Research study

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Study of foramen transversaria of first cervical vertebrae and its variations

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Abstract

Introduction

Knowledge of variations in foramen tranversarium of first cervical vertebrae is surgically relevant, as its anatomical relation with third part of vertebral artery is one of the proposed causative factor for cervicogenic headache. This study was aimed to determine the incidence, morphological and morphometrical variations of foramen transversarium (FT) of atlas vertebrae in North Indian population.

Methods

Fifty atlas vertebrae were collected from osteology museum of Maulana Azad Medical College, New Delhi. Each vertebra was examined for the presence of foramen tranversarium and their dimensions were measured. Any other variation observed was also noted. Results were statistically analysed for side and size variation.

Results

96% of vertebrae displayed bilateral presence of complete foramen in transverse process. Transverse foramen varied in shape with majority of vertebrae showing larger anteroposterior diameter than mediolateral diameter. The area ranged from 23.85mm2 to 38.06mm2 on right and 22.23mm2 to 39.41 mm2 on left side. No significant side variation in measurements of transverse foramen was noticed. 2% of vertebrae showed absence of FT and 2% had absent costal element.

Conclusion

Vertebral artery is predisposed to conditions like vertebrobasilar insufficiency, Barre Liou and cervicogenic syndromes. The spinal surgeons, neurosurgeons and radiologists should be aware of variations of FT of atlas and suggestively an absence of transverse foramen as it might affect the trajectory of the vertebral artery.

Introduction

The foramen transversarium of first cervical vertebrae, explicitly the atlas, reveals extensive variability in its morphology and morphometry. The third part of vertebral artery emerges from the foramen transversarium of atlas, lying within the occipital triangle and further enters into the cranial cavity through foramen magnum[1]. The vertebral artery on its way from foramen transversarium of atlas to the formation of basilar artery is vulnerable to damage or distortion from external factors like bony or ligamentous structures.

Developmental and acquired variations in course of third part of vertebral artery may account for variable anatomy of foramina transversaria (FT). It is postulated that tortuosity of the vertebral artery may cause bony erosion and may be a factor in size of foramina[2,3]. Also postural alterations in head and neck region can affect morphology of atlas[4]. Prevalence of neck syndromes related to vertebral artery like, Barre Liou and cervicogenic syndromes and its injury in atlanto-occipital region necessitates detailed study of foramen transversaria of atlas.

Numerous studies on variability in size, form, dispersal and absence of one or more of the foramina transversaria of the spinal column have been reported earlier[5]. However, there are fewer studies focusing on the qualitative and quantitative morphology of foramen transversaria of atlas in view of complex anatomy of occipital region[6].

This study was undertaken to look for any variations in the foramen transversarium (FT) of atlas vertebrae and to assess its measurements.

Materials and Methods

Atlas vertebrae were collected from osteology museum of Maulana Azad Medical College, New Delhi. A total of 50 specimens were obtained from adult dry skeleton with age range of 30-70 years, of unknown gender during undergraduate academic session 2013-2014. Broken or incomplete atlases with any pathological feature were excluded from the study.

All the specimens were examined for presence or absence of transverse foramen. Complete and incomplete foramina were noted on the right and left sides.

For morphometrical analysis Anteroposterior (D1) & Mediolateral (D2) diameters of FT on both sides were measured using a digital vernier calliper with an accurate resolution up to 0.01mm (Figure 1 and Figure 2). Cross-sectional area of each transverse foramen was calculated using formula for an ellipse: Area= 3.14XD1/2xD2/2 (mm^2). The metric data was analysed statistically with SPSS version 17 using student's t-test, with P value<0.05 taken as significant.

Results

97% of foramen transversaria were complete and bilaterally present (Table 1).

2% of FT with absent costal element were observed and were designated as having incomplete FT (Figure 3, Table 1). One atlas vertebrae had unilateral absence of foramen

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Table 1: Percentage incidence of occurrence of complete, incomplete and absent foramen transversaria of atlas vertebrae.

