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Original Article

Anatomy Section

Incidence of Ossification of Caroticoclinoid Ligament in Dry Adult Human Skulls with its Surgical Implications: A Cross-sectional Study from Telangana Region, India

K EPHRAIM VIKRAM RAO[1], RAMA DEVI AVULA[2], PARIMALA SIRIKONDA[3], RAJASEKHAR KATIKIREDDI[4]

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ABSTRACT

Introduction: The caroticoclinoid ligament extends from the Anterior Clinoid Process (ACP) to the Middle Clinoid Process (MCP). Occasionally, it gets ossified and forms the caroticoclinoid foramen. Anterior clinoidectomy is a common surgical procedure to treat internal carotid artery aneurysms or pituitary tumours. Abnormal ossification of the caroticoclinoid ligament may lead to intraoperative or postoperative complications as it is not normally present.

Aim: To find out the incidence of ossification of the caroticoclinoid ligament in adult human skulls.

Materials and Methods: This was an observational cross-sectional study that included 100 dry adult human skulls collected from the Department of Anatomy, Gandhi Medical College, Secunderabad; Osmania Medical College, Hyderabad; Bhaskar Medical College, Moinabad, Telangana, India, from January 2021 to February 2023. Adult human skulls with open vault were included. All the skulls were observed and skulls damaged in the clinoid regions were excluded from the study. The skulls were observed for the presence of any ossifications of the caroticoclinoid ligaments and the observations were noted. The qualitative data was presented as number and percentage was calculated. The data was recorded in MS excel version 2021.

Results: The incidence of ossification of caroticoclinoid ligament was 8 (8%). The incidence was higher on right-side when compared to the left-side. Bilateral complete ossification of the caroticoclinoid ligament was observed in 2 (2%) skulls; bilateral incomplete ossification was observed in 3 (3%) skulls, unilateral complete ossification was observed in 2 (2%) skulls on the right-side. In one skull 1 (1%), complete ossification was observed on the right-side and incomplete ossification was observed on the left-side.

Conclusion: Knowledge of the ossification of the caroticoclinoid ligament is important for neurosurgeons while performing anterior clinoidectomies or skull base surgeries. Radiological confirmation of the ossification of the caroticoclinoid ligament is essential to avoid complications.

Keywords: Carotid artery, Clinoidectomy, Internal, Paraclinoid, Sella turcica

INTRODUCTION

The lesser wing of the sphenoid is an important landmark for neurosurgery. The medial projecting ends of the lesser wing of sphenoid are called ACP and the MCP are small projections present at lateral ends of the tuberculum sellae, the anterior boundary of the sella turcica. The ACP is connected to the MCP by a ligament called the caroticoclinoid ligament or sometimes by a dural fold [1]. Sometimes this caroticoclinoid ligament or dural fold may undergo ossification and form caroticoclinoid foramen, as a bony bar which extends from the anterior to the MCP. The ossification of the caroticoclinoid foramen can be complete or incomplete [2].

The internal carotid artery is a chief artery that supplies blood to the forebrain structures. After entering the cranial cavity, the artery passes through the cavernous sinus and curves up medial to the ACP. Here, the artery emerges through the dural roof of the cavernous sinus, where it is completely enclosed by the connective tissue [3]. Any abnormal ossification of the dural folds or the caroticoclinoid ligaments may lead to internal carotid artery entrapment [4].

The surgical removal of ACP is called anterior clinoidectomy. It is performed to treat parasellar, proximal carotid region and skull base pathologies of the central part of the middle cranial fossa [5]. Paraclinoid aneurysms of the internal carotid artery are usually treated by anterior clinoidectomy. This treatment procedure becomes more difficult when the caroticoclinoid foramen is present with ossification of caroticoclinoid ligament, causing a higher possibility of serious haemorrhage. Anterior clinoidectomy is one of the most critical surgical procedures done for the successful and safe management of aneurysms of the ophthalmic part of internal carotid artery and tumours located in the paraclinoid region and cavernous sinus [6]. Proper knowledge of the bony bars or ossified caroticoclinoid ligaments is important for neurosurgeons while dealing with aneurysms of the internal carotid arteries in the intercavernous region and also while dealing with meningiomas of the tuberculum sellae [7]. The incidence of ossification of the caroticoclinoid ligament ranged from 3-37.19% in different ethnic populations [8,9]. There is limited literature available concerning the incidence of the caroticoclinoid ligament ossification in the Telangana region [8].

