

The foramen transversarium of dried typical cervical vertebrae: Morphology and Morphometry

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Received: Aug 18, 2026

Accepted: Sep 15, 2026

Published: Sep 17, 2026

ABSTRACT

The main characteristic feature of cervical vertebrae is presence of foramen in transverse process. It transmits second part of vertebral artery, vertebral vein and sympathetic fibres from superior cervical sympathetic ganglion. The foramen transversarium shows variations in the size, shape. They may be multiple or absent. Sometimes foramen transversarium may get divided into two parts by bony ridge forming an accessory foramen transversarium lying posterior. In such cases, larger anterior i.e. Main foramen transmits vertebral artery and an accessory transmits vertebral vein and nerve. The anatomical knowledge of morphometry and variations in foramen transversarium is useful for spine surgeons for preoperative planning and preventing injuries to neurovascular structures of foramen transversarium during cervical surgical approaches. 180 typical cervical vertebrae were utilized for this study. They were classified into different groups according to their shapes and direction of main diameter. Maximum and minimum diameters were measured by digital vernier calliper. Presences of accessory foramens were noted. The most common shape was circular followed by oval horizontal, oval oblique. Accessory foramen transversarium were found 8 on right and 6 on left side. The mean length and breadth of the foramen on left and right side were 6.17 ± 0.73 , 5.31 ± 0.83 and 6.16 ± 0.91 , 5.19 ± 0.78 respectively. Osteophytes are seen in four vertebrae. Hypoplasia of foramen is seen in two vertebrae.

Key words: *Cervical vertebrae, typical, foramen transversarium, vertebral artery*

Introduction: The characteristic feature of cervical vertebrae is the foramen transversarium (FT) i.e. transverse process containing foramen. These foramens are present bilaterally in all cervical vertebrae. The foramen transversarium of all cervical vertebrae except seventh transmits 2nd part of vertebral artery, vertebral vein and ascending branch of inferior cervical sympathetic ganglion [1]. There are variations in shape and number of the foramens. Sometimes accessory foramens may be present. These variations may be developmental or related with variations in the vertebral artery course [2]. Preoperative knowledge of variations in foramen transversarium of cervical vertebrae is helpful to the radiologist, neurosurgeons for proper operative planning and treatment [3].

Study design: Descriptive study.

Sample size: The study was done on 180 dried typical cervical vertebrae.

Sample size n = Sample size $n = [DEFF * Np(1-p)] / [(d^2 / Z^2_{1-\alpha/2} * (N-1) + p * (1-p)] = 171$ at 99% Confidence Level.

Statistical Analysis:

The statistical analysis was done by descriptive statistics as mean, SD, proportions, percentage etc.

The comparison of mean values of Diameter (in mm) at Left L, Right L and Left T, Right T was done by applying Student's Unpaired 't' test at 5% ($p=0.05$) and at 1% ($p,0.01$) level of significance.

The statistical analysis software namely, SPSS version 18 was used to analyse the data under study

Material and methods:

The study was carried out in the Department of Anatomy, Dr. B.V.P. Rural Medical college, Loni. after approval of institutional ethical committee (Reg no- PIMS/DR/RMC/2020/362). Present study was carried out on 180 dried typical cervical vertebrae irrespective of age and sex, from department of Anatomy in Rural

Medical College, Loni. Vertebrae will be carefully observed for foramen transversarium. The vertebrae were studied as seen from above in anteroposterior direction with spinous process facing posteriorly.

They were classified according to their shape and direction of main diameter into five types. Maximum and minimum diameters of the foramen of both right and left side were measured by digital Vernier caliper in mm. In circular foramens, length is measured antero-posteriorly and breadth transversely but in oval foramens, maximum oblique diameter was considered as length and at right angles to it, was the breadth. Unilateral or bilateral presence of accessory foramens were noted. Osteophytic encroachments originating from articular or uncinat process were noted. The data was tabulated and percentage of each type were computed and analyzed.