Foramen Transversarium	Number observed	Total Number Studied bilaterally	Percentage
Complete	97	100	97%
Incomplete (absent costal element)	2	100	2%
Absent	1	100	1%

Table 2: Percentage incidence of variable anteroposterior (AP) and mediolateral (ML) diameters of foramen transversaria of atlas vertebrae.

Foramen Transversarium	Number observed	Total Number Studied bilaterally	Percentage
AP=ML	18	97	18.5%
AP>ML	52	97	53.60%
ML>AP	27	97	27.83%

transversaria accounting for 1% incidence of absent FT (Figure 4, Table 1).

On morphometrical observations it was found that only 18.5% of FT was circular in shape with equal anteroposterior and mediolateral diameter. However, majority of the FT had anteroposterior diameter greater than mediolateral diameter. 27.83% of FT depicted mediolateral diameter greater than anteroposterior diameter. (Figure 5, Table 2).

There was no significant bilateral difference in anteroposterior, mediolateral diameters and area of FTs on right and left sides (Table 3).

Discussion

Vertebrae develops from sclerotome portion of the somites derived from paraxial mesoderm. Patterning of vertebral development is regulated through HOX genes. With subsequent development the sclerotome undergoes resegmentation wherein caudal half of each sclerotome grows and fuses with cephalic half of subjacent sclerotome. At the cranial most end of vertebral column where atlas vertebrae is developing, the caudal part of fourth occipital somite fuses with cranial part of first cervical somite forming proatlas, which gets assimilated in occipital condyles and apex of odontoid process in humans. The caudal part of first cervical sclerotome forms lateral masses and anterior and posterior arches of atlas. FT develops by vestigeal costal element anteriorly & true transverse process posteriorly. In atlas vertebrae true

Figure 1: Measurement of Foramen transversarium using Vernier caliper.

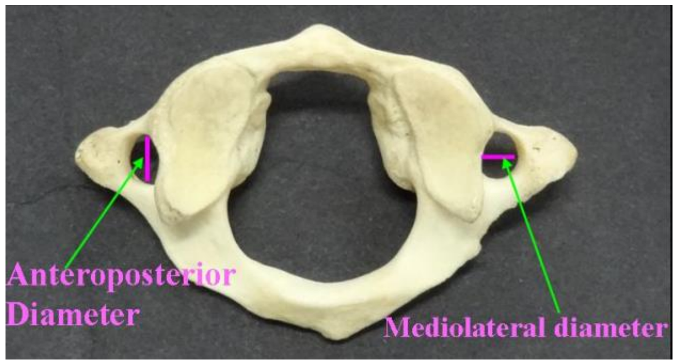

Figure 2: Figure showing method of taking anteroposterior (D1) and mediolateral diameter (D2).

Table 3: Mean and range of diameters and areas of foramen transversaria of right and left sides of atlas vertebrae.

	Right Side		Left Side		
	Range	**Mean**	**Range**	**Mean**	**P-Value**
AP diameter (mm)	7.63-5.65	6.64	8.24-5.86	7.05	>0.05
ML diameter (mm)	6.67-4.86	5.76	6.63-4.65	5.64	>0.05
Area (mm^2)	23.85-38.06	30.458	22.23-39.41	30.824	>0.05

transverse process is represented by a thick posterior bar in intrauterine life, which fuses eventually with thin anterior bar developed in third – fourth year of life from ventrolateral aspect of articular pillar and thus completes the formation of FT. Hence in atlas, the foramen transversarium is formed by fusion of anterior and posterior bars as they pass around the position of vertebral artery at the age of 3-4 years[7].

The variable shape of foramen transversarium as observed in current study were categorized on the basis of their

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Figure 3: Superior view of Atlas vertebrae with bilateral absence of costal element.