Thus, the present study was undertaken to find the incidence of ossification of the caroticoclinoid ligaments in Telangana region.

MATERIALS AND METHODS

The present study was an observational cross-sectional study conducted in the Department of Anatomy, Gandhi Medical College, Hyderabad from January 2021 to February 2023. The samples were collected from Department of Anatomy, Gandhi Medical College, Secunderabad; Osmania Medical College, Hyderabad, and Bhaskar Medical College, Moinabad, Telangana, India. The study included 100 skulls belonging to Telangana region.

Inclusion criteria: Dry adult human skulls with vault open were included in the present study.

Exclusion criteria: The skulls which were damaged or fractured at the anterior and the MCP and sella turcica were excluded from the study.

Study Procedure

The ACP and MCP were examined for any ossifications of the caroticoclinoid ligaments forming caroticoclinoid foramen. There are three types of connections which can exist between the ACP and MCP according to classification of Keyes JEL [10].

- Type-1 (Complete type): Formation of complete foramen without having any break.
- Type-2 (Contact type): Presence of a suture between the ACP and MCP.
- Type-3 (Incomplete type): Spicules of bone present between the ACP and MCP without any contact.

All the skulls were examined for any abnormal ossifications. The presence of caroticoclinoid foramen unilateral or bilateral was also recorded. All the findings were noted and photographed. The incidence was calculated.

STATISTICAL ANALYSIS

The quantitative data was presented as number and percentage. The data was recorded in MS excel version 2021 and the incidence was calculated.

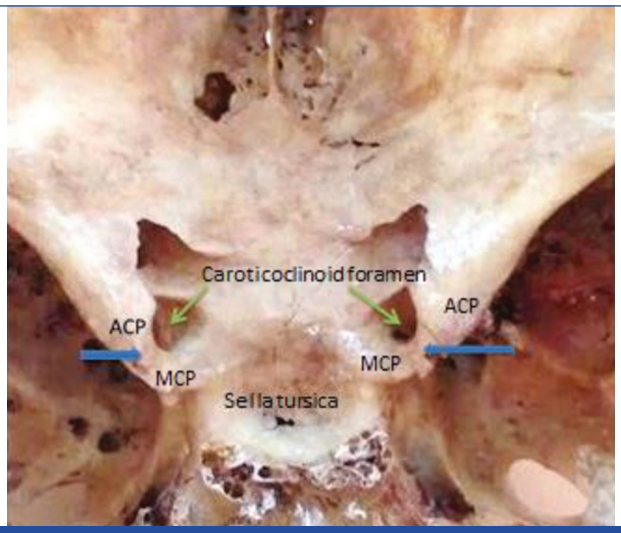
RESULTS

Out of 100 skulls observed, 8 (8%) skulls had ossification of caroticoclinoid ligaments. Caroticoclinoid foramen was observed unilaterally in 3 (3%) skulls and bilaterally in 5 (5%) of the skulls. The incidence of ossification was observed to be high on the right-side. There were no skulls found with ossified caroticoclinoid ligament on the left-side alone [Table/Fig-1].

Type of ossification		Incidence of the caroticoclinoid foramen
Unilateral	Right	3 (3%)
	Left	0
Bilateral		5 (5%)
Total		8 (8%)

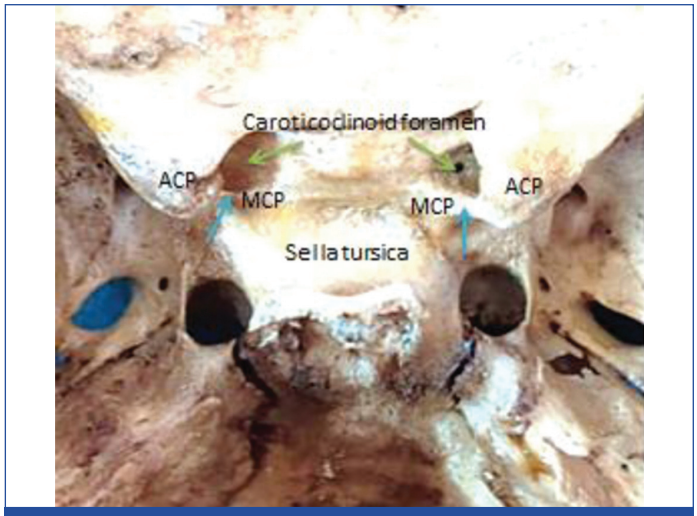
[Table/Fig-1]: Showing the incidence of the ossification of caroticoclinoid foramen.

