, oculomotor nerve, ophthalmic nerve, trochlear nerve*

ÖZET

Sinus kavernozusun lateral duvarında seyreden kraniyal sinirlerin radyolojik ve anatomik olarak değerlendirilmesi

Sinus kavernozus klinik olarak önemli bir yapıdır. Sinus kavernozusa yakın bölgenin cerrahisi esnasında sinus kavernozusun lateral duvarında seyreden kraniyal sinirlerin hasarı görülebilir. Sinus kavernozusun tanımı ve onun içeriği büyük farklılıklar gösterir. Sinus kavernozus içerisindeki kraniyal sinirlerin manyetik rezonans görüntüleme yöntemi ile gösterilmesi yararlıdır. Bu çalışmada sinus kavernozusun çapı ve şekli, onun dış duvarında bulunan sinirlerin seyri radyolojik ve anatomik olarak incelendi. İlave olarak, sinusun trabeküler venöz boşluğu çalışıldı. Normal glandula pituitaria'ya sahip 50 manyetik rezonans görüntüsü radyolojik çalışma için seçildi. On fetal ve 5 erişkin kadavra anatomik çalışma için kullanıldı. Sinus kavernozusun boyutu ve şekli ile onun lateral duvarındaki kraniyal sinirlerin seyri araştırıldı. Manyetik rezonans görüntüleme sırasında asimetrik kavernöz sinüslerle karşılaşıldı. Sinus kavernozusun lateral duvarındaki kraniyal sinirlerin seyir farklılıkları tespit edildi. Fetuslardaki ve erişkinlerdeki sinus genişliği ortaya kondu. Sinus kavernozusa komşu yapıların anatomisini bilmek sinus kavernozus ve hipofiz tümörlerinin rezeksiyonu veya bu bölgedeki diğer cerrahi uygulamalar esnasında ortaya çıkabilen komplikasyonları azaltmada büyük katkı sağlayacaktır.

Anahtar kelimeler: *Sinus kavernozus, nervus maxillaris, nervus oculomotorius, nervus ophthalmicus, nervus trochlearis*

* Department of Anatomy, Gulhane Military Medical Faculty

**Department of Radiology, Gulhane Military Medical Faculty

Reprint request: Yalçın Kırıcı, Department of Anatomy, Gulhane Military Medical Faculty, Etlik-06018, Ankara, Turkey

E-mail: ykirici@gata.edu.tr

Date submitted: January 08, 2010 • **Date accepted:** May 17, 2010

Introduction

The cavernous sinus (CS), located in a space between endosteal and meningeal dura, is a vascular channel of great importance and its contents show great variation (1,2). The CS extending from the tip of the petrous bone to the medial part of the superior orbital fissure, has a parasellar position (3,4). The CS contains the venous plexus, internal carotid artery (ICA) and abducent nerve, and on the its lateral wall cranial nerves (CNs) III (oculomotor nerve), IV (trochlear nerve), V1 (ophthalmic nerve) and V2 (maxillary nerve) (4,5). With the increasing frequency of surgical procedures to the CS, knowledge of the microanatomy of the CS has become essential. The most frequent complication seen during the CS surgery is the injury of cranial nerves. In addition, the contents of this sinus may be affected by trauma, tumors or infections (6). For these reasons, the knowledge of the anatomy of the cranial nerves on the lateral wall of this sinus is important. Imaging of CNs III, IV, V1, V2, and VI in the CS has been reported with both magnetic resonance imaging (MRI) and computed tomography (CT) (7-9). But a precise evaluation of these CNs in the CS is difficult by these methods. The three dimensional (3D) constructive interference in steady state (CISS) sequence depicts the small structures surrounded by the cerebrospinal fluid with high contrast and high spatial resolution (10), therefore, we assumed that contrast enhanced 3D-CISS MRI is more suitable for the evaluation of CNs in the sinus. In this study, we evaluated the normal structures (dimension and shape) in the CS with the 3D-CISS MRI and dissection. In addition, the trabeculated venous space of the sinus was studied.

The anatomy of the CS is still being investigated and different approaches to the region are given, which are of significant importance in guiding surgical intervention. This study presents many different topographic aspects and measurements of the region.

