

## A Morphometric Study of Anterior Clinoid Process and its Surgical Importance

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### Abstract

**Background:** Knowledge about the unusual ossification of the Carotico-Clinoid Foramen (CCF), would be essential for neurosurgeons and radiologists in day-to-day clinical practice as internal carotid artery, optic nerve may get compressed. **Aim:** To obtain knowledge about morphometry of Anterior Clinoid Process (ACP), Optic Strut (OS) and the type of ossification of Carotico-Clinoid Foramen which would be beneficial to guide surgeries related to the cavernous sinus and internal carotid artery. **Materials and Methods:** A total of 135 skulls were studied for various parameters such as the length of ACP from its base to the tip, the width at its base and the distance between the tip of ACP to optic strut were measured and were expressed in millimeters using digital calipers. SPSS 17<sup>th</sup> version was used for the statistical analysis. Paired t-test was applied to compare between right and left sides. Presence of carotico-clinoid foramen was observed and was classified as incomplete, contact form or complete. **Results:** The average length of ACP in the male skulls was  $8.8 \pm 1.3$  (right) and  $8.40 \pm 1.4$  mm (left). Its width was  $7.9 \pm 1.4$  mm and  $7.5 \pm 1.0$  mm. On female skulls the average length of the process was  $8.48 \pm 1.6$  mm on the right and  $8.0 \pm 1.4$  mm on left side, while the width measured  $7.3 \pm 1.5$  mm (right) and  $7.6 \pm 1.6$  mm (left), on the opposite side. In our sample, a complete carotico-clinoid foramen appeared in male and female skulls were 9 (6.0%) and 8 (6.6%), contact form in male and female skull 6 (4.0%) and 3 (2.5%). At last, an incomplete form of the foramen in male and female were 21 (14%) and 19 (15.8%). The anatomic variations of the investigated structures must be considered during the approaches to the cavernous sinus and neurovascular elements of the sellar region. **Conclusion:** Considering the immense anatomical surgical and radiological importance of morphology of ACP, OS and CCF, this study highlighted the detailed morphometry of these structures.

**Keywords:** Anterior Clinoid Process; Optic Strut; Carotico-clinoid Foramen; Carotico-clinoid Ligament.

### Introduction

Anterior Clinoid Process (ACP) is located on the medial end of the lesser wing of the sphenoid bone. The Carotico-Clinoid Ligament (CCL) joins ACP to the middle clinoid process (MCP) which is sometimes ossified. A dural fold extending between the anterior and middle clinoid processes or ossification of the CCL may result in the formation of the Carotico Clinoid Foramen (CCF) [1,2]. Removal of the anterior clinoid process (anterior clinoidectomy) allows a full approach to the anterior

portion of the cavernous sinus and to the vertical segment of the internal carotid artery. It's a significant problem in neurosurgical procedures to find a massive anterior clinoid process, which by removing can cause optic nerve and internal carotid artery injury [1]. The optic strut (OS) is a bony structure that is closely related to the significant structures such as the cavernous sinus, the internal carotid artery, the optic nerve and the pituitary gland [2]. In neurosurgical operations, the ACP is usually accessed to gain entry into the clinoid space. Intracranial course of internal carotid artery is related medially to the ACP. The presence of an ossified CCL may form a potential site for compression of the internal carotid artery, optic nerve and variations in the ACP may pose a risk while it is being removed in surgical procedures [3].

According to Williams [4] and Lang [5] this foramen is formed by the ossification of the carotico clinoid ligament in early childhood. The carotico clinoid foramen was first described by Henle [6].

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The presence of this foramen is of great importance to neurosurgeons and preoperative detection of CCF, by CT imaging, has a huge clinical significance during surgeries on tumors and aneurysms in the parasellar and suprasellar region, where anterior clinoid process and the optic strut must be moved from the lesser wing of sphenoid bone to provide a better approach to the operating field, primarily to the internal carotid artery and the optic nerve, and to minimize the need for brain retraction [7,8].

## Materials and Methods

### *Samples*

The present morphometry study was done in the Department of Anatomy, Kannur Medical College, Kannur, India. A total of 135 dried half skulls were studied for parameters such as length of ACP, measured from its base to the tip and the width at its base was noted and the distance between the tip of ACP to optic strut (OS) was also measured using manual caliper and expressed in millimeter. Presence of Carotico-Clinoid foramen was observed. If present, its type was classified as incomplete, contact form or complete according to the criteria given by Keyes, 1935 [9]. [Table and Figure 1,2]. Sexual dimorphism of the skulls was noted based on the criteria given by Walrath et al. [10]. The skulls with damaged ACPs were excluded from the study.