Type-1 or complete type was observed bilaterally in 2 (2%) of the skulls, in which one skull showed a thick bony bar extending from the ACP to MCP [Table/Fig-2] where as in another skull on the right-side a thick bony bar was present, but on the left-side a thin bony plate was extending from the ACP to the MCP [Table/Fig-3].

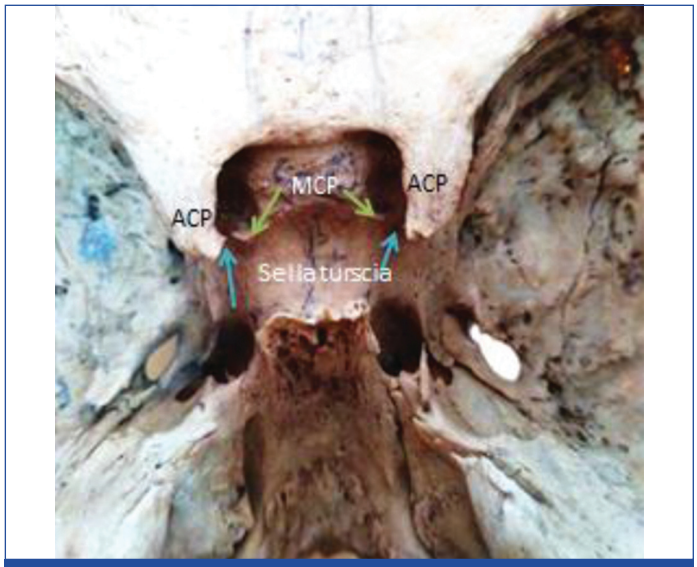


[Table/Fig-2]: Shows Type-1 or the complete ossification of the caroticoclinoid ligament bilaterally.
(Green arrow- Caroticoclinoid foramen; blue arrow- ossified bony bar of caroticoclinoid ligament; ACP: Anterior clinoid process; MCP: Middle clinoid process)

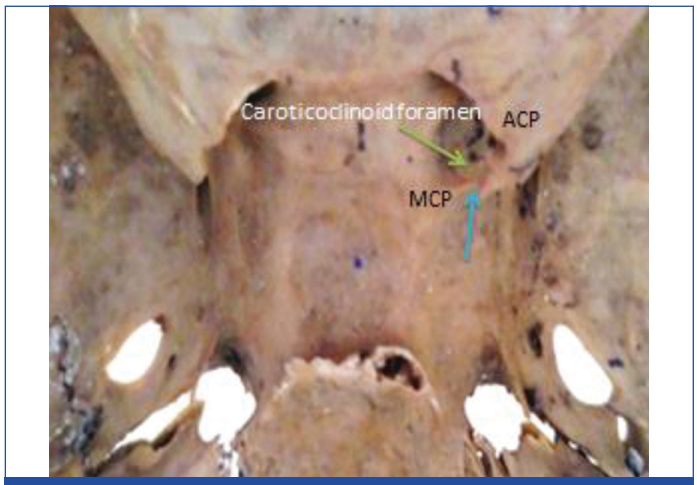
Type-2 or contact type was not observed in any of the skulls. Type-3 or incomplete ossification of the caroticoclinoid ligament was observed in 2 (2%) skulls bilaterally [Table/Fig-4]. Unilateral



[Table/Fig-3]: Shows ossification of the caroticoclinoid ligament as a thick bar on the right-side and a thin plate of bone on the left-side.
(Green arrow- Caroticoclinoid foramen; blue arrow- ossified bony bar of the caroticoclinoid ligament; ACP: Anterior clinoid process; MCP: Middle clinoid process)

