Original Article

Prevalence and Morphometry of Arcuate Foramen in Atlas Vertebrae in Pakistanis

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ABSTRACT

Objective: To assess the prevalence and morphometry of arcuate foramen and comparison with native foramen transversarium in atlas vertebrae of Pakistani population.

Study Design: Descriptive / observational study.

Place and Duration of Study: This study was conducted at Anatomy department, Sheikh Zayed Medical College Rahim Yar Khan and Wah Medical College Wah Cantt. during a period of two years from Jan 2012 to Dec. 2013.

Materials and Methods: The study included 150 dried human atlas vertebrae. Prevalance of complete arcuate foramina (CAFs) in atlas vertebrae were noted and its anteroposterior and superoinferior diameters were measured by vernier calipers with accuracy of 0.01 mm. Size and shape of CAFs were compared with native foramina transversaria (NFTs).

Results: Out of 150 atlas vertebrae, 13 (8.66%) showed CAF. The mean anteroposterior diameter of the right CAF was 6.71 mm and that of left was 6.76 mm. The mean superoinferior diameter was 5.07 mm on the right and on left side it was 5.22 mm.

The mean cross-sectional area of CAFs was 26.74 mm^2 and 27.77 mm^2 for the right and left sides respectively. The mean cross-sectional area of the right NFTs was 34.86 mm^2, while the mean area for the left was 35.31 mm^2.

Conclusion: This study provides information on the morphometry of arcuate foramen and ipsilateral native foramina transversaria (NFTs) and their implications. The observation that CAFs are smaller than ipsilateral NFTs suggests that they are an important cause of vertebral artery compression syndromes and needs careful investigations. Knowledge of CAF may help the surgeons undertaking procedures in the C1 region.

Key Words: Complete arcuate foramen, ponticulus posticus, atlas vertebra, native foramen transversarium.

INTRODUCTION

The vertebral artery, as it emerges from the native foramen transversarium of the atlas (C1) vertebra, travels posteriorly and medially behind the lateral mass of the atlas and lies in the neurovascular groove on posterior arch of the atlas. Sometimes bony spurs or outgrowths extend from the lateral mass to the posteromedial margin of the groove and are named as posterior bridges (also called ponticles) which convert the neurovascular groove into a sulcus, incomplete or complete foramen.[1] When present this complete foramen is named as arcuate foramen. The alternate names used for this foramen are Kimmerle's variant/anomaly/deformity, ponticulus posterior (ponticulus posticus) of the atlas, retroarticular canal, foramen retroarticulare superior, canalis vertebralis, retrocondylar vertebral artery ring, postglenoidal bridge, posterior bridge, retroarticular bridge, retroglenoidal bridge and superior retroarticular bridge, foramen arcuale, foramen posterius, foramen retroarticulare, or foramen sagittale.[2]

The arcuate foramen can be associated in producing symptoms which may include migraine, vertigo, diplopia, and neck pain.[3,4] It has even been suggested that ponticulus posticus may contribute to vertebral artery compression, vertebrobasilar insufficiency, or vertebral artery dissection.[5] Over the years, researchers have investigated the unilateral or bilateral occurrence of complete arcuate foramen.[6-9]

The present study was designed to determine the incidence of the arcuate foramen and the morphometric differences between the native foramen transversarium and arcuate foramen of atlas vertebrae in our population. The findings of this study might help to elaborate the correlation between occurrence of the bony bridges or ponticles and vertebral artery entrapment.

MATERIALS AND METHODS

This study is based on the examination of one hundred and fifty dry human atlas vertebrae obtained from the Anatomy department of Sheikh Zayed Medical College, Rahim Yar Khan and Wah Medical College, Wah Cantt, district Rawalpindi.

Measurements of maximum dimensions of the arcuate foramen in both anteroposterior (ventrodorsal or length) and superoinferior (rostrocaudal or height) directions were taken. The anteroposterior and mediolateral (horizontal) diameters of the ipsilateral native foramina transversaria (NFTs) were measured in all the atlas vertebrae. These measurements were taken by using

Vernier calipers (Peacock Co., Tokyo, Japan) sensitive to 0.01 mm.

The cross-sectional area of the arcuate foramen and ipsilateral native foramen transversarium was calculated using the formula for the ellipse[10]:

Area (A) = л x D1 x D2 x 1/4

Where D1 = horizontal length of the foramen.

D2 = vertical length of the foramen and

л (Pi) = 3.142 or 22/7

The data was analyzed using the SPSS software version 15.0.

RESULTS

Complete Arcuate Foramen (CAF): The complete arcuate foramen (CAF) was present in 13 vertebrae out of 150 atlas vertebrae (8.66%). The side of appearance of CAF was right in 6 cases (4%), left in 4 cases (2.66%) and bilateral (Fig.) in 3 cases (2%) (Table-I). When viewed as a group, the side of involvement was right in 46.15%, left in 30.77% and bilateral in 23.08%.

