Arcuate foramen and its clinical significance

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ABSTRACT

Objective: The present study determines the degree of ossification of the posterior atlanto-occipital membrane in dry bone, plane lateral cervical spine radiographs and computer tomography (CT). The average length, width and the area of the arcuate foramen were measured on dry bone and on cervical CT. Further, age, gender and complaints of the patients of shoulder and arm pain, neck pain, headache, vertigo, and lacrimation in relation to the presence of bony complete or incomplete arcuate foramen were evaluated.

Methods: From February 2004 to January 2005 60 dry atlases were obtained from the Anatomy Department, University of Marmara, Istanbul, Turkey and 416 lateral cervical spine radiographs were obtained from the Radiology department for neurological and orthopedic evaluations. Each complete arcuate foramen was calculated with the aid of Clemex Vision PE demo version computer program.

Results: Among the 60 dry atlases examined 7 (11.7%) had complete and 2 (3.3 %) had incomplete bony bridge formation. Of the 416 plane lateral cervical spine radiographs examined, 30 (7.2%) had complete and 26 (6.25%) had incomplete bony bridge formation. Of the 30 complete arcuate foramen 24 (80%) were females and 6 (20%) were males. The frequency of having a complete

arcuate foramen in females was 8.45%, and in males it was 4.55%. Further, of the 26 incomplete arcuate foramen 20 (76.9%) were females and 6 (23.1%) were males. The frequency of having an incomplete arcuate foramen in females was 7%, and in males was 4.55%. The statistical evaluations showed that patients with complete arcuate foramen had significant complaints of shoulder-arm pain (p=0.0072), neck pain (p=0.0072) and vertigo (p=0.0598) compared to patients with incomplete arcuate foramen. The patients with complete arcuate foramen had a headache ratio of 12:30 and this ratio was 2:26 in patients with incomplete arcuate foramen and the difference between complete and incomplete arcuate foramen was statistically significant (p=0.0062). Further, no statistically significant relation was observed between both complete and incomplete arcuate foramen and lacrimation. No relationship between age and the presence of complete and incomplete arcuate foramen was observed.

Conclusion: Presence of an arcuate foramen is always underestimated. Its presence should always be keep in mind in patients complaining of shoulder-arm and neck pain, headache and vertigo are examined.

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T he ossification of ligamentous structures in various part of the body is frequently observed. This may result in a clinical problem such as compression to neighboring structures and complications in regional surgery. The atlas consists of a neurovascular groove for the vertebral artery located behind each lateral mass at the posterior arch of the atlas¹ (Figure 1). Superiorly the vertebral groove is arched by the posterior atlanto-occipital

membrane, leaving an opening for the upwards passage of the vertebral artery and the outwards passage of the first cervical spinal nerve. In addition to the vertebral artery and the first spinal nerve, venous plexus and the peri-arterial sympathetic plexus also pass through this groove. The posterior atlantooccipital membrane can sometimes ossify partly or wholly to form a bony bridge over the vertebral groove, called arcuate

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foramen or foramen arcuale atlantis.² According to Shimizu et al,³ repeated rotational neck movements were the most likely mechanism underlying the ossification of the posterior atlanto-occipital membrane as well as fixing the vertebral artery in the vascular groove of the atlas. The bony foramen may limit the normal mobility of the vessels during flexion and extension of the neck and may cause disturbances of arterial flow and of the peri-arterial sympathetic plexus giving rise to symptoms similar to those found in the Barre-Lieou syndrome.² Furthermore, the vertebral artery can be pinched during neck rotations, which may lead to thrombus formation and embolism which causes cerebellar infarction (bow-hunter's stroke).³ The groove for the vertebral artery on the posterolateral surface of the atlas varies in size and depth from a slight impression to a clear groove therefore; the area of the arcuate foramen can vary significantly and can be a compressing factor for the vertebral artery. The aim of the present study is to determine the ossification state of the posterior atlanto-occipital membrane in dry bone, lateral cervical spine radiographs and computerized tomography (CT). Further, the age, sex and the complaints of the patients in relations to complete or incomplete, or both arcuate foramen were evaluated.

