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Research Article

ARCUATE FORAMEN OF ATLAS VERTEBRA

SENTHIL KUMAR B*, PANNEER SELVI G

Department of Anatomy, Vinayaka Mission's Kirupananda Variyar Medical College and Hospital, Salem - 636 308, Tamil Nadu, India.
Email: skdrchinu88@gmail.com

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ABSTRACT

The arcuate foramen is a bony arch which connects the posterior end of the superior articular fossa with the posterior arch of atlas. In the case of presence of arcuate foramen, the vertebral artery follows the normal course but it has to traverse through the osseofibrous ring (arcuate foramen).

Objectives: To determine the height, width, and area of the arcuate foramen and to determine the morphometric difference between the transverse foramen and the canal formed by bony bridges over the vertebral artery of the atlas vertebra.

Methods: A total of 75 dry human atlas vertebrae were taken for the study. These vertebrae were examined carefully for the presence of arcuate foramen. Measurements of the maximum dimensions of the arcuate foramen and foramen transversarium were taken. Area of the arcuate foramen was calculated. Differences in the dimension of arcuate foramen and foramen transversarium were compared. Side differences of arcuate foramen were compared using the unpaired Student's t-test.

Results: The dimension of the arcuate foramen of both sides as compared with a dimension of foramen transversarium was found to be more, so the chance of compression of vertebral artery on both sides was less. The percentage of the occurrence of arcuate foramen was 2.25% (bilateral), and ponticles was (1.5%) unilateral.

Conclusion: The dimension of arcuate foramen was more when compared to foramen Transversarium dimensions so the chances of compression of vertebral artery would be less. The knowledge of these foramina may be important for orthopedic surgeons, radiologists, neurosurgeons, and anthropologists.

Keywords: Ponticulus posticus, Arcuate foramen, Atlas vertebra, Foramen transversarium.

INTRODUCTION

Atlas vertebra is named after a Greek warrior atlas who carries the globe. Atlas is the first cervical vertebra which is ring-shaped, has no body, spinous process, and has anterior and posterior arches with two lateral masses. The anterior arch is shorter and articulates with the dens of the axis vertebra. The posterior arch has a groove on its superior surface through which the vertebral artery and the dorsal ramus of the first cervical spinal nerve traverse. Ponticles of atlas are the bony spurs like projections which arise from either the anterior or posterior margins of the groove for the vertebral artery sometimes the groove is converted into a foramen called arcuate foramen [1]. Percentage of the occurrence of arcuate foramen is about 14% [2]. Osseo fibrous ring on vertebral artery groove of atlas are described as foramen atlantoideum posterius/vertebrale, ponticulus posticus, posterior glenoid process retroarticular canal, kimmerle anomaly/variant/deformity, canalis arteriae vertebralis, ponticulus posterior (ponticulus posticus) of the atlas, pons posticus, foramen sagitale, atlas bridging, foramen retroarticular superior, retrocondylar bony foramen, posterior atlantoid foramen, and spiculum are the synonyms used for this foramen [3]. According to Miki *et al*., radiographically, the arcuate foramen can be classified into three types. (1) Full type in which a complete bony ring is formed, (2) incomplete type in which some portions of the bony ring is defective, and (3) calcified type in which there is a linear or amorphous calcification [4].

The arcuate foramen connects the retroglenoid tubercle of the superior articular fossa of the atlas with the posterior arch [4]. The vertebral artery, after leaving the foramen transversarium of the atlas vertebra, passes on its posterior arch and then pierces the posterior atlantooccipital membrane, to enter into the vertebral canal. In the case of presence of arcuate foramen, the vertebral artery follows the normal course but it has to traverse through the osseofibrous ring (arcuate foramen).

Objectives

To determine the height, width, and area of the arcuate foramen and to determine the morphometric difference between the transverse foramen and the canal formed by bony bridges over the vertebral artery (arcuate foramen) of atlas vertebrae.

