Case Report

Carotico-clinoid foramina and a double optic canal: A case report with neurosurgical implications

Matthew J. Zdilla, Leah M. Cyrus, H. Wayne Lambert

Departments of Natural Sciences and Mathematics, West Liberty University, West Liberty, and 1Neurobiology and Anatomy, West Virginia University School of Medicine, Robert C. Byrd Health Sciences Center, Morgantown, West Virginia, USA

E-mail: *Matthew J. Zdilla - mzdilla@westliberty.edu; Leah M. Cyrus - lmcyrus@westliberty.edu; H. Wayne Lambert - hwlambert@hs.c.wvu.edu

*Corresponding author

Received: 05 September 14  Accepted: 12 November 14  Published: 30 January 15

Abstract

Background: The lesser wing of the sphenoid is a clinically important structure, particularly with regard to its anatomical relationship with neurovascular structures including the optic nerve, ophthalmic artery, and internal carotid artery. Anterior clinoidectomy, a neurosurgical procedure utilized to access paraclinoid aneurysms and neoplasms, is often complicated by the presence of anatomical variants including the carotico-clinoid foramen and the accessory optic canal.

Case Description: A rare case report is presented documenting the simultaneous occurrence of bilateral carotico-clinoid foramina and a unilateral accessory optic canal.

Conclusion: The presence of an accessory optic canal may be misconstrued as a carotico-clinoid foramen or pneumatization of the anterior clinoid process, lesser sphenoidal wing, or optic strut. The case report documents two clinically important variant structures occurring ipsilaterally, each with the potential to masquerade as the other radiographically and present complications to both neurosurgeons and radiologists. Knowledge of the unique combination of anatomical variants presented in this report may prevent adverse surgical events during anterior clinoidectomy procedures including hemorrhage of the ophthalmic artery or internal carotid artery and subsequent vision loss or death.

Key Words: Anterior clinoidectomy, internal carotid artery, ophthalmic artery, ophthalmic foramen, optic foramen, paraclinoid aneurysm

INTRODUCTION

The lesser wing of the sphenoid is an important bony structure implicated in a variety of neurosurgical procedures including management of space occupying lesions such as aneurysms and neoplasms in the paraclinoid region.\(^1,3,8,13,20\) The lesser wing of the sphenoid has numerous bony formations that are intimate with a number of important anatomical structures in the paraclinoid area.\(^24\) These bony formations include, but are not limited to: (i) The optic canal, which transmits the optic nerve and ophthalmic artery (OphA) as well as corresponding sympathetic nerves and (ii) the anterior clinoid process (ACP), which is intimate with the internal carotid artery (ICA).

The ICA gives rise to the OphA, which travels through the optic canal alongside the optic nerve to reach the
Within the optic canal, the OphA most often travels inferolateral to the optic nerve (in 40.2% of individuals) [Figure 1]. Briefly, the ICA courses within the space provided by the carotid groove inferiorly, the optic strut anteriorly, the ACP superiorly, and the carotico-clinoid ligament posteriorly [Figure 1]. Occasionally, the carotico-clinoid ligament, or a dural fold normally extending between the anterior and middle clinoid processes, ossifies. The ossification of the carotico-clinoid ligament creates a foramen called the carotico-clinoid foramen (CCF) through which the ICA passes. An ossified carotico-clinoid ligament has been identified with black arrows in Figure 2b and d.

Reports have noted that the presence of the CCF causes morphological changes to the ICA in almost all cases. The presence of CCF has been reported to occur unilaterally and bilaterally with frequency ranging from 4.25% to 35.67%. While ossification of fibrous ligaments is common with age, reports have noted no age-associated ossification of the carotico-clinoid ligament and the presence of the CCF has been documented in both fetuses and children. However, a racial difference in the incidence of CCF has been documented by Lee et al. who organized data from prior reports, noting the lowest incidence in Japanese (3.9% males, 6.0% females), followed by Koreans (15.7%), “Alaskan Eskimos” (17%), Sardinians (23.4%), and Americans (34.8%), respectively.