Methods. Sixty dry atlases were obtained from the Anatomy Department, University of Marmara, Istanbul, Turkey the age distributions of the dry bones were unknown. Further, 416 (female n=284, male n=132) lateral cervical spine radiographs were obtained from the Radiology Department for neurological and orthopedic evaluations. The age range of the patients were between 26-79 and the mean was 49.5 ± 14.43 years. The presences of complete and incomplete ossification of the posterior atlantooccipital membrane on dry atlases was evaluated. Each complete arcuate foramen of dry bones was photographed with a millimetric scaled paper bar using a Nicon Coolpix 5000 digital camera. The images were loaded on a computer and the inner boundaries of the arcuate foramen were encircled with black lines using the Adobe Photoshop 6 computer program. The average length,

width and the area of the arcuate foramen were calculated with the Clemex Vision PE demo version computer program. All measurements were achieved by the same researcher. The length, width and the area of arcuate foramen results were evaluated statistically with paired t-test for Dry bones (n=60). The presence of the complete and posterior ossification incomplete of the atlantooccipital membrane on lateral x-rays graphics were evaluated. Only on x-rays in which the posterior elements were clearly observed were included in the study. The complaints of the patients were documented. The patients with complete ossifications were voluntarily invited for a CT scan (n=17, 10 male, 7 female). The average length, width and the area of the arcuate foramen was measured on CT scan. The gender and the left and the right side of CT scan results were evaluated statistically with Mann-Whitney U test. The age, gender and the complaints of the patients in relation to the presence of complete or incomplete, or both arcuate foramen were evaluated statistically with Fisher's exact test (Table 1).

Results. Among the 60 dry atlases examined, 7 (11.6%) had complete and 2 (3.2%) had incomplete bony bridge formation. Of the 7 complete bony bridge formation, one (1.6%) was bilateral, and 6 (10%) were unilateral. Of the 6 unilateral arcuate foramens, 3 were on the left and 3 were on the right (Figure 2a). Of the 2 incomplete bony bridge formation both were unilateral and located on the left side (Figure 2b). The average length, width and the area of the arcuate foramen was measured, and the average data were stated in Table 2. The difference of dimensions of arcuate foramen in CT scans between male and female and also between left and right side were not statistically significant (p>0.05). Of the 416 plane lateral cervical spine radiographs examined, 284 were females and 132 were males. Three (7.2%) had complete, and 26 (6.25%) had incomplete bony bridge formation (Figure 2c & 2d). The presence of bilateral complete or incomplete, or both, bony bridge formation could not be evaluated due to complications in visualizing cervical spine radiographs. Of the 30 complete

Table 1	-	The clinical	symptoms of th	he patients	with complete	or incomplete	arcuate foramen.
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Arcuate Foramen in x-ray	N=416	Male n=132	Female n=284	Vertigo	Shoulder, arm pain	Neck pain	Lacrimation	Headache
Complete	30	6	24	19	18	18	6	12
Incomplete	26	6	20	9	6	6	0	2
Total	56	12	44	28	24	24	6	14

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Figure 1 - A multislice MRI of a patient with a bony arcuate foramen showing the relationship between the arcuate foramen and the vertebral artery.



Figure 3 - Three dimensional cervical computerized tomography scan of a patient showing a unilateral complete arcuate foramen.

Variables	Dry bone (mm)	Computed tomography (mm)
Lenght		
Right	7.4 ± 0.1	6.1 ± 0.1
Left	7.3 ± 0.1	6.1 ± 0.1
Width		
Right	5.9 ± 0.1	4.7 ± 0.1
Left	6.0 ± 0.1	4.9 ± 0.1
Area		
Right	34.6 ± 0.1	22 ± 1.1
Left	34.3 ± 0.1	23 ± 0.1

Table 2 - The average length, width and the area of the arcuate foramen on dry atlas bones and CT.



Figure 2 - Complete and incomplete arcuate foramen on a & b) dry atlases and c & d) on x-ray graphics of patients.

arcuate foramen, 24 (80%) were female and 6 (20%) were male. The frequency of having a complete arcuate foramen was 8.45% in females and 4.55% in males. Further, of the 26 incomplete arcuate foramen, 20 (76.9%) were females and 6 (23.1%) were males. The frequency of having an incomplete arcuate foramen in females was 7%, and in males was 4.55%. The 30 patients with complete bony arcuate foramen were invited for a cervical CT scan; however, only 17 patients accepted to take on (**Figure 3**). The length, width and the area of the arcuate foramen for each patient was measured and the average data are shown in **Table 2**.

