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Bilateral ossification of the carotico clinoid ligament: clinical and surgical considerations

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Abstract: Introduction: The carotico clinoid foramen (CCF) is an anomalous foramen that is formed due to ossification of carotico clinoid ligament (CCL) in the sphenoid bone with a reported prevalence of around 8%. Ossified CCL is of tremendous clinical relevance considering its intimate relationship with important neurovascular structures in the parasellar region such as internal carotid artery, cavernous sinus, optic nerve and the pituitary gland.
Case presentation: This report describes a case of bilateral ossification of CCL that was incidentally observed in a dry human skull during routine demonstration to medical undergraduate students. In the present case, ossified CCLs were observed spanning the tips of the anterior and the middle clinoid processes bilaterally and they formed two distinct oval CCF on either side.
Discussion: Variable incidence of ossified CCL has been reported in anatomical studies. The exact reason for the ossification of CCL and other periclinoid ligaments are not known. Developmental anomalies of the sphenoid bone, ossification of fibrous tissue of the ligaments or the folds of dura mater bridging the interclinoid region are thought to be underlying reasons. The presence of a complete or partially ossified CCL can affect the internal carotid artery (ICA), cavernous sinus, its contents and the pituitary gland etc. Ossified CCL and CCF can lead to misinterpretation in radiological investigations and might pose difficulty in neurosurgical access and interventions in the skull base.
Conclusions: Considering the modest prevalence of carotico clinoid ligament across all major races, preoperative recognition of the same in imaging studies is warranted before approaching any parasellar intracranial lesions.

Keywords: carotico clinoid ligament, carotico clinoid foramen, sellar bridge.

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Introduction

The ligaments and dural folds stretching between the clinoid processes of the sphenoid bone can get ossified to various degrees in some individuals [1]. Depending on the extent of ossification, they may appear as trabecula or lamina and may form complete or partial connections between the clinoid processes resulting in complete or incomplete foramina [2, 3]. Carotico clinod ligament (CCL) is present between the anterior clinoid process (ACP) and the middle clinoid process (MCP). When the CCL ossifies, it results in the formation of carotico clinoid foramen (CCF). The ligament between the anterior clinoid process (ACP) and the posterior clinoid process (PCP) is termed interclinoid ligament (ICL) and the resultant foramen is termed interclinoid foramen (ICF) [3, 4]. The ossified ICL is also known as the 'sella turcica bridge' [5]. Another viewpoint about the formation of bony bridges between the clinoid processes is the ossification of dural folds in the region. The ossified dural folds extending between the clinoid processes are supposed to be responsible for CCF and ICF formation. There can be several patterns and combinations of ossified interconnection between the clinoid processes of the sphenoid and they occur either unilaterally or bilaterally [6]. Sometimes, collectively they are referred to as the sellar bridges [2, 3, 7]. The anterior foramen or the CCF is circular to oval in shape, and is intimately related to the internal carotid artery (ICA), and is in close proximity to the optic nerve, ophthalmic artery and the pituitary gland. The posterior foramen or the ICF is an irregular, triangular to pyramidal shaped foramen having close relations with the cavernous sinus and its tributaries [3, 8]. Ossified CCL becomes a bony bar and as a consequence, when the ICA passes through the CCF, it can get compressed or tightened which has been associated with occurrences of headache. Such compression can be the cause of transient vascular events [3]. In addition to that, the ossified CCL may be misinterpreted in a radiograph and it can provide hindrance to endoscopic skull base surgeries. This report describes an incidentally observed bilateral ossified CCL in a dry human sphenoid bone in skull base and discusses the clinical and surgical considerations.

Case presentation

During routine demonstration to students, a skull base with bilaterally ossified CCL was observed in the Department of Anatomy at All India Institute of Medical Sciences, New Delhi. We later examined all the sphenoid bones in the articulated skull including individual sphenoid bones (n = 26) present in the department, but no other specimens revealed such ossified ligaments and foramina. In the present case, strong bony bridges were observed spanning the tips of the anterior and the middle clinoid processes (MCP) bilaterally. The bony bridges were identified as the ossified CCLs. The bony bridges were complete bilaterally and formed two distinct oval foramina on either side of the anterior most part of the body of the sphenoid (Fig. 1 A–D). The foramina were bounded posteriorly by the ossified CCL, laterally by the ACP and medially by the body of the sphenoid. Anteriorly, both the foramina were related to the optic canals (Fig. 1 C, D). Rest of the features of the sphenoid bone were normal anatomically. The observed morphological features were photographed using a Nikon D3500 DSLR digital camera. The length of the ossified ligaments was measured between the tips of the ACP and MCP. The width of the ossified ligament was measured at the middle of the bony bridge.