Inclusive criteria: Typical cervical vertebrae of unknown age and sex in the department of anatomy.

Exclusive criteria: Typical cervical vertebrae with damaged transverse processes.

Results:

Present study observed six different shapes of the foramen transversarium as circular, oval horizontal, oval oblique, oval with spur, D shaped, and irregular.

Table No.1: Percentage of various shapes of foramen transversarium on left and right side

shape	Percentage on Left 100%(n=180)	Percentage on Right 100%(n=180)	Total percentage 100%(n=360)
Circular	38.89% (70)	43.33% (78)	41.11% (148)
Oval horizontal	33.34% (60)	26.67% (48)	30% (108)
Oval oblique	10% (18)	8.89% (16)	9.45% (34)
Oval with spur	11.11% (20)	16.67% (30)	13.89% (50)
'D' shaped	2.22% (4)	0	1.11% (4)
Irregular	4.44% (8)	4.44% (8)	4.445% (16)



Fig. 1: Typical cervical vertebra having both side circular foramen transversarium.

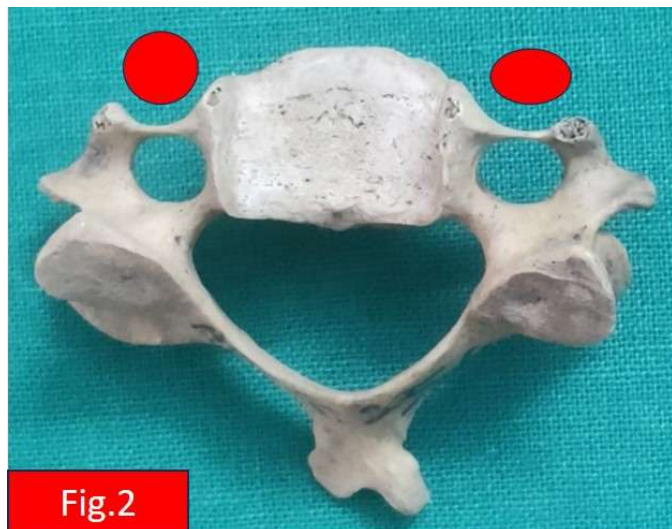
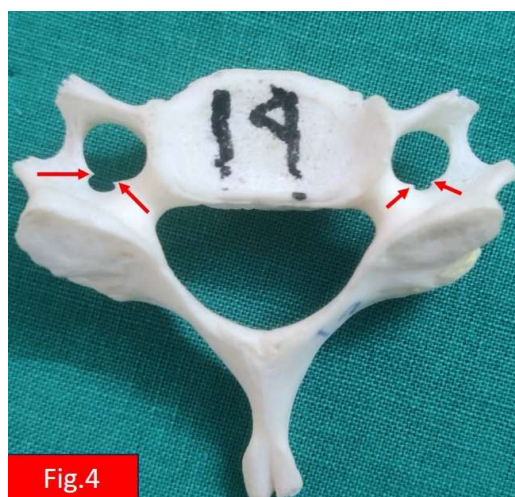


Fig.2: Typical cervical vertebra having left side circular and right side oval horizontal foramen transversarium.



Fig.3: Typical cervical vertebra having both side oval oblique foramen transversarium.



Fi.4: Typical cervical vertebra with bony spicule projecting in the foramen transversarium on both sides.



Fig.5. Typical cervical vertebra with D shape FT on left side and circular FT with osteophyte projecting in the FT on right side.



Fig.6. Typical cervical vertebra with bilateral accessory foramen transversarium shown by arrows.



Fig.7: Typical cervical vertebra with irregular shape of foramen transversarium on left side with single accessory FT and triple accessory FT on right side shown by arrows.

**Fig.8**

Fig.8: Typical cervical vertebra with bony spicule projecting in the foramen transversarium on left side and accessory foramen transversarium on right side.

