



Research Article

Morphometric Study of the Foramen Transversarium in Cervical Vertebrae

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ABSTRACT

There are seven cervical vertebrae in human body. It has foramen transversarium (FT) in their transverse process contains vertebral artery, vein & sympathetic nerve plexus, only vein will pass through C7, cervical vertebrae are of two types typical (C3-C6) and atypical (C1, C2 & C7). The main objective of this study was to observe and describe the anatomy and variations in the foramen transversarium 200 cervical vertebrae (102 typical & 98 atypical) with unknown age and sex from the department of anatomy were analyzed which included morphometry, morphology and incidence of foramen of vertebrae with digital vernier caliper accuracy of 0.01 mm. The mean diameter of anteroposterior and transverse of both right and left was measured and tabulated. Mean diameter of cervical vertebrae (5.69 ± 1.08 mm) & (5.84 ± 1.10 mm) of right side, (5.69 ± 1.06 mm) & (5.82 ± 1.19 mm) of left side. For shapes type A-F, Type A (round) shape is commonly seen (56%) in right and (46%) in left side. The anatomical knowledge of these variations is useful for spine surgeons in preoperative planning and for preventing vertebral vessel and sympathetic nerve injuries during cervical surgical approaches.

Keywords: Cervical vertebrae, Transverse foramen, Typical cervical vertebrae, Vertebral artery.

INTRODUCTION

Cervical vertebrae are the smallest of the movable vertebrae and are distinguished by the presence of foramen transversarium located in their transverse processes. The vertebrae C3, C4, C5, and C6 exhibit this common characteristic, thus they are referred to as typical cervical vertebrae. C6, has a slight variation; its anterior tubercle, known as the carotid tubercle, is more prominent as a result of the common carotid artery being pressed against it. C1, C2, and C7 possess unique features that classify them as atypical vertebrae.^[1] Transverse process has a foramen transversarium for vertebral vessels (except artery in C7). Composed of anterior and posterior roots with respective tubercles, joined by a costotransverse bar.^[2] Small, oval vertebral body with uncinate processes on the upper surface forming Joints of Luschka. Pedicles directed posterolaterally; laminae directed posteromedially. Superior and inferior notches formed by pedicle attachment. Lamina has a thin upper and thick lower border. Vertebral canal is triangular, contains the spinal cord. Spinous process is short and bifid. Articular pillar is formed by the lateral bulge at the pedicle-lamina junction, between superior and inferior articular facets. The anterior root, anterior tubercle, costotransverse bar, and posterior tubercle together form the costal element, which corresponds to ribs in thoracic vertebrae.^[1]

Foramen transversarium transmits the vertebral artery, vein, and sympathetic plexus (only vein passes through C7).^[2] The vertebral artery, a branch of the subclavian artery, supplies the brain and inner ear. Compression of the artery can lead to neurological and hearing issues. The foramen may vary in size, shape, and can be multiple or absent.

Variations in the size, shape, or number of foramen transversarium may be embryological or due to the vertebral artery's course. These variations can cause headache, migraine, or fainting due to artery compression. Awareness of such variations is important for clinicians and radiologists when interpreting X-rays and CT scans.^[3]

MATERIALS AND METHODS

This observational study was conducted on a sample of 200 human cervical vertebrae of unknown age and sex. The materials used included human cervical vertebrae (C1–C7) and a digital vernier calliper for precise measurements. The

inclusion criteria comprised cervical vertebrae with intact foramen transversarium (FT) on both sides. Vertebrae with any damage to the bone or the FT were excluded from the study.

For the measurement of the foramen transversarium (FT), only well-preserved cervical vertebrae without signs of trauma or deformities were selected. A digital vernier calliper with an accuracy of 0.01 mm was used to measure the various diameters. Before use, the calliper was calibrated by setting it to zero. The morphology of the FT was assessed macroscopically from the superior view. Each vertebra was placed on a stable platform, and both the anteroposterior and transverse diameters of the FT were measured. To minimize intra-observer error, measurements were taken three times for each dimension, and the average value was recorded. Foramen transversarium was considered round when the difference between its transverse and anteroposterior diameters was ≤ 1 mm. The presence and incidence of accessory foramina in the transverse process were also noted. Larger foramina were identified as the main FT, while smaller ones were classified as accessory foramina.