METHODS

A total of 75 dry human atlas vertebrae of unknown sex and age were taken for the study from the Department of Anatomy, Vinayaka Mission's Kirupananda Variyar Medical College and Penang International Dental College, Salem, Tamil Nadu, India. These vertebrae were examined carefully for the presence of arcuate foramen and ponticles. The vertebrae with ponticles were classified according to Miki *et al.* [4]. Measurements were taken of the maximum dimensions of the arcuate foramen in both ventro-dorsal (length) and rostro-caudal planes (height) Fig. 1. Area of the arcuate foramen was calculated using the formula (pi (D1/2×D2/2) wherein (D1 = horizontal length of the foramen, D2 = vertical length of the foramen and Pi = 3.14) [5]. Data were expressed as mean and standard error mean (SEM). Side differences were compared using the unpaired "Student's t-test," the level of significance was set at $p<0.05$.

RESULTS AND DISCUSSIONS

The ossification of ligamentous structures in various parts of the body results in compression of adjacent structures and resulting in various complications [1]. The ossification of posterior atlantooccipital membrane forms a bony bridge over the vertebral groove, called arcuate foramen [6]. Atlas bridges, also called ponticles (Fig. 2), are bony outgrowths occurring on the vertebral groove of atlas vertebra, converting it into a foramen, either incomplete or complete foramen (arcuate foramen) (Fig. 3) [7]. These bridges are formed due to the ossification of the posterior atlantooccipital membrane [7]. These posterolateral tunnels were found in primates and it was noticed that the bony rings are a permanent and normal feature in them. The superoinferior and anteroposterior diameters of the retroarticular canal have been shown to differ significantly [8].

Previously authors have studied about this foramen and mentioned its occurrence in 9.8-25.9% of the general population [9-13]. Taitz and Nathan (1986) in his study showed the presence of partial posterior bridging of atlas in 25.9% and complete bridging in 7.9% of the population [14]. A hypothesis was proposed stating that external mechanical factors, such as carrying heavy objects on the head, could play a role in the development of these bridges. The percentage of the occurrence of arcuate foramen was 2.25% (bilateral) and ponticles was (1.5%) unilateral in this study (Table 1). Paraskevas *et al.* (2005) showed the higher incidence of arcuate foramen in laborers as compared to the non-laborers [9]. Yamamoto and Kunimatsu proved that the arcuate foramen is a normal structure in adult Japanese macaques [15]. Authors like Unur *et al.* (2004) studied the dimensions of the arcuate foramen and mentioned that the mean height and length were to be 5.7 mm (3.7-8.5 mm) and 8.1 mm (5.7-10.0 mm), respectively. In this study, the length and height of arcuate foramen on right side was 0.88±0.01 cm and 0.77±0.01 cm (Table 2), whereas the foramen transversarium anteroposterior and transverse diameters were less, i.e. 0.77±0.08 cm and 0.67±0.03 cm (Table 3) so the chance of compression of vertebral artery on right side was less as diameter of arcuate foramen was more [16]. The length and height of arcuate foramen on the left side was 0.87±0.02 cm and 0.86±0.02 cm (Table 2), whereas the foramen transversarium anteroposterior and transverse diameters were less 0.80±0.05 cm and 0.60±0.01 cm (Table 3) so the chance of compression of vertebral artery on the left side was also less according to present study. Tubbs RS *et al.* 2007 have found that the mean area of the arcuate foramen is 14.2 mm^2 [3]. In this study, the mean area of arcuate foramen was less on both the sides; on right side it was 0.53 cm^2, whereas on left side it was 0.59 cm^2 (Table 2). Cushing *et al.* 2001 came out with an association between the presence of arcuate foramen and tethering of the vertebral artery in the arcuate foramen [17]. The 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 indentify the presence of arcuate foramen [18].