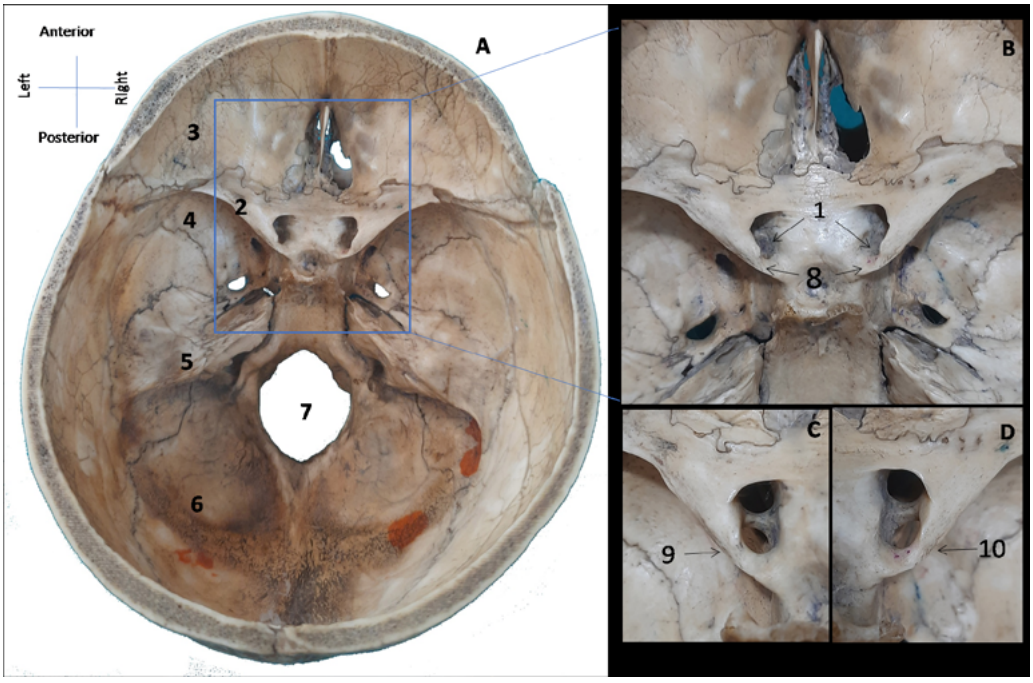

Fig. 1 A. The superior view of the base of the skull. **B.** Magnified view of the para sellar region in inset. **C.** The ossified carotico clinoid ligament (CCL) and carotico clinoid foramen (CCF) on the left side. **D.** CCL and CCF on the right side. 1 — carotico clinoid foramen (CCF), 2 — lesser wing of the sphenoid, 3 — orbital plate of the frontal bone, 4 — greater wing of the sphenoid, 5 — petrous part of the temporal bone viewed from inside the skull, 6 — occipital bone, 7 — foramen magnum, 8 — region of the tip of the middle clinoid processes, 9 — ossified CCL on the left side, 10 — ossified CCL on the right side.

Discussion

The earliest reports about the ossified CCL are available from the description of noted Scottish surgeon *Alexander Monro* and German physician *Jakob Henle* in 18th and 19th centuries [9]. Variable incidence of ossified CCL has been reported in anatomical studies conducted on dry adult human skulls in different population groups and incidences as high as 35.65% was noted [1]. A recent radiological study conducted by retrospective examination of computed tomography (CT) scan films of the head demonstrated 8.7% incidence [5]. The incidences of ossified peri-clinoid ligaments of different forms are now increasingly reported and they are believed to be more prevalent than what had been thought earlier. It is more commonly encountered in people of European descent. Studies on Indian dry human skulls have revealed slightly higher incidence compared to the other Asian races. A very recent Indian study reported an incidence of 8% occurrence of ossified CCL [10]. Some of the recent studies on ossified CCL with their important findings are presented in Table 1 highlighting the types and pattern of occurrence of ossified CCL. The exact reason for the ossification of CCL and other peri-clinoid ligaments are not very clear. Several theories have been propounded as explanations, and one such theory associates it with

Table 1. Incidence of ossification of carotico clinoid ligament and carotico clinoid foramen.