The lesser wing of the sphenoid may also possess another clinically remarkable finding – a ‘double optic canal’ variant which consists of the optic canal and an ‘accessory optic canal’ (AOC) [Figure 2b]. The AOC has been documented to occur at a frequency ranging from 0.22% to 16.6%. When present, the AOC may transmit the OphA, explaining its alternative name of ‘ophthalmic canal’ [Figure 2]. AOC have been reported to occur both unilaterally and bilaterally. As in the case of the CCF, the AOC has been reported in fetuses and children. Both the CCF and AOC are attached to the ACP of the lesser wing of the sphenoid and are therefore implicated in the management of space occupying lesions.

**CASE REPORT**

Examination of an isolated sphenoid bone dry specimen from an individual of undetermined sex and age, held in the anatomy collection at West Liberty University, led to the observation of bilateral CCF in addition to a unilateral AOC within the left optic strut. The left optic strut of the sphenoid bone served as both the anterior boundary of the left-sided CCF as well as the bony structure encompassing the AOC [Figures 2 and 3].

Mensuration of the AOC and CCF was accomplished via macro photography. A scale with line markers located at each millimeter was placed flush with, and adjacent to, each structure to be measured. A macro photograph was then taken with a 50× optical zoom camera (Canon PowerShot SX 50 HS, 12.1 Megapixel). The photographs were then analyzed via ImageJ (National Institutes of Health) software by using the scale as a reference for pixel calibration.

The widest diameter of the cranial end of the left-sided optic canal was 5.1 mm, the minimum diameter of the...
optic canal was separated from the AOC by a thin bony septum located superomedial to the main body of the optic strut, and measured 0.3 mm at its width between the foramina [Figures 1 and 2b and c]. The posterior aspect of the bony plate tapered to appear blade-like. The width of the optic strut, including the thin bony septum was 3.1 mm. The main body of the optic strut measured 1.7 mm in width [Figure 3]. The right optic canal was slightly larger than that of the left side with regard to the area it encompassed (17.4 and 14.6 mm², respectively). The maximum diameter of the right optic canal at its cranial end was 4.8 mm and the minimum diameter was 4.5 mm. The right optic strut was unremarkable and measured 1.8 mm in width. The left CCF was, for the most part, circular with a maximum diameter of 4.6 mm. The area enclosed within the left CCF measured 16.8 mm². The maximum diameter of the right CCF measured 5.0 mm and the minimum diameter was 4.3 mm. The right CCF enclosed an area of 18.3 mm² [Table 1].

The sphenoid was also positioned on an angle, with the aid of a ring stand, in order to capture a modified Rhese projection. After positioning the sphenoid, digital radiographs were taken with an intraoral X-ray system (Gendex GX-770 with a GXS-700 size 2 sensor, 70 kVp, 7 mA, 6 impulse exposure time). The radiograph

Figure 2: Sphenoid bone with carotico-clinoid foramina and a double optic canal with regional anatomy of the lesser wing of the sphenoid emphasized. (a) View of the variant sphenoid from the right and posterior. (Green box indicates the region of interest, which has been enlarged to produce Figure 2b-d) (b) Variant anatomy of the lesser wing of the sphenoid (ACP: Anterior clinoid process; OC: Optic canal; AOC: Accessory optic canal; CCF: Carotico-clinoid foramen; Blue arrow: Bony plate separating the optic canal from the accessory optic canal; Black arrow: Ossified carotico-clinoid ligament, which forms the carotico-clinoid foramen) (c) The contents of the optic canal and accessory optic canal in cross-section demonstrating a bony plate separating the optic nerve (ON) from the ophthalmic artery (OphA); Blue arrow: Bony plate separating the optic nerve from the ophthalmic artery) (d) The ossified carotico-clinoid ligament forms a carotico-clinoid foramen through which the internal carotid artery travels before giving rise to the ophthalmic artery (ICA: Internal carotid artery; Black arrow: Ossified carotico-clinoid ligament which forms the carotico-clinoid foramen)

Figure 3: (a) Cranial view of the left lesser wing of the sphenoid. (ACP: Anterior clinoid process; OS: Optic strut (formed by the BP: Bony plate and MB: Main body); OCCL: Ossified carotico-clinoid ligament; OC: Optic canal; AOC: Accessory optic canal; CCF: Carotico-clinoid foramen) (b) A modified Rhese projection radiograph of the sphenoid, which corresponds with Figure 3a. The arrow indicates radiolucency within the main body of the optic strut which may confound the assessment of the local anatomy due to its radiographic similarity with the accessory optic canal
had remarkable radiolucency inferior to the AOC within the main body of the optic strut [Figure 3b].