RESULTS AND OBSERVATION

A total no. of 29 C1, 33 C2, and 36 C7 vertebrae, along with 102 typical (C3, C4, C5, C6) cervical vertebrae, were analysed to assess the Morphometry of the foramen transversarium.

Morphometry -The mean anteroposterior and transverse diameters of the right and left main FT of typical and atypical cervical vertebrae are found in Table 1 with their standard deviations. The results of unpaired t-test for anterior-posterior diameter of FT of cervical vertebrae. Significant differences were found in the anterior-posterior diameter between C1 and typical vertebrae (right: $p < 0.01$) and between C2 and typical vertebrae (right: $p < 0.01$). No significant differences were found in other comparisons, which means that the anterior-posterior diameter varies more in C1 and C2 compared to typical vertebrae. For transverse diameter of FT of cervical vertebrae. Statistical comparison between atypical and typical vertebrae shows significant differences in the left transverse diameter between C1 and typical vertebrae ($p = 0.01$) and in the right transverse diameter between C7 and typical vertebrae ($p = 0.02$). This suggests specific morphological differences in these vertebrae.

Table 1- Vertebra type vs. anteroposterior and transverse diameters of the main FT (mm) for the right and left sides (with standard deviations)

Vertebra	Diameters of right side				Diameters of left side			
	Anteroposterior		Transverse		Anteroposterior		Transverse	
	Mean (mm)	SD (mm)	Mean (mm)	SD (mm)	Mean (mm)	SD (mm)	Mean (mm)	SD (mm)
Typical (n=102)	5.5	0.92	6.03	0.88	5.39	1.06	5.89	0.93
Atypical(n=98)								
C1	6.89	1.22	6.26	1.03	7.1	1.23	5.96	0.94
C2	5.28	0.77	5.35	1	5.16	0.82	5.29	1.22
C7	5.09	1.44	5.72	1.5	5.14	1.15	6.16	1.7

Morphology - The various shapes of the FT were classified into groups viz. Type A – F. Type A was described as being round; Type B was elliptical (oblique right to left), Type C was elliptical (oblique left to right), Type D was elliptical (transverse), Type E was elliptical (anteroposterior), Type F was others (Triangular, Rectangular, Square). The incidences of the shapes of the FT are recorded in Table 2& 3 for right and left sides, respectively. None of the shape variations showed significant differences ($p > 0.05$), indicating that the distribution of FT shapes across vertebrae is not significantly different.





Figure 1 – Variant shapes of the foramen.

Table 2 - Shape of main FT on the right side.

Shape of Right FT			Vertebra			
			Typical (n=102)	Atypical(n=98)		
				C1	C2	C7
Type A	Round		60	15	19	18
Type B	Elliptical (oblique right to left)		25	7	9	9
Type C	Elliptical (oblique left to right)		10	4	5	3
Type D	Elliptical (transverse)		6	2	0	4
Type E	Elliptical (anteroposterior)		1	1	0	1
Type F	Others (Triangular, Rectangular, Square)	  	0	0	0	1

Table 3 - Shape of main FT on the left side.

Shape of left FT			Vertebra			
			Typical (n=102)	Atypical(n=98)		
				C1	C2	C7
Type A	Round		44	12	20	16
Type B	Elliptical (oblique right to left)		32	7	8	8
Type C	Elliptical (oblique left to right)		15	5	5	4
Type D	Elliptical (transverse)		5	3	0	5
Type E	Elliptical (anteroposterior)		3	1	0	1
Type F	Others (Triangular, Rectangular, Square)	  	3	1	0	2

DISCUSSION

Foramen transversarium (FT) in cervical vertebrae lies in transverse process transmits the vertebral artery, vein, and sympathetic fibres. Accessory FT may form due to vertebral artery development from intersegmental arteries. Small FT may appear based on morphometric variation.