Authors	Type of study, population and sample size	Notable findings
Rao *et al.*, 2023 [10]	Anatomical study, Indian, 100	Bilateral complete ossification of CCL and CCF was observed in 2% specimens. Overall incidence of CCF was 8%. The incidence was higher on the right side when compared to the left-side.
Ghorbani *et al.*, 2020 [12]	Case report, Iranian, Single case	Bilateral ossified CCL and CCF were observed.
Gibelli *et al.*, 2018 [5]	Radiological study, Italian, 300	Overall incidence of CCF was 8.7%.
Purohit and Singh, 2018 [15]	Anatomic study, Indian, 200	Overall incidence of CCF was 10.5%. Bilateral and unilateral CCF were present in 3% and 7.5% specimens respectively. Complete and incomplete foramen was present in 5.5% and 5% specimens respectively.
Jha *et al.*, 2016 [6]	Anatomic study, Indian, 108	Overall incidence of CCF was 22.22. Maximum incidence of unilateral and incomplete type was observed. No particular sidedness was observed.
Özdoğmuş *et al.*, 2003 [4]	Autopsy study, Turkish, 50	Overall incidence of ossified CCL 27% Bilateral CCF was 18%.

developmental anomalies of the sphenoid bone. The ossified CCL and other interclinoid bony bridges were demonstrated in the skull of foetuses and infants, which suggests that at least some of them are congenitally occurring due to mutation in certain genes [11]. The other widely accepted explanation for occurrence of ossified CCL due to acquired causes is, ossification of fibrous tissue of the ligament or the folds of dura mater spanning the interclinoid region. The ossification of ligaments as such is considered to be a physiological age-related phenomenon and the ossified CCL observed in an elderly skull can be correlated to it [12]. However, studies have demonstrated pre-cartilaginous connections between the clinoid processes, which is against the theory of ossification in connective tissue. Few cases of peri-clinoid ligament ossification have been described, wherein all the ligaments between the corresponding clinoid processes were ossified [3]. This indicates towards ossification of dural fold. Ossified structures extending between the MCP and the lateral border of the dorsum sella have been observed which further testify the theory of ossification of dural folds [13].

The course of the ICA passing through the CCF has important clinical correlation with respect to the occurrence of paraclinoid aneurysms, and the meningiomas involving the CCL [14]. The presence of a complete or incompletely ossified CCL can compress or impinge upon the ICA causing vascular events and even degeneration, rupture and subsequent intracranial haemorrhage from the ICA. Furthermore, the cavernous sinus, its contents and the pituitary gland may be affected. Ossified CCL and CCF can lead to misinterpretation in radiological investigations and might pose difficulty in neurosurgical access and intervention procedures such as endoscopic

skull base surgeries. The presence of ossified CCL poses a problem to access ACP during 'anterior clinoidectomy' operation for surgical exploration of cavernous sinus [1]. There are chances of injury to the other important cranial nerves such as optic and the oculomotor nerves [13]. Extra care has to be taken while doing anterior clinoidectomy as sometimes the ACP itself can be pneumatized making it fragile leading to iatrogenic injuries. There are three types of CCL according to Keyers classifications; complete, contact and incomplete variety. In the complete variety, like in this present case, the ossification is proper and complete in the CCL. In the contact type, there is suture formation between the ACP and MCP. And in the incomplete variety, bony spicules are projected from both the ACP and MCP but do not touch each other. Sharp edges or incompletely ossified bony spurs of the ACP and MCP can easily injure adjacent neurovascular structures, especially during surgical intervention and hence considered dangerous [1, 15].

The shape and diameter of the carotico clinoid foramen vary depending on whether there is partial or complete ossification. Usually bilateral cases demonstrate equal sizes and shapes. In our case, the mean diameter of the CCF and mean width of the ossified CCLwas 4.6 mm and 1.79 mm in widest dimension, which corroborates with the existing literature. The average diameter of the interclinoid portion of the ICA is around 4 mm, which is smaller than the average diameter of the CCF to pass through ossified foramina without any hindrance. In the present case the CCF thus did not seem to impede the flow of blood through the ICA when the person was alive.

Conclusions

The anatomy of the sellar and the parasellar region is of paramount importance considering frequent endoscopic surgeries for lesions such as aneurysms; tumours etc. Presence of an aberrant ossified ligament reduces the accessible surgical field and may pose problems in endoscopic surgeries such as clipping of an aneurysm. Adequate mobilization of the ICA during cavernous sinus exploration may become difficult. Considering the modest prevalence of carotico clinoid ligament across all major races, preoperative recognition of the same in imaging studies is warranted before approaching any parasellar intracranial lesions.

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