Material and Methods

This study examined 15 formalin-fixed human cadavers (30 sides) without detectable malformations. These cadavers were from 5 adults (3 males and 2 females), ranging from 45 to 70 years old (average 56 years) and 10 spontaneously aborted fetuses (6 males and 4 females), ranging from 22 to 36 weeks of gestation (average 29 weeks). Permission had been obtained from the local ethics committee of Ankara Maternity and Health Academic and Research Hospital (Ref. No:5/16.10.03). In addition, 50 3D-CISS MRI with normal pituitary gland were chosen for radiological study. Patients, who were scanned with MRI, were 18 males and 32 females, ranging from 9 to 58 years old of age (average 28 years).

Following the removal to the calvaria and exposure of the brain, 15 CS were macroscopically examined. The sites of entrance for the oculomotor and trochlear nerves into the tentorial notch and roof of the sinus were identified before starting the dissection. A longitudinal incision was made throughout the entire length of the lateral surface of the sinus. The roof and the upper part of the lateral wall were removed, afterwards the anterior clinoid process was removed to give a better exposure of the structures of the superior part of the CS, and the CS region was microdissected under the stereoscopic microscope (Stemi 2000; Carl Zeiss, Jena, Germany). After removing the trabeculae and blood remnants, exposured the entire CS, the routes neural structures could easily be identified.

The important landmarks of the CS are CNs III, IV, V1 and V2 on the lateral wall of this sinus. Shape, location and dimension of the CS, courses of the nerves on the lateral wall of the CS wall were investigated. In addition, the trabeculated venous space of the sinus was studied.

We incorporated the contrast enhanced 3D-CISS sequence into the pituitary gland MRI protocol. Following the T2 and T1-weighted coronal, and T1-weighted sagittal sequence, we obtained postcontrast CISS and T1-weighted scans. Postcontrast coronal 3D-CISS images were obtained using the following parameters: TR/TE 11.7/5.8 ms; 180×180 matrix; 160×180 mm FOV; 0.5 mm slice thickness and two acquisitions. This sequence added only extra 2-3 minutes to total examination time. The intra cavernous segments of cranial nerves were retrospectively evaluated in midcoronal postcontrast CISS and T1-weighted image through the pituitary gland-stalk junction by one radiologist.

Results

The CS was observed between the petrous apex of the temporal bone and the superior orbital fissure. The width of the CS was 6-12 mm (mean 10.08) in the right side and 5-12 mm (mean 8.42) in the left side. The CS appeared symmetric in 13 cases, while it appeared asymmetric in 36 cases. The CS was not measured in one case, because Meckel's cave lay within the CS. The CNs III, IV, V1 and V2 were observed over lateral wall of the CS (Figure 1). The CN III pierced the roof of the sinus lateral to the posterior clinoid process and ran in the upper part of the lateral wall. The CN III travels superolateral to the ICA. The CN III was identified in all cases on both 3D CISS MRIs and dissection of the cadavers. However, significant differences were noted in all other CNs between the two techniques. The CN IV generally runs paralel, inferior and close to the CN III on the lateral wall of the sinus. The CN IV (which is much thinner than CN III) courses lateral to the ICA. The CN IV is inferior to the CN