A. Transverse diameter

In study done by Sheik-Abdul R, Lazarus L, Rennie C, Satyapal KS in 2018^[4], mean Transverse diameter of typical cervical vertebrae at left side (5.43mm) is greater than the right side (5.03mm). In atypical cervical vertebrae Rt. side of C1, C2 & C7 were 4.52mm, 5.48mm, & 2.12mm respectively & Lt transverse diameter of C1, C2 & C7 were 5.14mm, 5.36mm & 2.87mm respectively. Therefore, at Rt. Side transverse diameter for C1 & C2 are smaller whereas C2 had a greater Lt sided transverse diameter.

In another same study by Santosh Kaur Sangari, Paul-Michel Dossous, Thomas Heineman, and Estomih Phillip Mtui in year 201, stated that.^[5], the mean transverse diameter of Rt. Side (5.55± 0.87mm), whereas left was (5.48 ±0.77mm). The range of Transverse diameter on Rt Side was 2.00-8.65 mm while on Lt 2.62- 7.89mm in typical vertebra.

In present study, mean of transverse diameter in typical cervical vertebrae of Lt and Rt. side is 6.03 mm and 5.89mm respectively. Mean transverse diameter of C1, C2, & C7 - Rt side is 6.26 mm, 5.35 mm & 5.72 mm respectively & Lt side is 5.96 mm, 5.29 mm & 6.16 mm respectively. The C1 vertebra has the highest mean transverse diameter i.e. 6.26 mm on the Rt & 5.96 mm on the Lt, followed by typical cervical vertebrae. The lowest mean values were observed in C2 i.e. 5.35 mm right, 5.29 mm left. The range of transverse diameter on Rt Side was 3.3-8.1mm while on 2.9-7.9mm.

B. Anteroposterior diameter

1. In study done by Sheik-Abdul R, Lazarus L, Rennie C, Satyapal KS in 2018^[4], mean Anteroposterior diameter of Lt side (4.34mm) was slightly smaller than Rt side (4.60mm) in typical cervical vertebrae. In atypical cervical vertebrae the mean Rt. AP diameter of C1, C2 & C7 were 5.09 mm, 5.24mm, & 1.96mm respectively. Whereas mean Lt AP diameter in C1, C2 & C7 were 5.85 mm, 5.30mm & 2.51mm respectively. This Indicate that anteroposteriorly -Rt FT were smaller than Lt FT. When the Rt & Lt. AP diameter in typical & atypical cervical vertebra were compared, there were no significant difference.

2. Santosh Kaur Sangari, Paul-Michel Dossous, Thomas Heineman, and Estomih Phillip Mtui in year 2014,.^[5] stated that mean anteroposterior diameter of Lt side (5.13± 0.79 mm) was slightly smaller than Rt side (5.17± 0.89 mm) in typical cervical vertebrae. The range of AP diameter on Rt Side was 3 - 7.7mm while on Lt. 1.5-7.9mm.

In present study, the mean anteroposterior diameter of typical cervical vertebrae is 5.5 mm & 5.39 mm in Rt & Lt respectively. Whereas for AP in C1, C2 & C7 of Rt side 6.89mm, 5.28mm & 5.09mm respectively, For Lt C1, C2 & C7 was 7.1mm, 5.16mm & 5.14mm respectively. The anterior-posterior diameter is highest values in C1 (6.89 mm right, 7.1 mm left), followed by typical cervical vertebrae. C7 showed the lowest values (5.09 mm right, 5.14 mm left). The range of AP diameter on Rt Side is 3.3-8.1mm while on Lt. side is 2.9-7.9mm. Comparing C1, C2 & C7 with typical Cervical vertebrae separately of Rt side and Lt side (table no. 11&13), Statistical comparison between atypical and typical vertebrae shows significant differences in the left transverse diameter between C1 and typical vertebrae ($p = 0.01$) and in the right transverse diameter between C7 and typical vertebrae ($p = 0.02$). This suggests specific morphological differences in these vertebrae, which is not compared by other authors. Results of ANOVA shows there is significant differences in both transverse and anterior posterior diameters among C1, C2, and C7 vertebrae ($p < 0.05$). This suggests that these atypical vertebrae have distinct morphometric characteristics.