### *Statistical Analysis*

Statistical analysis was performed using SPSS version 15<sup>th</sup> and data were expressed in Mean  $\pm$  SD. The testing was performed by Student's t-test, and  $p < 0.05$  is considered statistically significant.

## Results and Discussion

The optic strut is a bony formation located between upper side of the body and the lesser wing of sphenoid bone and separates optic canal from the medial portion of superior orbital fissure. Position of the optic strut was determined based on relation between the length of anterior clinoid process and the distance measuring from the optic strut to the top of the anterior clinoid process.

In skulls of both genders on examination it has been found that the optic strut was attached to the anterior fifth of anterior clinoid process in 10.6%

cases on the right side, and in 12.5% on the left. Its attachment to the anterior two fifths of the process was registered in 42.0% on the right side and the 44.0% on the left side. The least seen positions of the attachment site are entirely to the front, by the base of anterior clinoid process – in 0.9% on the right side and 3.2% on the left side, as well as entirely to the back, by the top of the process in 2.0% on the right and 0.5% on the left side (Table 1).

On all the skulls we measured the width of anterior clinoid process in its base, and the length from the base's midline to the top as shown in (Figure 1). The anterior clinoid process in almost every observed male skull was triangular in shape, its base oriented to the front and top to the back and medially. In the total of 75 analyzed male skulls, the mean value of ACP width on the right side measured  $7.9 \pm 1.4$  mm. On the left side the ACP width is  $7.5 \pm 1.0$  mm, mean  $\pm$  SD. The length of the process in males measured  $8.8 \pm 1.3$  mm on the right, and  $8.40 \pm 1.4$  mm on the left (Table 3). On the skulls originated from females, the mean value of ACP width on the right side measured  $7.6 \pm 1.5$  mm, and  $7.3 \pm 1.6$  mm on the left side. The process mean value of length in females on the right side was  $8.5 \pm 1.6$  mm, and  $8.0 \pm 1.4$  mm on the left side (Table 2). There were statistically significant differences in mean width and in mean length of the anterior clinoid process between men and women on the both sides of the examined skulls ( $p < 0.05$ ).

The carotico clinoid foramen (CCF) is formed when tops of the anterior and middle clinoid processes merge on the upper side of sphenoid bone. The merge can appear to be complete and incomplete. Aside from these two forms of the foramen, we also analyzed the so called contact form when there is a suture between the two clinoid processes (Figure 2). The complete form of CCF on the total of 75 male skulls (150 sides) was found to be bilateral in three cases (2.0%). Unilaterally, it appeared in six skulls (3.9%), in four cases on the right side, and in remaining two cases on the left.

An incomplete caroticoclinoid foramen was found in larger number of male skulls. It appeared bilaterally in 10 skulls – 6.6% cases. The contact form of the foramen was found bilaterally in two male skulls (1.3%). Based on the results, we can conclude that the caroticoclinoid foramen in all three forms appeared in 36 cases, which is 14% (Table 3,4).

While analyzing female skulls (60 skulls - 120 sides), we found complete CCF bilaterally in four skulls (3.2%) and presence of CCF unilaterally two on right and left side respectively. Out of 19 skulls registered in incomplete form, nine skull noted

having incomplete form out of which five on right side (4.1%) and four on left side (3.3%). Bilateral incomplete form was noted in 8 skulls (6.6%). Similar to male skulls, incomplete CCF was found in larger number of female skulls as well: in eight skulls bilaterally (6.6%) and nine skulls unilaterally (7.4%). We haven't found the contact form of carotico-clinoid foramen bilaterally in female skulls.

Any abnormality in the anatomical structure of ACP combined with a completely ossified CCF, may have high risk of injury to the ICA and complete or partial removal of the ACP is an important step to approach to the cavernous sinus, paraclinoid aneurysms and radical removal of tumors and Therefore, understanding the complex morphometric anatomy of ACP and knowledge of the type of ossifications of the carotico-clinoid ligament serves special purpose to increase the success of surgery [8,9].

A study by Kapur et al. [7], reported the average length of the ACP in males 9.9±1.6mm on right and 9.3±1.4mm on left. The length in females was 9.3±1.6mm right side and 8.9±2mm on left side. The present study reported mean value of ACP length in males on the right and left side as 8.8±1.3 and 8.8±1.3 mm and in female of length of ACP on right and left side were 8.5±1.6 and 8.0±1.4 respectively when compared to the values in the literature.

Gupta et al. [8], reported the basal width of ACP 9.62±2.36 and 9.66±1.27mm on right and left side respectively. In a Korean study by Lee et al. [13],

the width of ACP was 9.97±1.58 and 9.29±1.39mm on right and left side respectively. The present study the width of ACP in males was 7.9±1.4 and 7.5±1.0 mm on right and left side and in females 7.6±1.5 and 7.3±1.6 mm respectively reported lower values when compared to the values in the literature.