Figure 4: Superior view of Atlas vertebrae with bilateral absence of costal element.

morphometrical measurements. Earlier Taitz et al described five types of foramina transversaria on the basis of their shapes as seen grossly8. Type 1 was round where probabaly anteroposterior diameter is eaqual to mediolateral diameter. Type 2 and 3 were elliptical with main diameters anteroposterior and mediolateral respectively. Type 4 and 5 were also elliptical with main diameter oblique from right to left and left to right respectively. In our study we have accounted maximal anteroposterior dimension along sagittal or paraasagittal plane and maximal mediolateral dimension in coronal plane. The variable shapes of foramina have been known to have a correlation with the tortuosity and size of vertebral artery, which is inturn dependent subsequent to loading forces and stresses in the neck.[9]

The vertebral artery covers about two thirds of the minimal diameter and more than half of maximal diameter of the transverse foramen[10]. The anteroposterior and mediolateral diameter didn't show any significant side variation. However in a study conducted on 102 atlas vertebrae of Kenyan population the antreoposterior diameter was found to be significantly larger on right side[11]. Majority of the vertebrae in the current study had anteroposterior diameter larger than mediolateral diameter. It is said that preponderance of osteophytes on lateral margins of FT could lead to narrowing of mediolateral diameter leading to compression of vertebral artery and its dissection[12]. Hence it can be assumed that 53.6% of vertebrae with anteroposterior diameter greater than mediolateral diameter had minimal risk of vertebral artery compression syndrome. Besides, it is well known that any narrowing of FT may result in formation of atheromatous plaques in vertebral artery which may result in thrombosis/emboli /reflex spasm presdisposing to vertebrobasilar insufficiency[13].

The mean cross sectional area observed in current study was 30.458mm^2 on right side and 30.824mm2 on left side. This value was lower when compared with a study conducted on Kenyan and another study on Indian population as depicted in Table 4 [11,14]. This difference could be attributed to variable regional differences due to multiple environmental and genetic factors. All these studies have shown that left FT has larger area as compared to right FT which is in parallel with bigger size of vertebral artery on left side[15]

Absent costal element were seen predominantly on right side in Kenyan population by Karau and Odula[11]. In another study in Indian population, absent costal element was noticed in 10% of atlas vertebrae16. When compared with current study conducted on similar North Indian specimens, whereby only 1% of atlas vertebrae had

Table 4: A comprehensive chart depicting comparison of findings in current study with earlier studies in various population groups. (NR-Not reported, NA: Not applicable).

Author/s	Year	Population	N	Incidence of FT	Absent FT	Incomplete/ Absent Costal Element	Area Right FT	Area Left FT
Karau PB et al	2013	Kenyans	102	100%	0	7.8%	36.30mm^2	37.20mm^2
Gupta C et al	2013	Indians	35	NR	NR	8.57%	NR	NR
Chauhan R et al	2013	Indians	50	100%	NR	10%	NR	NR
Hasan et al	2001	Indians	34	100%	NR	NR	46.68-53.79 mm^2	50.67-51.46 mm^2
Nayak S	2007	Indian	1	NA	+	NA	NA	NA
Vasudeva N	1995	Indian	1	NA	+	NA	NA	NA
Our study	2014	Indian	50	96%	2%	2%	30.458mm^2	30.824mm^2

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Figure 5: Atlas vertebrae showing variable shape of foramina transversaria.

bilateral absence of costal element. This can be explained by the phenomenon of epigenetic variations observed commonly in a population group.

Absence of FT observed in our study could be substantial or concurrent to regional developmental abnormalities, suggesting an altered trajectory of the vertebral artery. The probable cause could be excessive posterior growth of costal element fusing completely with transverse element. Individual cases of absent foramen transversaria of atlas vertebrae have been reported in earlier literature[17,18], however its incidence is still unknown (Table 4) Unilateral absence of FT should be borne in mind of clinicians while understanding the anatomical basis of cervicogenic pains which are often unilateral.

Conclusion

Hence it can be concluded that FT of atlas vertebrae can show a range of variations in its shape, dimensions, its absence and being incomplete. Therefore, these variations when considered together are relevant to the spinal surgeons, neurosurgeons, and to the radiologists while managing any injury or condition afflicting atlanto-occipital region. This study can be further investigated on the subject, based on dissection of specimens, angiograms and correlation of the findings with clinical symptoms as required for a complete overview.

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