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Anatomical observations including morphometric pattern of foramina transversaria of atlas vertebrae in North Indians

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SUMMARY

The Foramen Transversarium (FT) is the result of a special formation of cervical transverse processes formed by fusion of vestigial costal elements to the body and true transverse process of the atlas that transmits the vertebral vascular bundle. The aim of this study was to investigate the morphology and variations, if any, in the FT of the atlas which can compromise the course of the vertebral artery leading to its insufficiency. Sixty foramina transversaria of 30 dry adult human atlas vertebrae obtained from the Anatomy Department, Government Medical College, Amritsar, Punjab, India, were employed to carry out this study. Linear measurements of FT Length, Width and Depth were carried out with the help of a vernier caliper. On the basis of shape, 5 different types of FT, i.e. Rounded, Elliptical-Anteroposterior, Elliptical-Transverse, Elliptical Right-Left and Elliptical Left-Right, were classified. The presence of unilateral and bilateral accessory foramina transversaria was also noted. Results indicate that the mean of right and left sides of FT Length was 6.81 mm, Width 5.28 mm and Depth 5.39 mm respectively. The most common shape of the FT was Type 4 with highest frequency of 56.6% (17) on the right side and 33.3% (10) on the left side. Out of 30 vertebrae, only 7(23.3%) presented accessory FT, 4 (13.3%) showed single FT, 1 (3.3%) showed double FT unilaterally on the left side and 2 vertebrae (6.6%) presented single accessory FT bilaterally. To conclude, morphological and morphometric knowledge of the FT is clinically important as the Vertebral Artery passing through it contributes blood supply not only to the brain, but also to the inner ear, and its compression may lead to neurological and labyrinthine disturbances. FT variations are also helpful in the interpretation of radiographic pictures or CT scans for diagnostics.

Key words: Foramen transversarium – Vertebral vascular bundle – Sympathetic plexus

INTRODUCTION

The Atlas (First cervical vertebra) holds the globe of the skull and is devoid of body and spine. It differs in structure from all the other cervical vertebrae, and is often identified by the presence of the Foramen Transversarium (FT) in the transverse processes. The FT transmits the vertebral vascular bundle and sympathetic plexus. On its way the third part of the vertebral artery appears from the FT of the atlas, turns backwards and medially behind the lateral mass of the atlas, and lies in the neurovascular groove on the posterior arch of the atlas (William et al., 2005). The vertebral artery, on its exit from the FT to the formation of the basilar artery in the cranial cavity, is vulnerable to damage

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or distortion from external factors like bony or ligamentous structures (Anderson and Norman, 1970).

Absence or presence of accessory or double FT are rare conditions, and may affect the course of the vertebral artery (Ebraheim et al., 1998). The vertebral vessels in such situations may be compressed by head movements, and consequently may give rise to vascular insufficiency. Clinically it can present as headache, vertigo, migraine and fainting attacks. Knowledge of the variations in the anatomy of the FT of the atlas can improve the success rate of surgeries, thus preventing damage to the adjoining vital structures like the spinal cord, nerve roots, cranial nerves and the vertebral arteries (Macalister, 1869; Taitz et al., 1978).

There are various studies focusing on the origin and course of the vertebral artery, but also paucity of literature regarding the morphology of accessory and absent FT in the cervical vertebrae and its incidence. The aim of this study was to investigate the morphology and variations, if any, in the FT of the atlas which can compromise the course of the vertebral artery and its insufficiency. Data provided in this study can be helpful in the correct interpretation of radiographic pictures or in computerized axial tomography and angiograms. This information may be also helpful in avoiding and reducing complications such as vertebral artery injury and spinal cord injury during spine surgeries (Nathan, 1962).

MATERIAL AND METHODS

Thirty dry adult human atlas vertebrae of unknown sex "(belonging to North Indian individuals)" were obtained by maceration from the cadavers made available for the purpose of dissection, in the Department of Anatomy, Government Medical College, Amritsar, Punjab, India. All the atlas vertebrae were thoroughly cleaned and numbered from 1 to 30. Damaged and pathological Atlas vertebrae were excluded from the study.

Fig. 1. Superior view of atlas vertebra showing dimensions of FT length, width and depth.