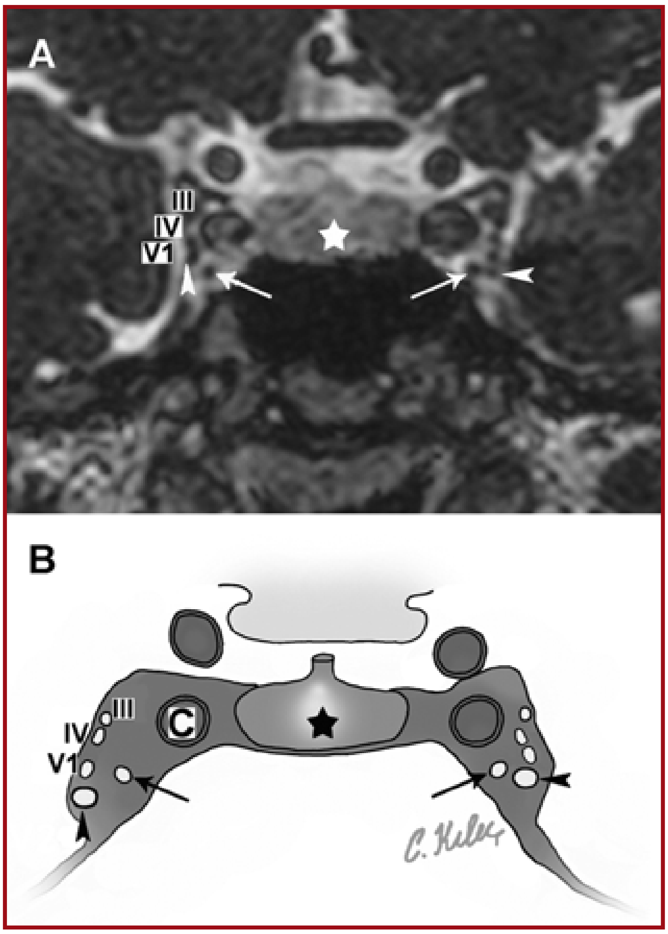

Figure 1. A. Coronal CISS image at the level of the pituitary gland (star) demonstrates that left 6th cranial nerve (arrow) is close to the lateral wall of the cavernous sinus at the level of the V2 branch (arrowhead) of the 5th nerve. **B.** The schematic drawing of the image. The pituitary gland (star), internal carotid artery (C), 3rd nerve (III), 4th nerve (IV), 6th nerve (arrow) and, V1 (V1) and V2 branches (arrowhead) of the 5th nerve

III. We also observed two CN IV (4%) lying very close to V1 for its whole course on the lateral wall of the CS. The V1 courses inferolateral to the upper portion of the ICA siphon, and V2 runs in the inferolateral aspect of the CS (Figure 2). In all fetuses, the CNs III, IV, V1 and V2 travels from medial to lateral, respectively.

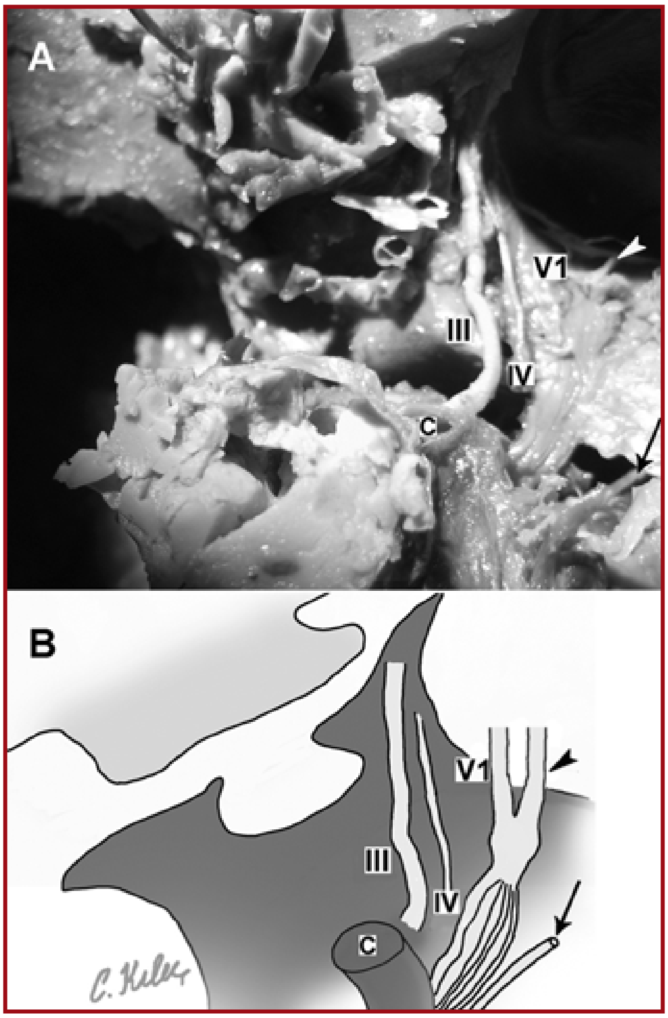

Figure 2. A. The structures running lateral wall of the cavernous sinus in adult cadaver. **B.** The schematic drawing of the structures. The internal carotid artery (C), 3rd nerve (III), 4th nerve (IV), 6th nerve (arrow) and, V1 (V1) and V2 branches (arrowhead) of the 5th nerve

We found that all CN III were thick and all CN IV were thin. Also, the CN III and IV were very close in two cases (Figure 3). Intracavernous segments of CNs III, IV, V1 and V2 were identified on 3D CISS MRIs in 50 (100%), 49 (98%), 47 (94%) and 41 (82%) of the 50 CS, respectively. In 35 (70%) of 50 patients, all CNs in the CS were identified (Figure 1). We showed no apparent trabeculation in the fetal material but all of the adult sinuses had a few trabeculae running inferiorly from the medial side of the internal carotid artery to the floor of the CS (Figure 4).