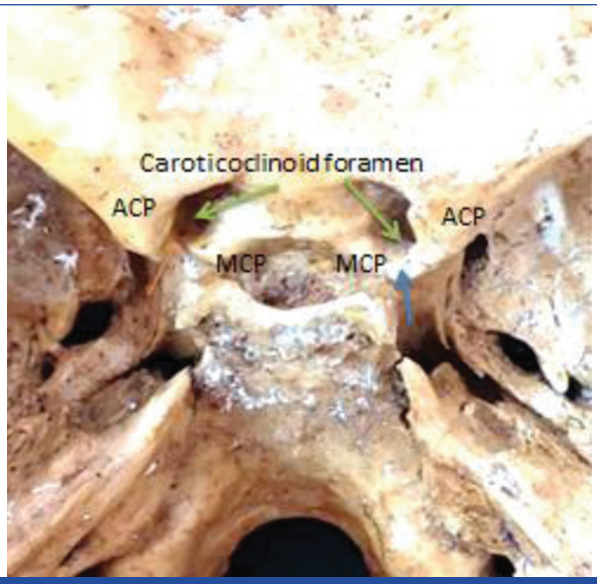


[Table/Fig-4]: Shows incomplete ossification of the caroticoclinoid ligament bilaterally.
Green arrow- Ossified bony spurs from the middle clinoid process; blue arrow shows incomplete ossification



[Table/Fig-5]: Shows unilateral incomplete ossification of the caroticoclinoid ligament on the right-side.
(Green arrow- Caroticoclinoid foramen; blue arrow- ossified bony bar of the caroticolcinoid ligament; ACP: Anterior clinoid process; MCP: Middle clinoid process).

incomplete ossification of the caroticoclinoid ligament was observed in 3 (3%) skulls on the right-side only [Table/Fig-5]. In one skull (1%) complete ossification of the caroticoclinoid ligament was observed on the right-side and incomplete ossification was observed on the left-side [Table/Fig-6].



[Table/Fig-6]: Shows complete ossification of the caroticoclinoid ligament on the right-side and incomplete ossification of the left-side.
(Green arrow- Caroticoclinoid foramen; blue arrow- ossified bony bar of the caroticolcinoid ligament; red arrow - incomplete ossification of caroticoclinoid ligament ACP: Anterior clinoid process; MCP: Middle clinoid process)

DISCUSSION

The caroticoclinoid ligament extends between the ACP and MCP. Ossification of this ligament forms the caroticoclinoid foramen. Keyes JEL described the boundaries of the caroticoclinoid foramen as follows: laterally- ACP; medially- the body of the sphenoid bone; posteriorly- a bony bridge extending between the ACP and MCP; and anteriorly- base of the lesser wing of the sphenoid bone [10]. Ossification is a normal physiological process and is age dependent [11]. But, the ossification of the caroticoclinoid ligament is not age-dependent as it was also observed in foetuses and infants. Hochstetter F and Kier EL reported that the ossified caroticoclinoid ligament forms the caroticoclinoid foramen and also the interclinoid osseous bridge in foetal and infant skulls. This explains that, the caroticoclinoid foramen is a developmental anomaly which exists from foetal life [12,13].

Studies suggest that the incidence of the caroticoclinoid foramen was more in cases with hormonal imbalance or disturbances, developmental disorders, criminals, and also epileptics [14]. The internal carotid artery calibre is greater in the clinoid region, which could be a causative factor for headache due to compression of the internal carotid artery [15].

There are many clinical implications related to mineralisation of the caroticoclinoid ligament and the dural ligaments attached to the dorsum sellae. Especially while planning surgeries of pituitary gland, internal carotid artery at cavernous sinus and the sellar and parasellar regions [16,17]. Anterior clinoidectomy is a surgical procedure where the ACP is removed. It is performed for better access to the optic nerve, internal carotid artery and its branches. Ossification of the caroticoclinoid ligament whether complete or incomplete requires additional drilling and may need extra care while retracting the ACP [10,18].

Sometimes, the ACP may be pneumatised or may have variation in the bone density [19,20]. So care must be taken to avoid injury to the internal carotid artery and optic nerve. Preoperative radiological examination should be done to avoid injury to internal carotid artery, oculomotor nerve, and optic nerve [14,21,22].

In the present study, incidence of the ossification of caroticoclinoid ligament was observed in 8% skulls which was within the range of the other Indian studies. The incidence of the caroticoclinoid ligament ossification and formation of caroticoclinoid foramen had a range between 6-37% in the Indian population. In South India, the incidence was reported to be between 6-20%. The incidence of the caroticoclinoid ligament ossification was observed to vary with ethnicity [Table/Fig-7] [4,8-11,14,23-27].