The optic strut was most commonly attached to front two fifths on the lower side of anterior clinoid process (42% on the right side and 44% on the left). The data on size and dimensions of the optic strut should be kept in mind during surgical procedures on cavernous sinus and region of orbital apex. Knowing the precise location of the optic strut and its variations are very important while analyzing CT images, since it represents a valuable landmark in proper evaluation and differentiation of the optic canal, superior orbital fissure and anterior clinoid process on coronal and axial scans [8].

In our sample consisting of 75 male and 60 female skulls (270 sides) the complete form of CCF was discovered in 17 cases (15.2%). The contact form of the foramen was noticed in 9 cases, which is (12.9%) in a sample of 270 sides. The incomplete form was present in 40 cases (56.0%). On observing the results it shows that the complete, contact and in-complete forms of caroticoclinoid foramen were more often found in men, and were more often found on right side regardless of gender (Table 3,4).

Hochstetter [11] and Kier [12] postulated that an osseous CCF was a developmental anomaly and showed its existence in the fetal and infant skulls.

**Table 1:** Location of the optic strut in relation to the anterior clinoid process (ACP)

Attachment Site	Right Side	Left Side
By the base of the ACP	0.9%	3.2 %
Anterior fifth of the ACP	10.6%	12.5%
Anterior two fifths of the ACP	42.0%	44.0%
Anterior four fifths of the ACP	4.4%	5.0%
Posterior fifth of the ACP	2.0%	0.5%

**Table 2:** Incidence of complete, incomplete and contact form caroticoclinoid foramen (CCF) in male skulls (n=150)

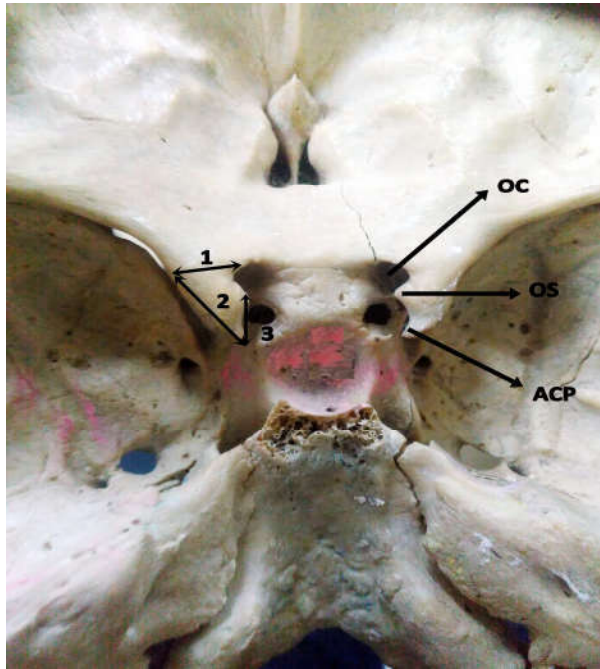
Male skull		Complete form	Contact form	Incomplete form
Unilateral	Right	4 (2.6%)	1 (0.6%)	7 (4.6%)
	Left	2 (1.3%)	3(2.0%)	4 (2.6%)
Bilateral		3 (2.0%)	2(1.3%)	10 (6.6%)
Total		9 (6.0%)	6 (4.0%)	21 (14%)

**Table 3:** Incidence of complete, incomplete and contact form caroticoclinoid foramen (CCF) in female skulls (n=120)

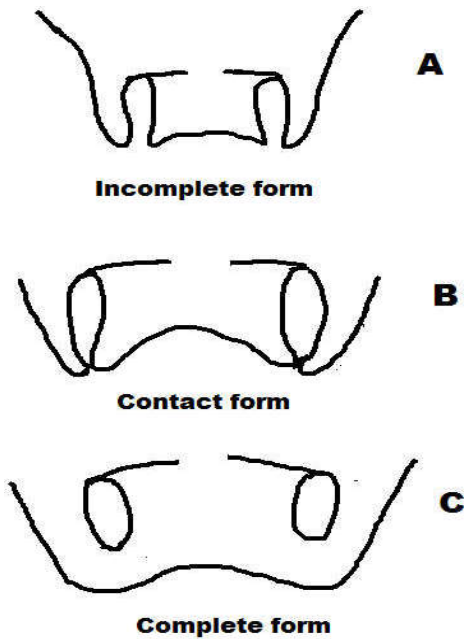
Female skull		Complete form	Contact form	Incomplete form
Unilateral	Right	2 (1.6%)	1 (0.8%)	5 (4.1%)
	Left	2(1.6%)	2 (1.6%)	4 (3.3%)
Bilateral		4 (3.3%)	Nil	8 (6.6%)
Total		8 (6.6%)	3 (2.5%)	19 (15.8%)