The mean anteroposterior diameter of the right CAF was 6.71 mm. The mean superoinferior diameter was 5.07 mm (Table-2). On the right side, the anteroposterior diameter was significantly larger than the superoinferior (p = 0.002).

On the left side, the mean anteroposterior diameter of CAF was 6.76 mm. The mean superoinferior diameter was 5.22 mm. As on the right side, there was statistically significant difference between the anteroposterior and superoinferior diameters.

Native Foramen Transversarium (NFT): On the right side, the mean anteroposterior diameter of native foramen transversarium (NFT) was 7.47 mm. The mean mediolateral or horizontal diameter was 5.94 mm (Table-II). There was significant difference between the anteroposterior and mediolateral diameters (p=0.003).

The mean anteroposteior diameter on the left NFT was 7.44 mm. The mean mediolateral or horizontal diameter was 6.04 mm. As on the right side, there was also statistically significant difference between the two parameters.

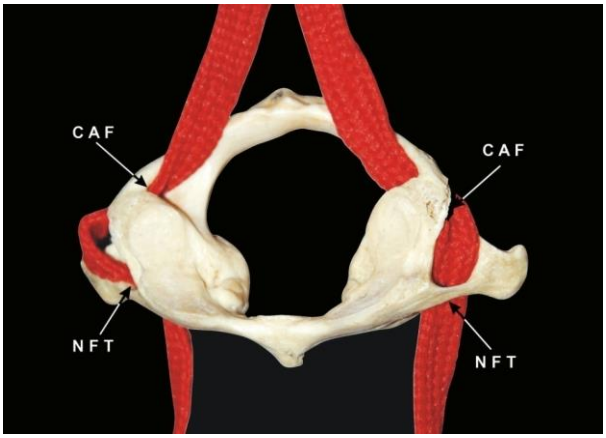

Figure No.1. Photograph of atlas vertebra showing bilateral complete arcuate foramina (CAFs) & native foramina transversaria (NFTs).

Table No.1: Incidence of complete arcuate foramen (CAF) in Pakistani population.

Number of atlas vertebrae studied	Complete Arcuate Foramen (CAF)	Bilateral CAF	Right side CAF	Left side CAF
	n	n	N	n
150	13 (8.66%)	3 (2%)	6 (4%)	4 (2.66%)

Table No.2: The mean diameter and cross sectional area of Complete Arcuate Foramen (CAF) and Native Foramen Transversarium (NFT) present in the atlas vertebrae.

CAF Diameter (mm)				NFT Diameter (mm)				Cross Sectional Area (mm^2)			
Anteroposterior		Superoinferior		Anteroposterior		Mediolateral (Horizontal)		CAF		NFT	
Right	Left	Right	Left	Right	Left	Right	Left	Right	Left	Right	Left
6.71	6.76	5.07	5.22	7.47	7.44	5.94	6.04	26.74	27.77	34.86	35.31

Cross- sectional Area of CAF and NFT: The mean area of complete arcuate foramen (CAF) was 26.74 mm^2 and 27.77 mm^2 for the right and left sides respectively. There was no statistically significant difference in the area on the right and left sides.

The mean area of the right native foramina transversaria (NFTs) was 34.86 mm^2, while the mean area for the left was 35.31 mm^2. There was no statistically significant difference between the two sides.

The mean area of NFT was invariably larger than that of the CAF. On the right side, the statistical significance was 0.05 while on left side it was 0.03.

Ponticle Thickness: There were numerous variations with respect to thickness and configuration of the ponticuli. The mean ponticle thickness was 2.64 mm (1.60 – 3.30 mm).

DISCUSSION

Complete Arcuate Foramen (CAF): The ponticulus posticus is a bony outgrowth over the groove for the vertebral artery located dorsal to the lateral mass on the posterior arch of the atlas vertebra and the foramen formed when complete is called arcuate foramen.

Acurate foramen has been studied in skeletal bones,[11-16] radiographs,[17-22] and CT Scans[23,24] in different populations. In the studies performed on skeletal bones, retroarticular canal of atlas vertebra is classified in three groups. Class-I represents retroarticular impression on the posterior arch of atlas vertebra, Class-II is defined retroarticular sulcus, and Class-III represents complete bony ring or complete arcuate foramen (CAF).

Table No.3: Incidence of complete arcuate foramen in human atlas vertebrae reported by different researchers in the literature.[7]

Sr. No.	Study		Source	Incidence %
	Researcher	Year		
1	Pyo	1959	Radiographs	12.60
2	Romanus	1964	Radiographs	14.30
3	Lamberty	1973	Osteologic Specimens	15.00
			Radiographs	7.50
4	Basaloglu	1983	Osteologic Specimens	9.50
5	Stubbs	1991	Radiographs	13.00
6	Cankur	1995	Osteologic Specimens	14.20
7	Mitchell	1998	Osteologic Specimens	9.80
8	Malas	1998	Radiographs	2.60
9	Hassan	2001	Osteologic Specimens	3.40
10	Unur	2004	Radiographs	5.10
11	Present Study	2013	Osteologic Specimens	8.66

Table No.4: Comparison of anteroposterior (AP) and Superoinferior (SI) diameters of the complete arcuate foramen (CAF) in different populations.