**DISCUSSION**

The presence of bilateral CCF has been reported at a frequency ranging from 2.5% to 18%,[10,21] while the presence of a unilateral left-sided AOC is particularly rare with studies in accord at a frequency of approximately 1% [Table 2].[11,22,23] To date, this case report is unique in that it documents the occurrence of a rare combination of sphenoid variants. Although rare, it is particularly important to radiologists and surgeons to be aware of the potential for the simultaneous existence of an ipsilateral CCF and AOC.

**Clinical significance of the carotico-clinoid foramen**

Removal of the ACP is often necessary to expose the cavernous sinus and access the clinoid segment of the ICA for management of aneurysms and tumors within the paraclinoid region.[1,3,13,20] The presence of a CCF, formed by an ossified carotico-clinoid ligament (identified by the black arrow in Figure 2), has been reported to add difficulty to ACP removal, particularly when an aneurysm is in the vicinity.[13,19] If there is retraction of the ICA in the presence of a CCF, the ICA may tear or rupture leading to subsequent death.[18] Pneumatization of the ACP is another important finding, which, if not properly identified, may lead to surgical complications including pneumocephalus and rhinorrhea,[1] and both the CCF and the AOC may make differentiation of structures via standard radiography and CT difficult.[4,5] Because, in the case of a bony foramen, the CCF has been measured to be a smaller diameter than that of the ICA, reports have noted a high possibility of headache due to compression, tightening, or stretching of the ICA in the presence of a CCF.[21]

**Clinical significance of the accessory optic canal**

The CCF is formed largely by the ACP. The optic strut, too, is attached to the ACP and is therefore also a structure of concern with regard to surgical procedures involving the ACP. As noted by Lee et al., the optic strut is often detached along with the ACP from the lesser wing of the sphenoid to: (i) Facilitate access of the cavernous sinus or posterior orbit, and (ii) prevent a scenario in which a remaining optic strut causes injury to the optic nerve or ICA during surgery.[18] The OphA has been reported to travel through the AOC, and has thus been referred to as the ‘ophthalmic canal’. [26] If the OphA were to traverse the AOC (illustrated in Figure 2b and c), the OphA would be damaged when the optic strut is removed in conjunction with the ACP. Damage to the OphA may cause subsequent vision loss.[21]

**CONCLUSION**

Neurosurgeons and radiologists should be aware of the potential simultaneous ipsilateral occurrence of a CCF and AOC. Knowledge of the unique combination of anatomical variants presented in this report may prevent adverse surgical events during anterior clinoidectomy including hemorrhage of the ophthalmic artery or ICA and subsequent vision loss or death.

**ACKNOWLEDGMENTS**

Research was supported by funding from the WV Research Challenge Fund [HEPC.dsr.14.13] and a West Liberty University Faculty Development Grant. The authors would like to thank Michele Sweeney, MSDH, Professor of Dental Hygiene, Sarah Whitaker Glass School of Dental Hygiene, West Liberty University for facilitating the radiography within this report.

