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Case Report

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

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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

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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

eye. Within the optic canal, the OphA most often travels inferolateral to the optic nerve (in 40.2% of individuals) [Figure 1].[12] 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.[21]

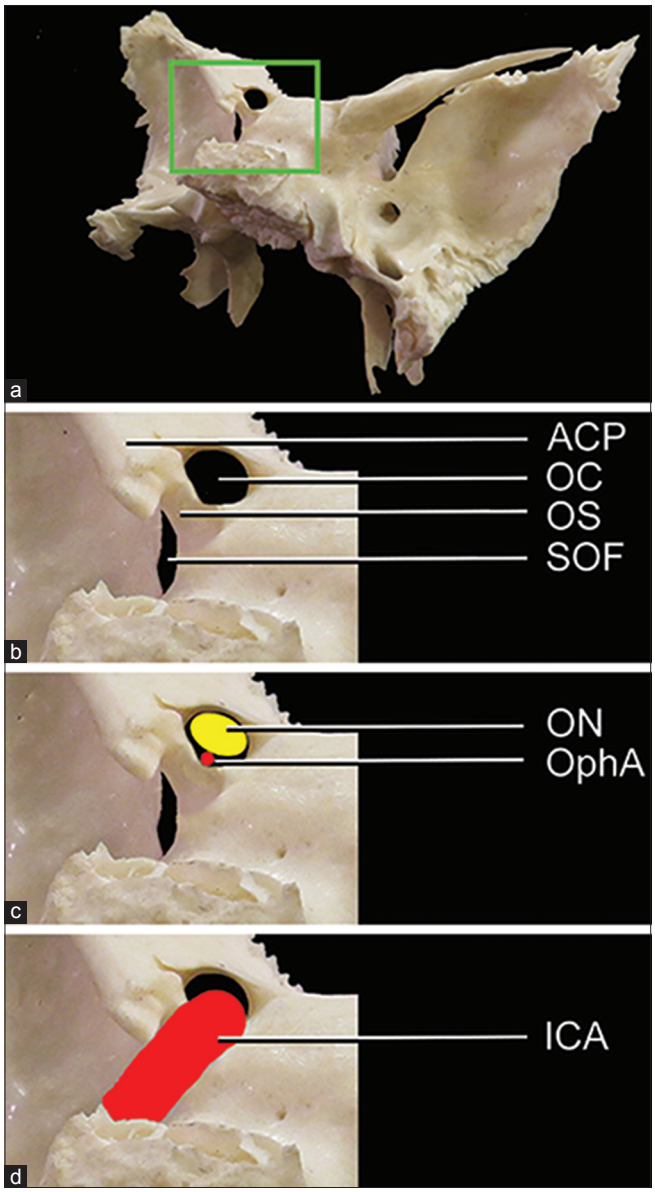

Figure 1: A normal sphenoid bone with regional anatomy of the lesser wing of the sphenoid emphasized. (a) View of a normal sphenoid from the right and posterior. (Green box indicates the region of interest, which has been enlarged to produce Figure 1b-d) (b) Normal anatomy of the lesser wing of the sphenoid (ACP: Anterior clinoid process; OC: Optic canal; OS: Optic strut; SOF: Superior orbital fissure) (c) The normal contents of the optic canal in cross-section demonstrating the anatomical relationship between the optic nerve (ON) and ophthalmic artery (OphA) (d) The internal carotid artery (ICA) normally travels medial to the anterior clinoid process before giving rise to the ophthalmic artery into the optic canal

Reports have noted that the presence of the CCF causes morphological changes to the ICA in almost all cases.[7] The presence of CCF has been reported to occur unilaterally and bilaterally with frequency ranging from 4.25% to 35.67%.[9,14] 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.[16,17,27] 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 (34.84%), respectively.[18]

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].[26] The AOC has been documented to occur at a frequency ranging from 0.22% to 16.6%.[15,16] When present, the AOC may transmit the OphA,[2,16] explaining its alternative name of 'ophthalmic canal' [Figure 2].[26] AOC have been reported to occur both unilaterally and bilaterally.[5,6,25] As in the case of the CCF, the AOC has been reported in fetuses and children.[2,26] 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 [Figure 2].[13,18,19]

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

cranial end of the canal measured 3.5 mm. The AOC was circular and had a diameter of 1.4 mm. The main 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 mm^2, 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 mm^2. 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 mm^2 [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