Author and population	Complete Arcuate Foramen			
	AP diameter (mm)		SI diameter (mm)	
	Right	Left	Right	Left
Mitchell, 1998, mixed South Africans	6.4	6.6	5.3	5.1
Unur et al, 2004, Turkish	8.2	8.0	5.7	-
Paraskevas et al, 2005, Northern Greek	6.4	6.7	5.4	5.4
Karau et al, 2010, Kenyans	6.29	6.00	5.11	5.16
Present study, 2013, Pakistanis	6.71	6.76	5.07	5.22

A less detailed description is given in radiologic studies, in which arcuate foramen is classified as complete or incomplete.[17] Depending on the method of study, reported incidence changes between 3.4-15% in skeletal bone studies, and between 2.6-14.3% in studies carried out on radiographs (Table-3). In a study involving both the skeletal bones and radiographs of 60 European spines, the reported incidences are 15% and 7.5%, respectively.[7] In general, the radiographic incidence for CAF seems to be lower than that of skeletal bone studies[17], however, variations in different populations and races should also be considered.

In general, the incidence of arcuate foramen is not related with sex. In a study conducted by Unur et al[7] it was concluded that age and sex do not appear to be related to the frequency of occurrence of complete arcuate foramina. Although Stubbs[17] has reported that CAF is more common in males. The age and gender difference of the foramina remained unexplored in our study due to limitations in this regard.

In a study conducted by Mitchell,[10] the incidence of complete retroarticular canal was 9.8%, of which 17% were on the right, 36.1% were on the left and 46.6% were bilateral. The figures in our study 46.15%, 30.77% and 23.08% respectively differ which might be due to ethnic variation.

In our findings for the complete arcuate foramen, the mean anteroposterior (AP) diameter was 6.71 mm on the right and 6.76 mm on the left side. The mean superoinferior (SI) diameter was 5.07 mm on the right and 5.22 mm on the left side. These measurements corroborate with those of the previous workers (Table-4).

Cross- sectional Area of CAF and NFT: There are limited studies comparing the Morphometry of complete arcuate foramen and that of ipsilateral native foramen transversarium. In the present study, the mean area of CAF was found to be 26.74 mm^2 and 27.77mm^2 on the right and left sides respectively. Nearly similar results were obtained by Karau et al[11] which showed mean area of 23.44 mm^2 on the right and 24.98 mm^2 on the left side. But the study of mean area of CAF by Tubbs et al[2] showed 14.2 mm^2 among Iranians and 12.5 mm^2 among Americans. Perhaps this difference might be in part due to ethnic variations and method disparity. The previous workers did not detail the instrument they used, whereas we used the vernier calipers.

The mean cross sectional area of the right native foramina transversaria (NFTs) was 34.86 mm^2 while that of the left was 35.31 $mm^{2.}$ These findings appear to be similar with those of Karau et al[11] who found 36.30 mm^2 on the right and 37.20 mm^2 on the left NFTs. These readings are higher than that measured among Iranians and Americans by Tubbs et el.[2] It is a notable fact that areas of CAFs are significantly smaller than the area of the ipsilateral NFTs on both sides. The difference in the dimensions of the CAFs and NFTs means that the space for vertebral artery to pass through is reduced, and this may compromise blood flow in the vessel.[11]

Our study supports the previous assertions that presence of complete atlas bridges can lead to compression of the vertebral artery in the absence of arterial disease, and may be an aggravating factor in case of disease.[10,11,16] In extreme manipulations of neck this compression becomes evidently symptomatic.[25] The prevalence of

arcuate foramen in the path of vertebral artery leads to prevalence of compression syndromes. It is possible that the third segment of the vertebral artery may be a reserve length to allow for neck rotation without injury or compression to the artery. Presence of these ponticles may limit this reserve length, predisposing to entrapment of the artery.

Ponticle Thickness: Search of literature revealed that there is paucity of data on the measurement of the ponticle thickness. To our knowledge, only Unur et al[7] measured the mean ponticle thickness on radiographs which was 2.2 mm (1.0-3.5 mm). In our study performed on dried bones, the mean ponticle thickness was 2.64 (1.60 – 3.30 mm) which also needs research in other populations.

CONCLUSION

The prevalence of complete arcuate foramen (CAF) in the atlas vertebrae among Pakistanis are comparable to that in other populations. This study provides information on the morphometry of arcuate foramen and ipsilateral native foramina transversaria (NFTs) and their implications. The observation that CAF are smaller than ipsilateral NFTs suggests that they are an important cause of vertebral artery compression syndromes and needs careful investigations of multifactorial aetiology for the syndromes. Knowledge of CAF may help the surgeons undertaking procedures in the C1 region.

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