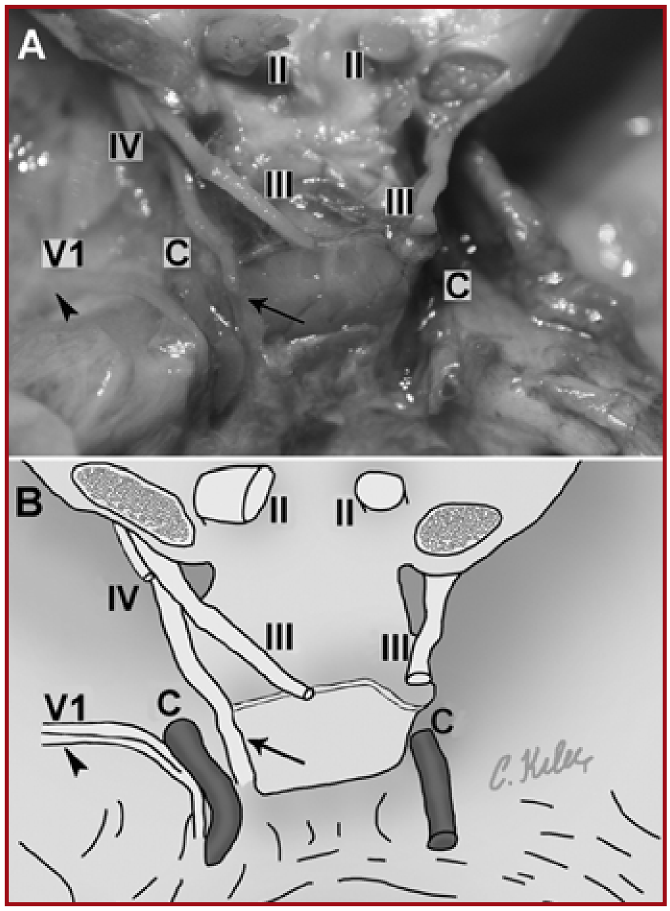

Figure 3. A. The structures running lateral wall of the cavernous sinus in fetal cadaver. **B.** The schematic drawing of the structures. The internal carotid artery (C), 2nd nerve (II), 3rd nerve (III), 4th nerve (IV), 6th nerve (arrow) and, V1 (V1) and V2 branches (arrowhead) of the 5th nerve

Figure 4. The trabeculation structures in the cavernous sinus in adult cadaver. Trabeculations are showed (arrow)

Discussion

The CS is of particular importance due to its particular location, contents and relations. Many studies have been made on this region and its contents, but the exact nature of the CS has not yet been clearly defined. The anatomy of the CS has been studied both on the adult and fetal cadaveric studies (2,5,6,11-14). Many researchers have reported the CS structures on MRI (7-10) and on CT (15). The contrast-enhanced 3D CISS sequence has been used to demonstrate various other CNs detectability rates for CNs III, IV, V1, and V2 on the CS were 100%, 61%, 92% and 88% respectively (10). We identified intracavernous segments of CNs III, IV, V1 and V2 on contrast-enhanced 3D CISS MRI in 50 (100%), 49 (98%), 47 (94%) and 41 (82%) of the 50 the CS, respectively. These rates are higher than those of the previous studies (9,10). Cranial nerves III and IV, V1 and VI, and V2 were seen on 75% of dynamic images each; they were seen, respectively, on 62%, 30%, and 28% of conventional postcontrast images (9). The images depicted the intracavernous segments of CNs III, IV, V1, V2, and VI in 76 (100%), 46 (61%), 70 (92%), 67 (88%), and 73 (96%) of the 76 sinuses, respectively (10).

We found that CN IV sometimes ran close to CN V1. Tuccar et al. noticed two trochlear nerves (5%) curving along the lateral wall at a distance from nerve III (14).