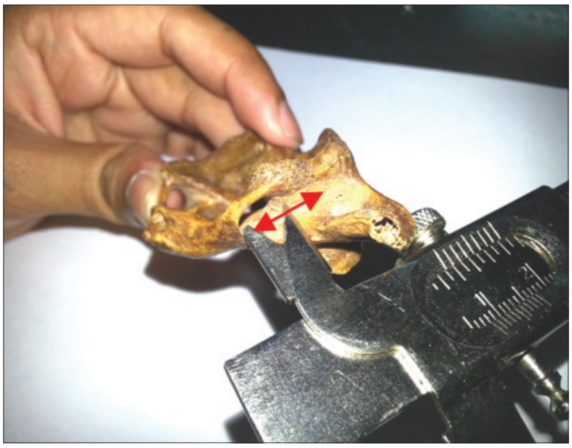

Fig. 1: Measuring the arcuate foramen (length) with Vernier caliper

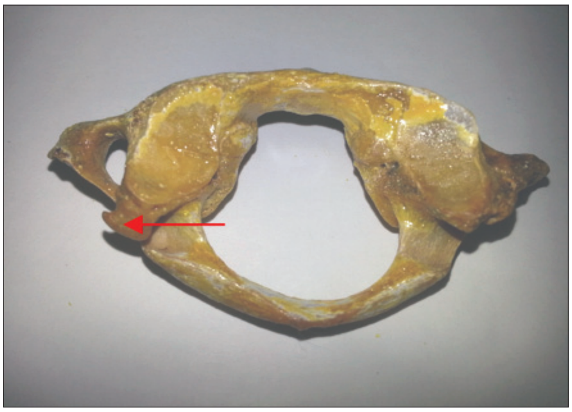

Fig. 2: Ponticles forming incomplete foramen

Fig. 3: Arcuate foramen

Table 1: Prevalence of ponticulus posticus and ponticles in atlas vertebra

Prevalence	Side	Frequency	Percent
Arcuate foramen	Bilateral	3	2.25
Ponticles	Unilateral	2	1.5
Absence	Bilateral	70	96.25
Total	Bilateral	75	100

Table 2: Dimensions of arcuate foramen

Side	Length (cm) Mean±SEM	Height (cm) Mean±SEM	Area of foramen (cm^2)
Right	0.88±0.01	0.77±0.01	0.53
Left	0.87±0.02#	0.86±0.02**	0.59

Number of specimens with arcuate foramen - 3, SEM,
**p<0.01, #Statistically not significant

Table 3: Dimensions of foramen transversarium

Side	Mean±SEM	
	AP dm (cm)	T dm (cm)
Right	0.77±0.08	0.67±0.03
Left	0.80±0.05#	0.60±0.01*

Number of specimens with arcuate foramen - 3, AP: Anteroposterior,
T: Transverse, dm: Diameter, SEM, *p<0.05, #Statistically not significant

Table 4: Dimensions of ponticles forming incomplete foramen

Vertebra	Side	Length (cm)	Width (cm)
Specimen 1	Right	0.79	0.69
Specimen 2	Left	0.64	0.57

Ponticles (bony spur) was found in two atlas vertebra bilaterally (Table 4). Causes of ponticles of atlas are congenital variant, genetic trait, ossification due to ageing. Clinical significance of ponticle of atlas is vertebrobasilar insufficiency lead to death attributed to reduction in blood flow, circulation stroke, vascular lesion of posterior cranial fossa, dizziness, unconsciousness, sight, and hearing disturbances [19].

CONCLUSION

However, the dimensions of arcuate foramen were more when compared to foramen transversarium dimensions, so the chances of compression of vertebral artery could be less in all three specimens of this study. The observation on the ponticles of atlas suggests that they are an important cause of vertebral artery compression. The relatively high prevalence of the bony ponticles of the atlas compared to vertebral artery compression syndromes suggests multifactorial etiology for the syndromes. This variation may facilitate the interpretation of radiological findings, and also may guide for certain neurosurgical interventions, a note of caution when craniovertebral manipulations are carried out. Vertebral artery can be easily compressed during extreme rotation of the head and neck within the arcuate foramen and result in compromised blood flow. Hence, such anatomical variations should be kept in mind during a surgical manipulation. The knowledge of this foramen would be important for the orthopedic surgeons, radiologists, neurosurgeons, and anthropologists.

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