Linear dimensions of FT, i.e. length, width and depth (Fig. 1), were measured with the help of a vernier caliper with a minimum count of 0.02 mm, and each dimension was then read from the graduated scale of the caliper. All the measurements were taken directly from the bones and then the data were stored on the computer sheet. Shape of the foramen transversarium was noted on both the sides of vertebrae as Rounded, Elliptical-Anteroposterior, Elliptical-Transverse, Elliptical Right-Left and Elliptical Left-Right (Figs. 2 and 3). Presence of any accessory or absent FT and osteophytic encroachments, if any, were also studied (Fig. 4).

The Student's t-test was applied to evaluate the existence of possible difference between the mean of right and left sides of the vertebrae. Results have been considered significant when $p<0.05$".

Foramen Transversarium Length (FTL): It is the

Fig. 2. Superior view of atlas vertebra showing different shapes of foramen transversarium (FT): type 1, type 2 and type 3.

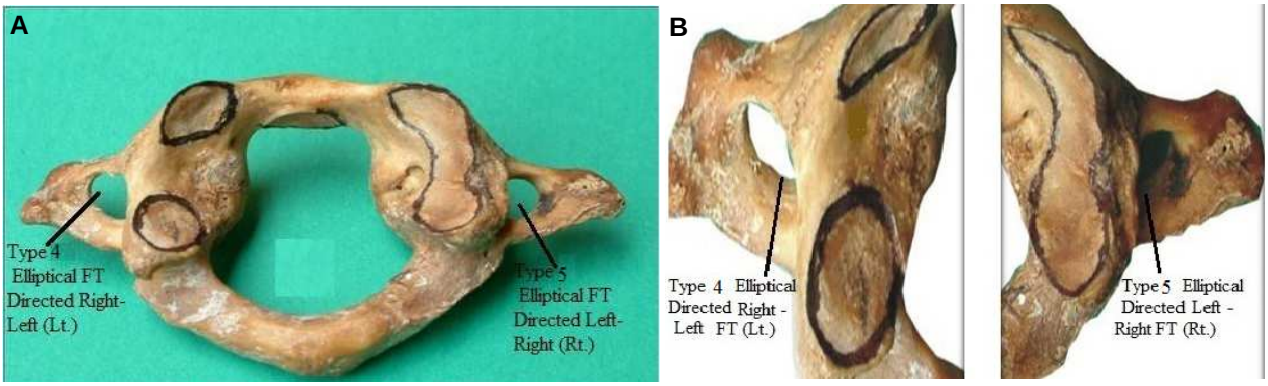

Fig. 3. Superior view of atlas vertebra **(A,B)** showing different shapes of foramen transversarium (FT): types 4 and 5.