CN III was identified in all cases on both contrast-enhanced 3D CISS and contrast-enhanced T1-weighted MR imaging. However, significant differences were noted in all other CNs between the two imaging techniques (10). MR demonstrates the cranial nerves effectively. Cranial nerves III, V1, V2, and VI on the lateral wall of the CS also can be shown with MR because they are surrounded by low-intensity signal from flowing blood (7). Unfortunately, we were unable to image cranial nerve IV on the CS, probably because of its small size and close proximity to cranial nerve III. Many authors have included the V2 component of the trigeminal nerve as a component of the CS (3,16). Most authors have considered the V2 as a component of the CS (4,16). Korogi et al. reported that V1 and V2 were seen on 75% of dynamic MR images but on only 28% of conventional post contrasted MRI (9). Yagi et al. reported that V2 was seen in the CS in 88% of the patients (10). The finding of this author is similar to our results (82%). The presence of the trabeculae of the adult sinuses have been demonstrated in many studies (3,4,12). In the literature, we found very little to work with the fetus. The trabeculae were virtually non-existent in fetal materials by Bedford (1). The result of this is similar to our present study. Many researchers have expressed that 3D-CISS MRI is more useful than other methods (10,17,18). This imaging technique is useful for the differentiation between paraclinoid and cavernous sinus aneurysms. The CS has a very complex structure and important vascular and neural contents. It is extremely difficult for the surgeon to reach and operate on the sinus. Understanding of the microsurgical anatomy of the region is essential for the surgeon operating in and around the CS for neoplastic and vascular lesions. This study and other anatomic and morphometric studies of the region performed on cadavers and radiological materials will provide a great benefit in minimizing the rate of complications which may occur during the resection of tumors of the cavernous sinus and the hypophysis, or other surgical procedures at this region.

References

1. Bedford MA. The cavernous sinus. Br J Ophthalmol 1966; 50: 41-46.
2. Kawase T, van Loveren H, Keller JT, Tew JM. Meningeal architecture of the cavernous sinus: clinical and surgical implications. Neurosurgery 1996; 39: 527-534.
3. Moore KL, Dalley AF. Clinically Oriented Anatomy. 4th ed. Philadelphia: Lippincott Williams & Wilkins, 1999: 692-693.
4. Williams PL, Bannister LH, Berry MM, et al. Gray's Anatomy. 38th ed. New York: Churchill-Livingstone, 1995: 1585-1586.
5. 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: 387-393.
6. Kayalioglu G, Govsa F, Erturk M, Pinar Y, Ozer MA, Ozgur T. The cavernous sinus: topographic morphometry of its contents. Surg Radiol Anat 1999; 21: 255-260.
7. Daniels DL, Pech P, Mark L, Pojunas K, Williams AL, Haughton VM. Magnetic resonance imaging of the cavernous sinus. AJR Am J Roentgenol 1985; 144: 1009-1014.
8. Dietemann JL, Kehrli P, Maillot C, et al. Is there a dural wall between the cavernous sinus and the pituitary fossa? Anatomical and MRI findings. Neuroradiology 1998; 40: 627-630.
9. Korogi Y, Takahashi M, Sakamoto Y, Shinzato J. Cavernous sinus: correlation between anatomic and dynamic gadolinium-enhanced MR imaging findings. Radiology 1991; 180: 235-237.
10. Yagi A, Sato N, Taketomi A, et al. Normal cranial nerves in the cavernous sinuses: contrast-enhanced three-dimensional constructive interference in the steady state MR imaging. AJNR Am J Neuroradiol 2005; 26: 946-950.
11. Kehrli P, Ali M, Reis MJr, et al. Anatomy and embryology of the lateral sellar compartment (cavernous sinus) medial wall. Neurol Res 1998; 20: 585-592.
12. Marinkovic S, Gibo H, Vucevic R. Anatomy of the cavernous sinus region. J Clin Neurosci 2001; 1: 78-81.

13. Tubbs RS, Hill M, May WR. Does the maxillary division of the trigeminal nerve traverse the cavernous sinus? An anatomical study and review of the literature. Surg Radiol Anat 2008; 30: 37-40.
14. Tuccar E, Uz A, Tekdemir I, Elhan A, Ersoy M, Deda H. Anatomical study of the lateral wall of the cavernous sinus, emphasizing dural construction and neural relations. Neurosurg Rev 2000; 23: 45-48.
15. Chui M, Tucker W, Hudson A, Bayer N. High resolution CT of Meckel's cave. Neuroradiology 1985; 27: 403-409.
16. Snell RS. Clinical neuroanatomy for medical students. 4th ed. Philadelphia: Lippincott Williams & Wilkins, 2001: 496-498.
17. Zausinger S, Yousry I, Brueckmann H, Schmid-Elsaesser R, Tonn JC. Cavernous malformations of the brainstem: three-dimensional-constructive interference in steady-state magnetic resonance imaging for improvement of surgical approach and clinical results. Neurosurgery 2006; 58: 322-330.
18. Hirai T, Kai Y, Morioka M, et al. Differentiation between paraclinoid and cavernous sinus aneurysms with contrast-enhanced 3D constructive interference in steady- state MR imaging. AJNR Am J Neuroradiol 2008; 29: 130-133. Epub 2007 Nov 1.