Author	Ethnicity	Incidence of the ossified caroticoclinoid ligament		
		Bilateral	Unilateral	Total
Keyes JEL (1935) [10]	Caucasian American population	-	-	27.46%
Azeredo RA et al., (1988) [23]	Portuguese population	4.05%	2.22%	6.27%
Lee HY et al., (1997) [24]	Korean population	1.4%	15.7%	17.1%
Erturk M et al., (2004) [14]	Turkish population	11.69%	23.98%	35.67%
Desai SD and Sreepadma S (2010) [9]	North Interior Karnataka	13.44%	23.74%	37.19%
Magadum A, (2012) [8]	South Indian	-	6%	6%
Bansode S et al., (2017) [25]	South Indian	14.2%	5.75%	20%
Binita JP and Praveen RS (2018) [4]	Gujarat	3%	7.5%	10.5%
Priya A et al., (2021) [26]	Bihar (North India)	2%	7%	9%
Vibhash KV et al., (2022) [27]	North India	7.5%	17.5%	25%
Present study (2023)	Telangana region	5%	3%	8%

[Table/Fig-7]: Comparison of the incidence of ossified caroticoclinoid ligament in various ethnic populations [4,8-10,14,23-27].

In the present study, incidence was higher on the right-side which was similar with the findings of Desai S and Sreepadma S reported in Karnataka population [9]. Incomplete ossification was observed in 6% of skulls whereas complete ossification was observed only in 2% of skulls. In the present study, the incidence of incomplete ossification of the caroticoclinoid ligament was observed to be higher than the complete type which was similar with the results of the study in Turkish and Korean populations. Erturk M et al., reported the complete type, contact type and incomplete type in 4.09%, 4.68%, and 14.91%, respectively in Turkish specimens and in a Korean study, the incidence of complete caroticoclinoid canal was reported in 4.1% and incomplete in 11.6% of skulls [14,24]. The incomplete type is more dangerous than the complete type because the bony spurs may impinge on internal carotid artery during pulsations of the internal carotid artery or in case of aneurysms of internal carotid artery which may lead to severe bleeding [11].

The ossified caroticoclinoid ligament can cause compression or stretching of internal carotid artery which may lead to headache and other neurological symptoms due to lack of blood supply to brain [21,22,28]. The treatment option for the internal carotid artery decompression in this region is the anterior clinoidectomy. The oculomotor nerve, trochlear nerve, abducent nerve, and ophthalmic division of trigeminal nerve pass within a dural fold just infero-lateral to the ACP in the lateral wall of the cavernous sinus. Any of these structures can be damaged during anterior clinoidectomy [21,22,28,29]. Care must be taken to avoid injury to the internal carotid artery and the nerves. Radiological investigations such as computed tomography must be performed before planning surgery to avoid intraoperative and postoperative complications related to this region.

Limitation(s)

The present study was limited to only the incidence of ossification of the caroticoclinoid ligament in dry human adult skulls. Further studies on the diameter of the caroticoclinoid foramen, thickness of the ACP and the distance between the ACP and MCP on a large sample can be carried out.

CONCLUSION(S)

The incidence of ossification of the caroticoclinoid ligament in Telangana population was 8%. Abnormal ossifications in the interclinoid regions especially caroticoclinoid ligament ossification are important for neurosurgeons while performing anterior clinoidectomies or skull base surgeries. Even incomplete ossifications may impinge on the internal carotid artery and lead to profuse bleeding. Ossification of caroticoclinoid ligament must be confirmed by radiological investigations to avoid complications during neurosurgeries of this region.

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PARTICULARS OF CONTRIBUTORS:

1. Assistant Professor, Department of Anatomy, Gandhi Medical College, Secunderabad, Hyderabad, Telangana, India.
2. Associate Professor, Department of Anatomy, Gandhi Medical College, Secunderabad, Hyderabad, Telangana, India.
3. Assistant Professor, Department of Anatomy, Osmania Medical College, Hyderabad, Telangana, India.
4. Assistant Professor, Department of Anatomy, Gandhi Medical College, Secunderabad, Hyderabad, Telangana, India.

NAME, ADDRESS, E-MAIL ID OF THE CORRESPONDING AUTHOR:
Dr. K Ephraim Vikram Rao,
12-11-332, Warasiguda, Secunderabad-500061, Hyderabad, Telangana, India.
E-mail: dr.ephraimvikram@gmail.com

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