ORIGINAL PAPER

Arcuate foramen of atlas: incidence, phylogenetic and clinical significance

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Abstract

Arcuate foramen is less known trait of the human atlas vertebra formed by a delicate bony spiculum, which arches backward from the posterior end of the superior articular process. Examination of 1044 human atlas vertebra revealed that the trait was present in 13.8% of the samples. The mean length of the arcuate foramen form was 7.16 mm on the left side and 9.99 mm on the right side in bilateral positive samples while it was 8.14 mm and 9.26 mm respectively in unilateral positive samples. The mean vertical height of this foramen was 6.57 mm on the left side and 6.52 mm on the right side in bilateral positive samples while it was 4.91 mm and 5.38 mm respectively in unilateral positive samples. The sides did not show any statistical significant differences. The importance of the arcuate foramen lies in the external pressure it may cause on the vertebral artery as it passes from the foramen transversarium of the first cervical vertebra to the foramen magnum of the skull.

***Keywords*:** human atlas vertebra, arcuate foramen, vertebral artery, phylogeny.

Introduction

In the human atlas vertebra, immediately behind each superior articular process is a groove (*sulcus arteriae vertebralis*), transmitting the vertebral artery and the suboccipital (first spinal) nerve. This is sometimes converted into a foramen (arcuate foramen) in about 14% of the individuals by a delicate bony spiculum, which arches backward from the posterior end of the superior articular process [1].

Kimmerle anomaly/variant/deformity, *ponticulus posterior* (*ponticulus posticus*) of the atlas, *pons posticus*, *foramen atlantoideum posterius/vertebrale*, *canalis arteriae vertebralis*, *foramen sagitale*, retroarticular VA ring, foramen retroarticular superior, retrocondylar bony foramen, posterior atlantoid foramen, atlas bridging, posterior glenoid process and spiculum are the alternate names used for this foramen [2].

Authors have reported the occurrence of the arcuate foramen of atlas in 9.8–25.9% of the population The importance of the arcuate foramen lies in the external pressure it may cause on the vertebral artery as it passes from the *foramen transversarium* of the 1st cervical vertebra to the *foramen magnum* of the skull. In the present study, the authors have tried to know the incidence, types, phylogenetic and clinical significance of the arcuate foramen in the Indian population.

Material and methods

A total of 1044 complete/undamaged dry human atlas vertebrae of unknown sex and age were studied from the collection in the Department of Anatomy, Kasturba Medical College, Mangalore, India.

These vertebrae were examined for evidence of exostosis from the posterior margin of superior articular facet. The specimens exhibiting such bony outgrowths were classified as having either a partial or a complete left and/or right arcuate foramen. Measurements were taken of the maximum dimensions of the arcuate foramen in both ventro-dorsal (length) and rostro-caudal planes (height). Data were recorded separately for both sides and expressed as mean and standard deviation. Side differences were compared using the unpaired "Student's t test", the level of significance was set at $P<0.05$.

Results

One hundred and forty four (13.8%) vertebrae showed the presence of a bony exostosis from the posterior margin of the superior articular facet. Partial bony outgrowth/incomplete arcuate foramen were found in 57 (5.5%) vertebrae, and 87 (8.33%) vertebrae had a complete arcuate foramen. Bilateral complete foramen was present in 12 (1.14%) of these samples and in the remaining 75 vertebrae (7.18%), the occurrence was on unilateral side. Twenty-seven (2.58%) vertebrae showed complete arcuate foramen on the right side while 48 (4.59%) vertebrae showed it unilaterally on the left. The mean length of the arcuate foramen form was 7.16 mm on the left side and 9.99 mm on the right side in bilateral samples while it was 8.14 mm and 9.26 mm respectively in unilateral samples.

The mean vertical height of this foramen was 6.57 mm on the left side and 6.52 mm on the right side in bilateral samples while it was 4.91 mm and 5.38 mm respectively in unilateral samples. The sides did not show any statistical significant differences.

Table 1 – ***Different measurements in bilateral arcuate foramen***

Sides[a]	Length of the arcuate foramen	Height of the arcuate foramen
Left	7.16 (1.62; 5.28–9.56), t = 5.85	6.57 (0.834; 5.24–7.36), t = -0.161
Right	9.99 (0.412; 9.35–10.4), t = 5.85	6.52 (0.372; 6.00–6.90), t = -0.161

[a]*Data are shown as mean (standard deviation; range)*

Table 2 – ***Different measurements in unilateral arcuate foramen***

Sides[a]	Length of the arcuate foramen	Height of the arcuate foramen
Left	8.14 (1.01; 6.73–9.43), t = 5.40	4.91 (0.670; 3.75–5.93), t = 3.55
Right	9.26 (0.464; 8.63–9.92), t = 5.40	5.38 (0.228; 5.04–5.68), t = 3.55

[a]*Data are shown as mean(standard deviation; range)*

Discussions

The ossification of ligamentous structures in various parts of the body may result in clinical problems such as compression to neighboring structures and complications in regional surgery. The posterior atlantooccipital membrane when ossified partly or wholly forms a bony bridge over the vertebral groove, called arcuate foramen [3]. Previously authors have studied about this foramen and mentioned its occurrence in 9.8–25.9% of the general population [4–8]. Taitz C [9] mentioned about the presence of partial posterior bridging of atlas in 25.9% and complete bridging in 7.9% of the population. They also proposed a hypothesis that external mechanical factors, such as carrying heavy objects on the head, could play a role in the development of these bridges.