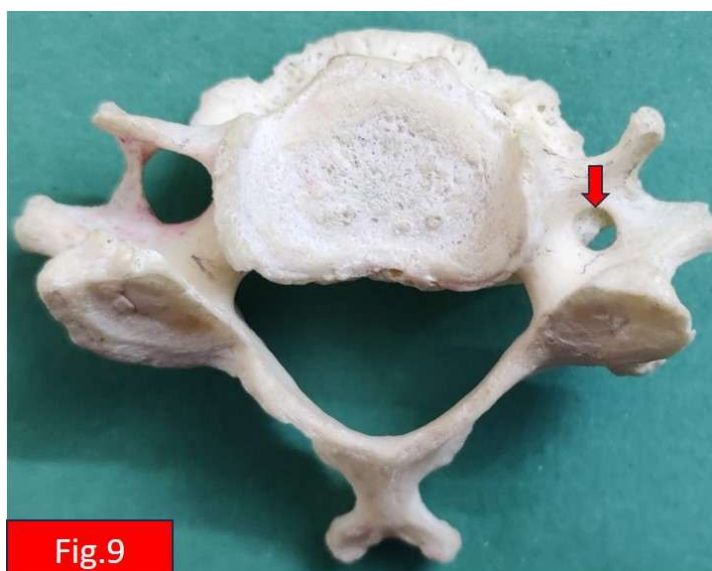
**Fig.9**

Fig.9: Typical cervical vertebra with hypoplastic foramen transversarium on right side with osteophyte on the body shown by arrow.

Table No.2: Comparison of mean and SD values of Diameter (in mm) at Left L(Length), Left T (Transverse diameter) , Right L (Length)and Right T(Transverse diameter)(n=180):

	Diameter (in mm)			
	Left L	Left T	Right L	Right T
	Mean $\pm$ SD	Mean $\pm$ SD	Mean $\pm$ SD	Mean $\pm$ SD
	6.17 $\pm$ 0.73	5.31 $\pm$ 0.83	6.16 $\pm$ 0.91	5.19 $\pm$ 0.78
Range (Min-Max)	3.82-8.51	2.95-7.86	3.00-8.72	2.72-7.68

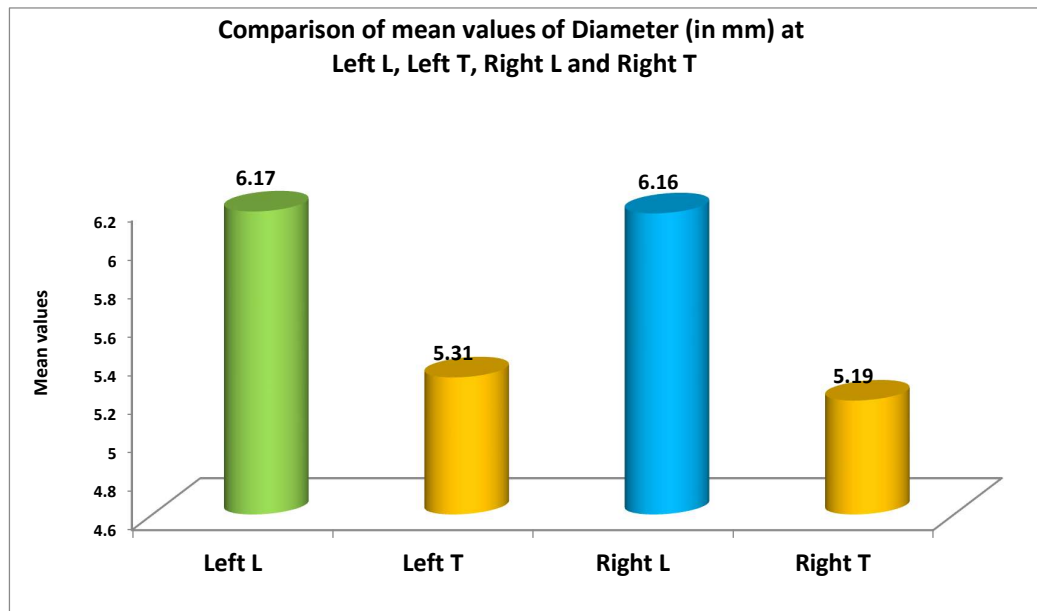


Table No.3: Comparison of mean and SD values of Diameter (in mm) at Left L(Length), V/s Left T(Transverse diameter), and Right L(Length) V/s Right T(Transverse diameter) (n=180): (Student's Unpaired 't' test results)