C. Shape of foramen transversarium

In the study by Sheik-Abdul et al. (2018)^[4], the most common shape of foramen transversarium (FT) in typical cervical vertebrae was type A (round) on both the right (34.15%) and left (32.93%) sides. In atypical vertebrae, type B (elliptical AP) was most common in C1 (9.09%), type D (elliptical Rt-Lt) in C2 (9.09%), and type M (double bubble) in C7 (13.64%) on the right. On the left side, C1 showed type B and E equally (4.55%), while type A was most seen in C2 (22.45%) and type D in C7 (18.18%). The p-value for FT shape variation among vertebrae was <0.001 .

Ramachandran et al. (2014)^[3] found the round FT most common (63.3%), followed by elliptical shapes: AP (10%), transverse (12.5%), oblique Rt-Lt (10.9%), and oblique Lt-Rt (3.3%). Patra et al. (2021)^[6] reported the round FT as most common (23.85%), with the Rt side predominantly round (27.13%) and the Lt side showing more elliptical Rt-Lt shapes (27.63%). Das and Basu (2022) observed type 4 as the most common FT shape on the right (39.67%), followed by type 5 (30.21%) and type 1 (28.57%).

In 2022 Kumar Niloy Das and Urmimala Basu^[7] studied the shape of cervical vertebrae. According to their observation type 4 () is the most common in the Rt side 39.67%, type 5 () 30.21% which is commonest category were, type 1 () 28.57% .

In our study , percentage of the shape are mention in table 4.

Table 4 – Percentage of shape of vertebrae

Type of vertebrae	Total no. of vertebra	Type A 	Type B 	Type C 
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		Right	Left	Right	Left	Right	Left
C1	29	51.72%	41.37%	24.13%	24.13%	13.70%	17.20%
C2	33	57.57%	60.60%	27.27%	27.27%	15.15%	15.15%
C7	36	50.00%	44.44%	25.00%	25.00%	8.33%	11.11%
Typical	102	58.82%	43.13%	24.50%	24.50%	9.80%	14.70%
Type of vertebrae	Total no. of vertebra	Type D 		Type E 		Type F   	
		Right	Left	Right	Left	Right	Left
C1	29	6.89%	10.34%	3.40%	3.40%	0.00%	3.40%
C2	33	0%	0%	0%	0%	0.00%	0.00%
C7	36	11.11%	13.88%	2.77%	2.77%	2.77%	5.55%
Typical	102	5.88%	4.90%	0.98%	0.98%	0.00%	2.94%

Overall, above information tells us the most prevalent shape across all cervical vertebrae, with the right side generally showing a higher frequency than the left.

CONCLUSION

The foramen transversarium, a key feature of cervical vertebrae, is located on the transverse processes and typically transmits the vertebral artery, vein, and surrounding sympathetic plexus. However, at the C7 level only the vertebral vein passes through. Since the vertebral artery supplies blood to the brain and inner ear, understanding the anatomy of the foramen transversarium is crucial, especially for avoiding complications during cervical surgeries. Variations in its size, shape, and presence of accessory foramina, along with transverse and anteroposterior diameters, are significant for radiologists and spine surgeons. Recognizing these anatomical differences aids in accurate diagnosis, surgical planning, and treatment in the neck region. Such morphometric data enhances the interpretation of medical imaging and correlates with clinical findings, highlighting the need for further research in this area.

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