The statistical evaluations with Fisher's exact test showed that patients with complete arcuate foramen had significant complaints of shoulder-arm pain (p=0.007), neck pain (p=0.007) and vertigo (p=0.0598) compared to patients with incomplete arcuate foramen. The patients with complete arcuate foramen, had a headache ratio of 12:30 and this ratio was 2:26 in patients with incomplete arcuate foramen, and the difference between complete and incomplete arcuate foramen was statistically significant (p=0.006). Further, no statistically significant relation was observed between both complete and incomplete arcuate foramen and lacrimation. The ratio of both complete and incomplete arcuate foramina was higher in females than males. No relationship between age and the presence of complete and incomplete arcuate foramen were observed in Fisher's exact tests.

Discussion. Although the presence of complete or incomplete bony bridge over the vertebral groove of the atlas has been mentioned briefly in anatomy texts books, the detailed anatomy and its clinical significance have received less attention. Early studies on dry atlas and cervical spine radiographs showed inconstant data on the arcuate foramen.⁴⁻⁸ Our dry atlas observations (11.6% complete, 3.3% incomplete) were in accordance with the results of Wysocki et al,⁴ (complete + incomplete 13.8%) but considerably lower than Lambert and Zivanovic's⁵ (complete + incomplete 56.1%) studies. Our cervical spine radiographs results (complete 7.2%, incomplete 6.25%) were in accordance with Kendrick and Biggs⁶ (complete + incomplete 15.8%), Pyo and Lowman⁷ (complete + incomplete 12.7%) and Stubbs⁸ (complete 13.5%, incomplete 5.2%) studies. Dugdale¹⁷ observed both complete (14.8%) and incomplete (11.7%) arcuate foramen in high frequency compared to the present and the former studies. The low occurrence of the complete arcuate foramen in cervical spine radiographs may be due to difficulties in visualization.

The diameter of the arcuate foramen can be related to the caliber of the vertebral artery, with the calibers of the right and left vessels showing great variations. Anatomical studies showed that the left vertebral artery is larger than the right in 45%, the right vertebral artery being larger than the left in 21%, and the arteries were equal size in 34%.⁹ Further, racial differences were documented on the diameter of the vertebral artery. Argenson et al¹⁰ revealed that the vertebral artery was larger in Africans (right 4.4 mm, left 5.3 mm) than Europeans (right 4.3 mm, left 4.7 mm). The difference in the results of various studies can be due to racial differences. Therefore, racial differences should be taken into consideration in evaluation of the data.

Stubbs⁸ studied the variability in the distribution of arcuate foramen in relation to gender, and found that complete arcuate foramen was more common in males and incomplete arcuate foramen in Caucasian females. Pyo and Lowman,⁷ described the ratio of arcuate foramen as 11.8% in females, and 13.9% in males. Kendrick and Biggs,⁶ studied the occurrence of arcuate foramen in children, and found the ratio of 14.6% in boys and 16.9% in girls. Although ossification is age-dependent, this is not the case in arcuate foramen. Kendrick and Biggs6 and Cushing et al¹¹ reported the existence of bony arcuate foramen in children. In accordance with the former studies the results of the present study showed no between the ossification of relation the atlanto-occipital membrane and age and gender. Therefore, it can be suggested that the formation of the arcuate foramen is not a hypertrophic process or a kind of osteophyte formation.

In the presence of a bony arcuate foramen, rotation occurring at C1-C2 can be accompanied by a physiological stretching of the vertebral artery.^{12,13} The artery on the opposite side is elongated and may be narrowed and in some cases it will compress against the lateral mass of the atlas, thus impairing blood flow. Certain studies suggested that as a consequence of this extreme rotation there can be a physiological change in length of the vertebral artery as a response to taking up of the slack of the vessels in 2 places: 1. The section of the artery that winds around the lateral mass of the atlas, and 2. In the loop between C1 and C2. Krayenbuhl and Yasargil¹⁴ considered these physiological "reserve loops" of the vertebral artery as enabling the artery to follow the movements of the cervical vertebrae and head. In addition to this physiological condition occurring at the region, a bony arcuate foramen can enhance the clinical symptoms and can be a potential compressing factor for the vertebral artery. Cushing et al¹¹ 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. Our results also agree with those of Sun et al,¹⁵ is who found among 69 patients complaining of vertigo out of 923 patients treated with the cervical

syndrome, a ratio of 7.4% having complete arcuate foramen. Further, radiological evaluations of patients with ischemic attacks occurring repeatedly following voluntary neck rotation, showed a complete arcuate foramen.¹⁶ Surgical decompression of the vertebral artery relieved the symptoms. ^{3,16-18}

Our results showed that the patients with complete arcuate foramen have various significant complaints which may cause compression of the sympathetic plexus around the vertebral artery. 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.

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