Diameter (in mm)					
Left L	Left T	Student's Unpaired 't' test and significance	Right L	Right T	Student's Unpaired 't' test and significance
Mean $\pm$ SD	Mean $\pm$ SD		Mean $\pm$ SD	Mean $\pm$ SD	
6.17 $\pm$ 0.73	5.31 $\pm$ 0.83	7.066, p=0.0001, significant	6.16 $\pm$ 0.91	5.19 $\pm$ 0.78	7.417, p=0.0001, significant

By applying Student's Unpaired 't' test there is a significant difference seen in the mean values of Diameter (in mm) when Left L compared with Left T and Right L compared with Right T. (p=0.0001).

It suggests that length of the foramen on both left and right were more than the breadth means shape of most the foramens were oval than circular.

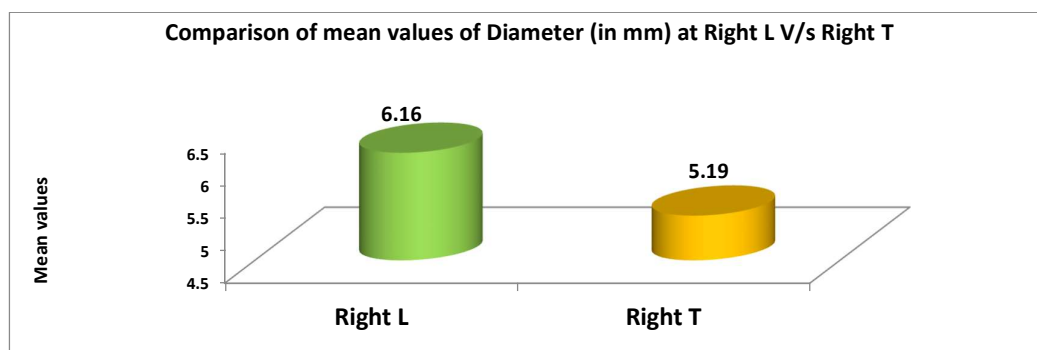
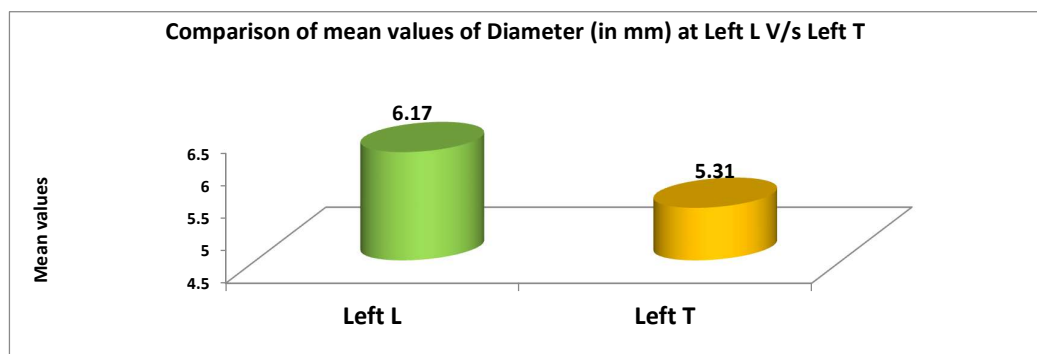
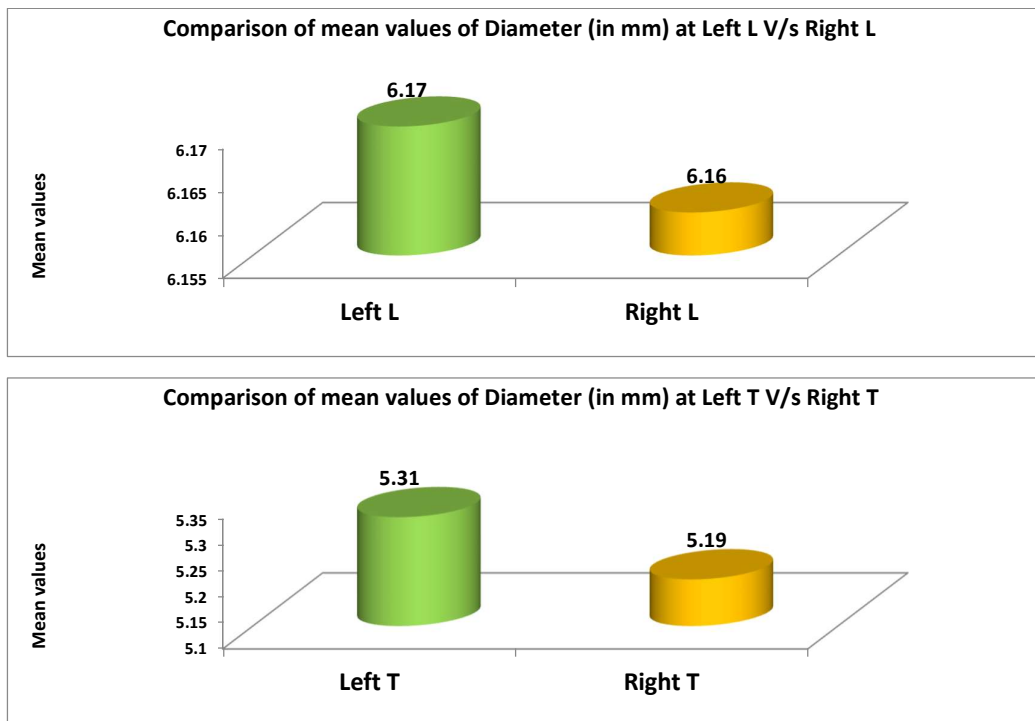