**Table 4:** Dimensions of the ACP in millimeter including gender and side of the examined skulls

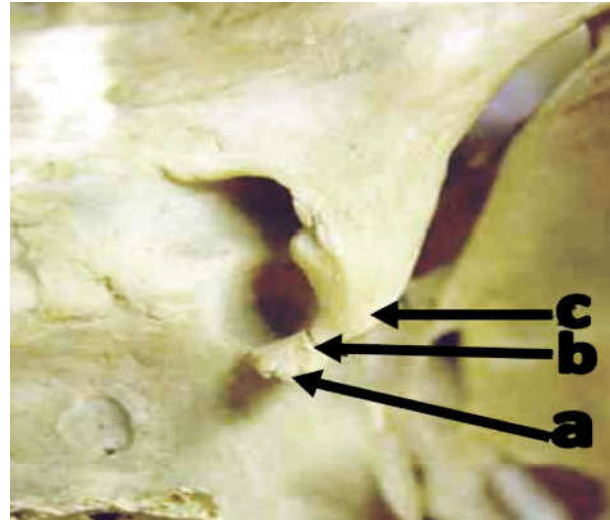
	Male		Female	
	Right	Left	Right	Left
Width	7.9±1.4	7.5±1.0	7.6±1.5	7.3±1.6
Length	8.8±1.3	8.40 ±1.4	8.5 ±1.6	8.0 ± 1.4



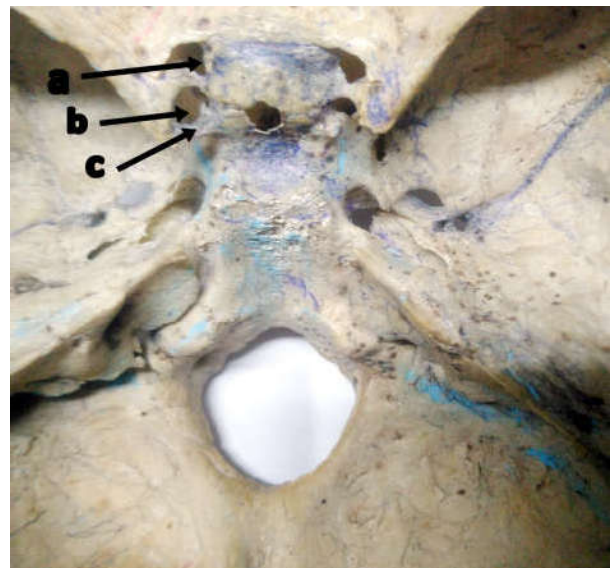
**Fig. 1:** The measured parameters on the anterior clinoid process. 1-width in the base, 2-length from base to the top, 3-length from the top to the posterior margin of the optic strut (ACP- anterior clinoid process, OP-optic strut, OC-Optic canal)



**Fig. 2:** Illustration of three forms of caroticoclinoid foramen. ACP- anterior clinoid process, MCP - Middle Clinoid process. A- incomplete form, B - contact form, C - complete form



**Fig. 3:** Male skull (right side). Contact form of the caroticoclinoid foramen. a-middle clinoid process, b-carotidoclinoid foramen, c- anterior clinoid process



**Fig. 4:** Male skull (left side) Complete form of the caroticoclinoid foramen. a-optic canal, b-carotidoclinoid foramen, c-middle clinoid process

In the study by Lee et al [13], the complete and incomplete forms of caroticoclinoid foramen were found in 17.0% cases, while Keyers [9] registered their appearance in 27.4% among American caucasians, predominantly on the left side. Azeredo et al. [14] registered caroticoclinoid foramen in the skulls of Portuguese population in 6.27%. Erturk [16] found the three forms of the foramen in 23.8% cases.

Most studies proclaim higher incidence on the right side, with an exception of studies performed in USA [5], that indicate higher incidence of caroticoclinoid foramen on the left side, as well as more significant number of complete or incomplete foramina bilaterally.

### Conclusion

Considering the immense anatomical surgical and radiological importance of ACP, OS and CCF, this study highlighted the detailed morphometry of these structures and may be immensely contribute to surgeons during the surgical interventions on tumors and aneurysms in the sellar region, mobilization of the ACP and the OS and prevent inadvertent damage to internal carotid artery and the optic nerve. The study also has explained the sexual dimorphism in their morphology.

### Conflict of Interest

The authors declare that they have no conflict of interest.

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