Paraskevas G [8] mentioned about the higher incidence of complete canal for vertebral artery in laborers to the non-laborers. He also mentioned about the higher occurrence of incomplete canal for vertebral artery in the 5–44-years-age range. Stubbs DM [10] mentions that complete foramen is significantly more common in males and partial foramen in white females. Mitchell J [7] mentions that the foramen is lower in whites than in black. Cakmak O [11] contradicts the above theory and mentions about the higher occurrence of complete foramen in the females to that of males. Yamamoto A [12] in his study has mentioned that the complete posterior bridge is a normal structure of adult Japanese macaques.

Authors like Unur E *et al.* [13] have studied about the dimensions of the arcuate foramen and mention that the mean height and length are 5.7 mm (3.7–8.5 mm) and 8.1 mm (5.7–10.0 mm) respectively. Tubbs RS *et al.* [14] have found that the mean area of the arcuate foramen is 14.2 mm^2.

Authors like Hasan M *et al.* [15] have classified the arcuate foramen into six groups. In class I: Impression for the vertebral artery was noticeable, class II: Impression was seen as a distinct groove or sulcus, class III: Partial posterior ponticulus was noted as a bony spicule, class IV: Complete posterior ponticulus could be detected, class V: Lateral bridge extended from the lateral mass to the transverse process, class VI: Posterolateral tunnel made its appearance as a combination of complete posterior (class IV) and lateral (class V) bridges.

The arcuate foramen is an underestimated structure and clinicians should be alerted to a possible arcuate foramen with patients complaining of vertigo, headache, shoulder-arm, and neck pain. Cervical spine radiography is a simple and useful technique to indicate the presence of arcuate foramen [11].

Cushing EK *et al.* [16] found an association between the presence of arcuate foramen and tethering of the vertebral artery in the arcuate foramen and dissection from repetitive trauma with movement of the neck.

Conclusions

Neurologists, neurosurgeons and medical community in general should have knowledge about the present variation and try to look for it when dealing with the patients complaining of symptoms of vertebro-basilar insufficiency like headache, vertigo, shoulder and arm pain.

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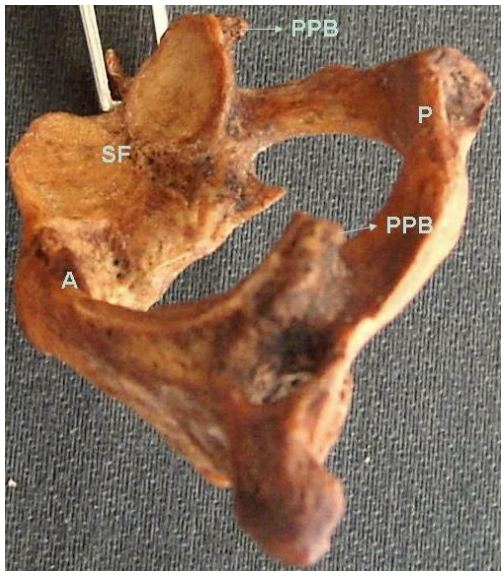

Figure 1 – ***Left lateral view of the atlas vertebra showing the presence of partial posterior bridging: A – Anterior arch, P – Posterior arch, SF – Superior articulating facet, PPB – Partial posterior bridging***

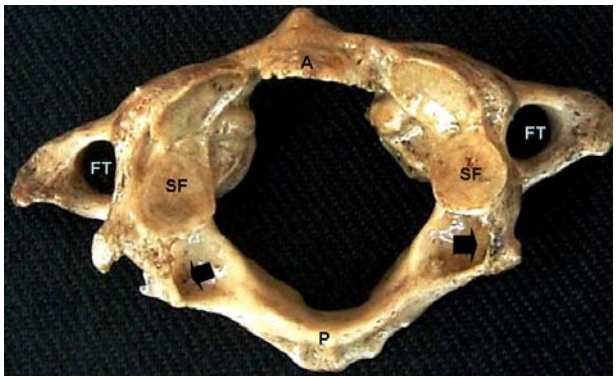

Figure 2 – ***Superior view of the atlas vertebra showing the presence of bilateral complete arcuate foramen: A – Anterior arch, P – Posterior arch, SF – Superior articulating facet, FT – Foramen transversarium, Block arrows – Arcuate foramen***

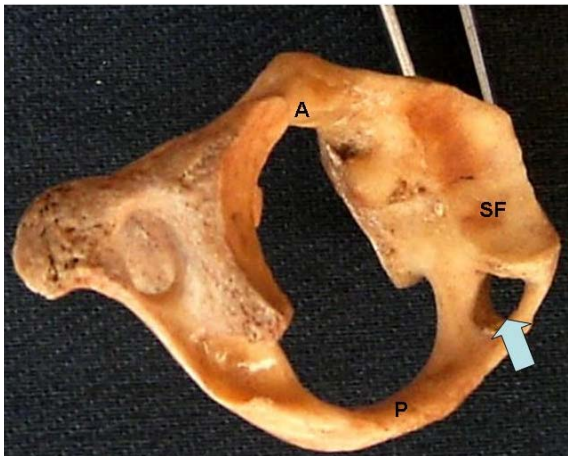

Figure 3 – ***Left supero-lateral view of the atlas vertebra showing the presence of complete arcuate foramen on the right side: A – Anterior arch, P – Posterior arch, SF – Superior articulating facet, Block arrow – Right sided complete arcuate foramen***

Figure 4 – ***Right supero-lateral view of the atlas vertebra showing the presence of complete arcuate foramen on the left side: SF – Superior articulating facet, Block arrow – Left sided complete arcuate foramen***

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