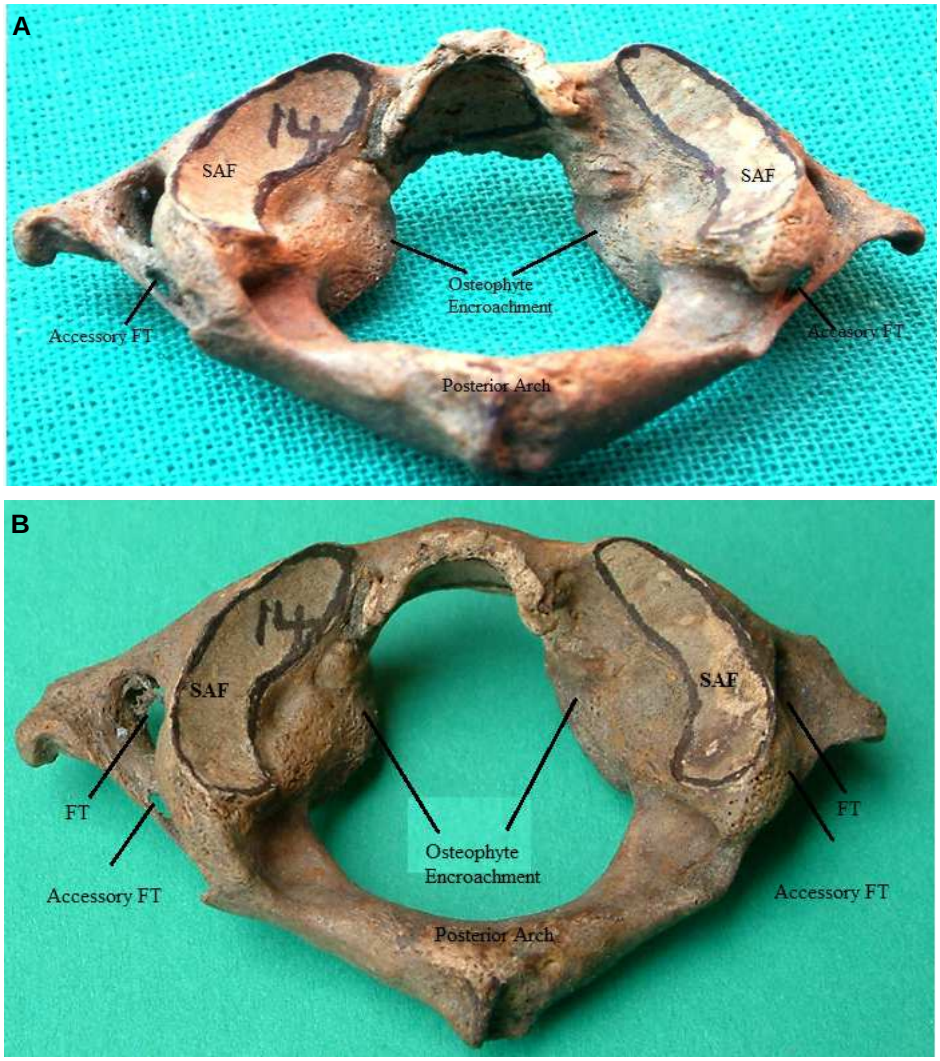

Fig. 4. Superior view of atlas vertebra **(A,B)** showing bilateral accessory foramen transversarium (FT) and osteophyte encroachment.

maximum distance in antero-posterior plane and was marked as MN as shown in Fig. 1.

Foramen Transversarium Width (FTW): It is the maximum distance in medio-lateral plane and was marked as mn as shown in Fig. 1.

Foramen Transversarium Depth (FTD): It is the maximum distance in supero-inferior plane and was marked as OP as shown in Fig. 1.

Based on the observations of shape of foramen transversarium, 5 different types of FT were classified i.e. rounded as type 1, elliptical with antero-posterior direction as type 2, elliptical with transverse direction as type 3, elliptical with right to left direction as type 4 and elliptical with left to right direction as type 5 (Figs. 2 and 3).

The FT transmits vertebral vessels, i.e. vertebral

artery and vein and the accessory foramen transversarium may be present to compartmentalize the contents of FT. Thus it can be assumed that the variations in the course of the vertebral vessels will cause variation in the FT, and variations in the FT can be useful in estimating the variations of the vertebral vessels. Therefore an absence of the FT could mean absence of the VA or the artery running along the transverse process and narrowing of the foramina may indicate narrowing of the vessels. Similarly, single or double accessory FT could mean duplication of the vertebral vessels (Taitz et al., 1978).

Single and double accessory FT and osteophytic encroachments were also observed on both the sides of the vertebrae (Fig. 4).

RESULTS

Table 1 showing the results of Foramen Transversarium parameters of atlas vertebrae.

The mean of FTL was found to be 6.72 mm and 6.90 mm on right and left sides respectively and difference of mean of length of FT was statistically insignificant (p=0.271).

The mean of FTW was 5.17 mm and 5.40 mm on right and left sides respectively and difference in mean of width of FT was statistically insignificant (p=0.186).

The mean of FTD was 5.30 mm and 5.49 mm on right and left sides respectively and difference of mean of length of FT was statistically insignificant (p=0.246).

The most common shape of the FT was found to be Type 4 with highest frequency of 56.6% (17) on right side and 33.3% (10) on left side, which is followed by Type 2 i.e. 20% (6) on right side and 20% (6) on left side, Type 5 10% (3) on right side and 30% (9) on left side, Type 1 10% (3) on right side and 13.3% (4) on left side and then by Type 3 3.3% (1) on right side and 3.3% (1) on left side in that order.

The present study showed 7 (23.3%) vertebrae having accessory FT, unilateral 5 (16.6%) being

Table 1. Results of foramen transversarium parameters of atlas vertebrae.

S No.	Parameters	Number	Mean (mm)	SD	Range (mm)	P Value	–		
1.	Foramen Transversarium Length (FTL)	30 (60 sides)	6.81	0.92	3.5-8.5	(p=0.271)	–		
2.	Foramen Transversarium Width (FTW)	30 (60 sides)	5.28	0.99	3.0-7.0	(p=0.186)	–		
3.	Foramen Transversarium Depth (FTD)	30 (60 sides)	5.39	1.16	1.80-7.30	(p=0.246)	–		
4.	Type FT	30 (60 sides)	–	–	–	(p=0.743)	**Type FT**	**Rt.**	**Lt.**
							Type 4	56.6 (17)	33.3 (10)
							Type 2	20%(6)	20%(6)
							Type 5	10%(3)	30%(9)
							Type 1	10% (3)	13.3% (4)
							Type 3	3.3% (1)	3.3% (1)
5.	Accessory FT	30 (60 sides)	–	–	–	–	No. Acc. FT	Rt.	Lt.	Bl.
							Single	0	13.3% (4)	6.6%(2)
							Double	0	3.3% (1)	0

Table 2. Comparison of foramen transversarium length (FTL) of atlas vertebrae.