**REFERENCES**

1. Avci E, Bademci G, Ozturk A. Microsurgical landmarks for safe removal of anterior clinoid process. Minim Invasive Neurosurg 2005;48:268-72.
2. Bertelli E. Metoptic canal, duplication of the optic canal and Warwick’s foramen in human orbits. Anat Sci Int 2014;89:34-45.
3. Boyan N, Ozsahin E, Kizilkanat E, Tekdemir I, Soames R, Oguz O. Surgical importance of the morphometry of the anterior clinoid process, optic strut, caroticoclinoid foramen, and interclinoid osseous bridge. Neurosurg Q 2011;21:133-6.
4. Cares HL, Bakay L. The clinical significance of the optic strut. J Neurosurg 1971;34:355-64.
5. Choudhry R, Anand M, Choudhry S, Tuli A, Meenakshi A, Kalra A. Morphologic and imaging studies of duplicate optic canals in dry adult human skulls. Surg Radiol Anat 1999;21:201-5.
6. Choudhry R, Choudhry S, Anand C. Duplication of optic canals in human skulls. J Anat 1988;159:113-6.
7. Das S, Suri R, Kapur V. Ossification of caroticoclinoid ligament and its clinical importance in skull-based surgery. Sao Paulo Med J 2007;125:351-3.
8. Dolenc VV combined epi- and subdural direct approach to carotid-ophthalmic artery aneurysms. J Neurosurg 1985;62:667-72.
9. Ertürk M, Kayalioglu G, Govsa F. Anatomy of the clinoidal region with special emphasis on the caroticoclinoid foramen and interclinoid osseous bridge in a recent Turkish population. Neurosurg Rev 2004;27:22-6.
10. Freire AR, Rossi AC, Prado FB, Groppo FC, Caria PH, Botacin PR. Caroticoclinoid foramen in human skulls: Incidence, morphometry and its clinical implications. Int J Morphol 2011;29:427-31.
11. Gha R, Sinha P, Raiguru J, Jain S, Khare S, Singla M. Duplication of optic canal in human skulls. J Anat Soc India 2012;61:33-6.
12. Govsa F, Erturk M, Kayalioglu G, Pinar Y, Ozer MA, Ozgur T. Neuro-arterial relations in the region of the optic canal. Surg Radiol Anat 1999;21:329-35.
13. Inoue T, Rhoton Al Jr, Theele D, Barry ME. Surgical approaches to the cavernous sinus: A microsurgical study. Neurosurgery 1990;26:903-32.
14. Kapur E, Mehic A. Anatomical variations and morphometric study of the optic strut and the anterior clinoid process. Bosn J Basic Med Sci 2012;12:88-93.
15. Keyes JE. Observation on four thousand optic foramina. Grafe Arch Clin Exp 1935;13:538-68.
16. Kier EL. Embryology of the normal optic canal and its anomalies. An anatomic and roentgenographic study. Invest Radiol 1966;1:346-62.
17. Lang J. Structure and postnatal organization of heretofore uninvestigated and infrequent ossifications of the sella turcica region. Acta Anat (Basel) 1977;98:121-39.
18. Lee HY, Chung IH, Choi BY, Lee KS. Anterior clinoid process and optic strut in Koreans. Yonsei Med J 1997;38:151-4.
19. Narolewski R. Significance of anatomic variants of bony surroundings of the internal carotid artery and their significance for lateral surgical approaches to the cavernous sinus. Ann Acad Med Sotin 2003;49:205-29.
20. Natori Y, Fukui M, Rhoton AL. Microsurgical anatomy around the anterior clinoid process. Int Congr Ser 2002;1247:29-35.
21. Ozdoğan O, Saka E, Tuly C, Gürdal E, Uzün I, Cavdar S. The anatomy of the carotico-clinoid foramen and its relation with the internal carotid artery. Surg Radiol Anat 2003;25:241-6.
22. Patil GV, Kolagi S, Padnavithi G, Rairam GB. The duplication of the optic canals in human skulls. J Clin Diag Res 2011;5:536-7.
23. Perrini P, Cardia A, Fraser K, Lanzino G. A microsurgical study of the anatomy and course of the ophthalmic artery and its possibly dangerous anastomoses. J Neurosurg 2007;106:142-50.
24. Reisch R, Vutskits L, Filippi R, Patonay L, Fries G, Pernezczyk A. Topographic microsurgical anatomy of the paraclinoid carotid artery. Neurosurg Rev 2002;5:177-83.
25. Singh M. Duplication of optic canal in adult Japanese human skulls. J Anat Soc India 2005;5:1-9.
26. Warwick R. A juvenile skull exhibiting duplication of the optic canals and subdivision of the superior orbital fissure. J Anat 1951;85:289-91.
27. White LE. An anatomic and x-ray study of the optic canal. Boston Med Surg J 1924;189:741-8.