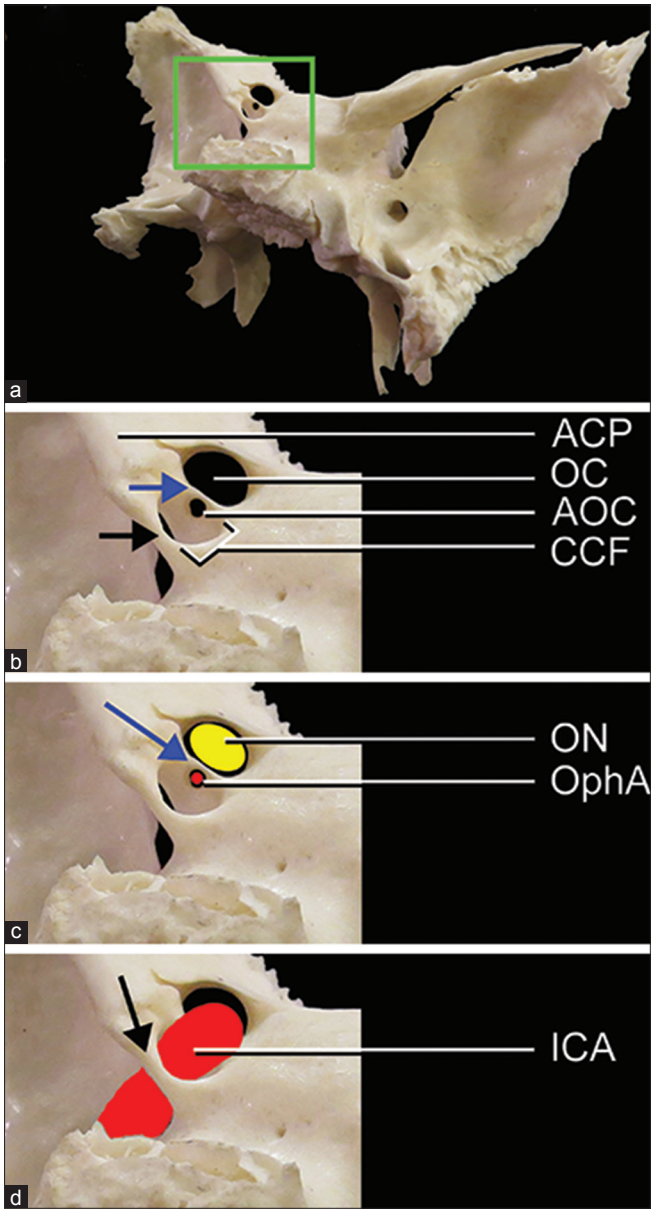

Figure 2: Sphenoid bone with carotico-clinoid foramina and a double optic canal with regional anatomy of the lesser wing of the sphenoid emphasized. (a) View of the variant sphenoid from the right and posterior. (Green box indicates the region of interest, which has been enlarged to produce Figure 2b-d) (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)

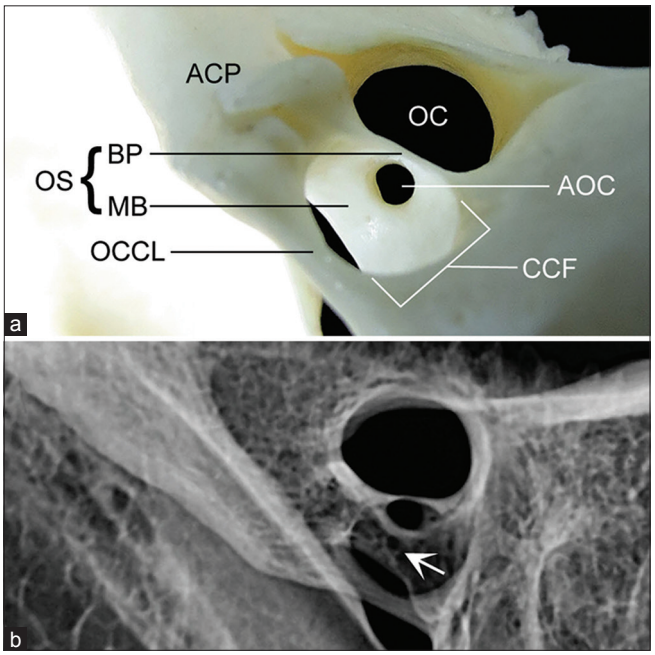

Figure 3: (a) Cranial view of the left lesser wing of the sphenoid. (ACP: Anterior clinoid process; OS: Optic strut (formed by the BP: Bony plate and MB: Main body); OCCL: Ossified carotico-clinoid ligament; OC: Optic canal; AOC: Accessory optic canal; CCF: Carotico-clinoid foramen) (b) A modified Rhese 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].[11,22,25] 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.[1,3,8,13,20] 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]

Table 1: Morphometric characteristics of normal and variant foramina and canals associated with the lesser wings of the sphenoid

Foramen/Canal	Maximum diameter (mm)	Minimum diameter (mm)	Area contained (mm^2)
Left side			
Optic	5.1	3.5	14.6
Accessory optic	1.4	1.4	1.5
Carotico-clinoid	4.6	4.5	16.8
Right side			
Optic	4.8	4.5	17.4
Carotico-clinoid	5.0	4.3	18.3

Table 2: Reported prevalence of left-sided accessory optic canals

Author (s)	Year	Ratio	Frequency (%)
Singh[25]	2005	4:435	0.92
Patil *et al.*[22]	2011	4:400	1.00
Ghai *et al.*[11]	2012	2:194	1.03

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.[23]

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.

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