References	Population	N	Side	FTL (mm)	
				Mean±SD	**Range**
Taitz et al. (1978)	Nonspecific mixed populations of India and Israel	33	Right	7.26±0.87	5.1 - 8.9
			Left	7.23±0.98	5.4 - 8.9
Ebraheim et al. (1998)	Ohio	50	-	5.65±1.05	4 - 8
Unur et al. (2004)	Turkish	-	-	5.7	-
Paraskevas et al. (2005)	Northern Greeks	-	-	5.4	-
Mitchell (1998)	Mixed South Africans	-	Right	5.3	-
			Left	5.1	
Karau Bundi et al. (2010)	Kenya	102	Right	5.11	-
			Left	5.16	
Present study (2014)	North Indians	30	Right	6.72±1.05	3 - 9
			Left	6.90±0.99	4 - 8
			Bilateral	6.81±0.92	3.5 - 8.5

more common than bilateral 2 (6.6%).

DISCUSSION

To put the current study into perspective, an inter-population comparison of FT shape is informative. As shown in Table 2, the length of FT of atlas vertebrae in North Indians in the present study was slightly shorter (6.81 mm) than those obtained by Taitz et al. (1978) based on nonspecific mixed populations of India, and longer than those observed in Turkish, Ohio, Northern Greek, South Africans and Kenyan population. Whereas Table 3 in the present study showed that the FT Width was same as compared to work done by Taitz et al. (1978) but was found to be slightly more as compared to work done by Ebraheim, (1998) in the population of Ohio. The FT depth was 5.39 mm, however no comparative data could be found from the available literature.

As shown in Table 4, the present study showed the highest frequency of Type 4 FT on right (56.6%) and left sides (33.3%), followed by Type 2, Type 5, Type 1 and then by Type 3 on both the sides of the vertebrae in that order respectively, and the difference between the percentage of types of shape of right and left sides of FT was found to be statistically insignificant (p=0.743). Similar were the findings by Taitz et al. (1978), who also found the highest frequency was Type 4 FT and least was Type 3 FT. Rekha and Neginhal (2014) observed the highest incidence of Type 4 FT (50.8%) on the right side and Type 5 (45.5%) on the left side followed by Type 2, Type 1, Type 5 and Type 3 on right side and Type 2, Type 1, Type 3 and Type 4 on left side.

As shown in Table 5, single accessory FT was found in 4 cases on the left side and 2 cases on both the sides, whereas double accessory FT were found in 1 case on the left side only whereas Wysocki et al. (2003) found only 1 accessory FT on the right side only. No triple FT was found. Accessory foramina when found were smaller in size than FT. Incomplete formation or absent FT was not observed in any of the atlas vertebra studied.

Morphological and morphometric knowledge of FT is clinically important as the Vertebral Artery (VA) passes through it. Large FT may be due to the presence of large vessels or veins as normally seen in the FT of seventh cervical vertebra. Similarly, the presence of accessory single or double FT could mean variations in the number and

Table 3. Comparison of foramen transversarium width (FTW) and depth (FTD) of atlas vertebrae.

References	Population	N	Side	FTW (mm)	FTD (mm)
				Mean±SD Range	Mean±SD Range
Taitz et al. (1978)	Nonspecific mixed populations of India and Israel	33	Right	5.52±0.93 (3.8-7.6)	-
			Left	5.76±0.98 (5.4-8.9)	-
Ebraheim et al.	Ohio	50	-	4.50±1.5 (3.0-6.0)	-
Present study, (2014)	North Indians	30	Right	5.17±1.09 (3.0-7.0)	5.30±1.30 (1.60-7.50)
			Left	5.40±1.11 (3.0-8.0)	5.49±1.18 (2.0-7.9)
			Bilateral	5.28±0.99 (3.0-7.0)	5.39±1.16 (1.8-7.3)

Table 4. Types of foramen transversarium of the atlas vertebrae on the basis of shape.

Shape of foramen transversarium (FT)	Taitz et al. (1978) n=33				Rekha and Neginhal (2014) n=153				Present study (2014) n=30			
	Right		Left		Right		Left		Right		Left	
	n	%	N	%	n	%	n	%	n	%	N	%
Type 1 (Round)	-	9.1	-	9.1	11	7.26	11	7.26	3	10	4	13.3
Type 2 (Elliptical-Anteroposterior)	-	24.2	-	36.4	56	36. 9	65	42.9	6	20	6	20
Type 3 (Elliptical-Transverse)	-	3.0	-	0	3	1.98	4	2.6	1	3.3	1	3.3
Type 4 (Elliptical-Right-Left)	-	57.6	-	6.1	77	50.8	4	2.6	17	56.6	10	33.3
Type 5 (Elliptical-Left-Right)	-	6.1	-	48.5	4	2.64	69	45.5	3	10	9	30

Table 5. Features of accessory foramen transversarium of atlas vertebrae.

References	Population	n	Accessory FT	Right side		Left side		Bilateral	
				n	%	n	%	N	%
Wysocki et al. (2003)	Poland	92	_	1	1.1	0	0	0	0
Present study, (2014)	North Indians	30	Single	0	0	4	13.3	2	6.6
			Double	0	0	1	3.3	0	0

course of the VA. Regarding the double FT, one foramen can be occupied by an artery and other by veins or each FT by branches of both the vessels. Such Possible variations of the vessels and their branches as described may therefore provide an explanation for this kind of anatomical puzzle of single or double accessory FT (Taitz et al., 1978).

Chandravadiya et al. (2013) observed an incidence of 4.76% double accessory FT in 210 cervical vertebrae. The Double accessory FT was found mainly in C5, C6, C7 and none in the atlas vertebra. These variations are possibly linked with duplication of the vertebral artery (Rekha and Neginhal, 2014). A bilateral absence of FT in an atlas vertebra was observed and reported as a case report by Nayak (2007). Incomplete FT was seen in 8.57% of specimens in a study by Gupta et al. (2013) and 3.92% by Rekha and Neginhal (2014). However, it is documented that tortuousity of the vertebral artery may cause bone erosion or impede the complete formation of the transverse foramen (Rekha and Neginhal, 2014). The absence of the FT was explained by the absence of the vertebral artery or a variation where the artery runs along the transverse process without entering the foramen (Karau and Odula, 2012).

The external mechanical factors such as custom of carrying heavy objects on the head could play a role in the development of anomalies of the atlas (Taitz and Nathan, 1986). The shapes of the foramina have a correlation with the vertebral artery. It is possible that extreme rotatory movements at the cervical spine in an individual may result in compression of vertebral artery and compromised blood flow.

Osteophytic encroachment in the FT of Atlas Vertebrae: Osteophytes were observed in the FT of Atlas vertebrae in North Indian population in 4 cases i.e 13.3% of cases. Osteophytes can distort or decrease the inner lumen of the FT, which can lead to the vertebral artery insufficiency. The shape and size of the foramina have a correlation with the vertebral artery. Tortuousity and size of the vertebral artery is in turn dependent on loading forces and stress in the neck region.

Occipital headache was reported in a case report by Senthilnathan and Rajitha (2011) due to hypoplastic anterior costal bars of C1 and C2 FT. Contrast examination revealed medially displaced left vertebral artery within the C2 vertebral foramen along with a large lateral loop of the vertebral artery between the C2 and C1 vertebrae.

Conclusion

The study has observed certain variations in the FT of the atlas vertebrae among North Indians. No significant difference was observed in the length, width and depth of the FT on either side of the atlas vertebra. Accessory FT and osteophytes were observed in a few cases.

Impingement of osteophytes from articular processes can cause compression of the vertebral artery or irritation of surrounding sympathetic plexus. Numerous surgical procedures such as interlaminar clamp, inter-spinous wiring and plate and transarticular and transpedicular screws fixation have been currently employed to correct the instability of the atlanto-axial complex or occipito-cervical junction, thus stabilizing the cervical column produced by numerous traumatic and non-traumatic conditions. Maintaining the vertebral artery intact constitutes an important concern during cervical surgical procedures.

Thus knowledge of variations of the FT of the atlas vertebra is important for radiologists, otolaryngologists, neurologists and orthopaedicians. It is suggested that a correlation should be worked out between angiograms, X-rays and clinical symptoms, keeping in view the valuable inputs from the study of osteology and dissection of the cadavers.

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