Table No.4: Comparison of mean and SD values of Diameter (in mm) at Left L V/s Right L, Left T V/s Right T (n=180): (Student's Unpaired 't' test results)

Diameter (in mm)					
Left L	Right L	Student's Unpaired 't' test and significance	Left T	Right T	Student's Unpaired 't' test and significance
Mean $\pm$ SD	Mean $\pm$ SD		Mean $\pm$ SD	Mean $\pm$ SD	
6.17 $\pm$ 0.73	6.16 $\pm$ 0.91	0.1166, p=0.9073, not significant	5.31 $\pm$ 0.83	5.19 $\pm$ 0.78	1.012, p=0.3128, not significant

By applying Student's Unpaired 't' test there is no significant difference seen in the mean values of Diameter (in mm) when Left L compared with Right L (p=0.9073) and Left T compared with Right T (p=0.3128)



Discussion:

Morphometry of foramen transversarium is important for spine surgeons during foraminotomy, screw fixation surgeries of cervical region.

Table No. 4: comparison table of dimensions of foramen transversarium of typical cervical vertebrae on left and right side in mm.

Researcher	Left side		Right side	
	Anteroposterior	Transverse	Anteroposterior	Transverse
Taitz C et al [4]. 1978	6.55	5.38	6.21	5.12
Sangari et al [5] 2015	5.13 $\pm$ 0.79	5.17 $\pm$ 0.89	5.87 $\pm$ 0.89	5.69 $\pm$ 1.04
Abdul RS et al [6] 2018	4.60 $\pm$ 1.67	5.43 $\pm$ 2	4.34 $\pm$ 1.63	5.03 $\pm$ 1.97
Ananthi Vet al [7] 2019	5.56 $\pm$ 0.48	6.66 $\pm$ 0.42	5.45 $\pm$ 0.12	6.72 $\pm$ 0.22
Prabavathy G et al [8] 2021	-	6.18		5.9
Ibrahim S. et al [9] 2024	3.98 $\pm$.985	4.87 $\pm$ 1.038	3.70 $\pm$.989	4.71 $\pm$ 1.005
Pande MK et al [10] 2025	5.39 $\pm$ 1.06	5.89 $\pm$ 0.93	5.5 $\pm$ 0.92	6.03 $\pm$ 0.88
Present study	6.17 $\pm$ 0.73	5.31 $\pm$ 0.83	6.16 $\pm$ 0.91	5.19 $\pm$ 0.78

Present study, observation of dimensions of foramen transversarium are very close to Taitz et al [4]. Prabavathi et al studied the transverse diameter of the foramen transversarium of 350 cervical vertebrae and incidence of accessory foramen transversarium. They observed statistically significant increase in transverse diameter of left foramen than the right. Also, they observed increased incidence of accessory foramen in the 6th cervical vertebrae. They reported transverse diameter of foramen transversarium of first cervical vertebrae is more than the other cervical vertebrae and the reason behind it may be the largest calibre of the vertebral artery at first cervical vertebra level [8]. Cagnie B et al observed greater diameter on the left side than the right at all vertebral level. Present study didn't observe significant difference in transverse diameter of left and right foramen transversarium [11].

Manjunath MV et al in their study of FT of cervical vertebrae of south Indian origin, observed accessory foramen were more common in typical than atypical cervical vertebrae [3].

Murlimanju et al observed that the accessory foramen was smaller in size than the main foramen. The incidence of unilateral accessory foramen is more than the bilateral. They found triple foramina in one vertebra [12]. Present study also found triple foramen in one, on right side (Fig.7).

Table No.5: Comparison table of incidence of accessory foramen transversarium.

Researcher	Number of vertebrae	Incidence of accessory foramen	Unilateral	Bilateral
Das et al [2]	132	1.5%		
Taitz et al [4]	480	7%		
Sharma et al [13]	200	8%	3.50%	4.50%
Murli Manju et al [12]	363	1.60%	1.30%	0.50%
Chaudhari et al [14]	133	23.15%	14.36%	11.49%
Shital et al [15]	210	16.19%	9.52%	6.67%
Patra et al [16]	150	22%	10.67%	11.33%
Akhtar et al [17]	174	14.36%	11.49%	2.87%
Gujar et al [18]	150	27.33	18%	9.33%
Mishra et al [19]	220	14.09%	4.54%	9.54%
Ambali MP et al [20]	163	14.72%	4.90%	9.52%
Prabavathy G et al [8]	350	19%	6%	13%
Present study	180	11.11%	4.44	6.67%

The absence of foramen transversarium is rare. Its absence is noted in 4 typical cervical vertebrae by Taitz al [4], in which 3 are 6th and one is 5th cervical vertebra, Kimura et al [21] observed it in 18 and Wysocky et al [22] in one vertebra. Present study didn't observed absence of foramen transversarium

Metin Tellioglu A. et al in their study on 987 cervical vertebrae, the antero-posterior and transverse diameter of foramen transversarium were measured from multidetector computed tomography (CT) images. They observed transverse diameter was less than anteroposterior diameter in all vertebrae except C1 and C7. Absence of FT is considered as agenesis and diameter less than 2mm as hypoplastic. Agenesis was found in 37 vertebrae. Out of that 34 at C6 level and 3 at C7 level. There was no agenesis found up to C6 vertebral level. Hypoplasia was seen in 27 vertebrae [23].

Taitz et al observed single hypoplastic in 8 vertebrae. Out of that four are 7th cervical three are 6th and one is 5th cervical vertebrae [4].

Present study observed hypoplastic foramen transversarium in two cases. In one vertebra there was hypoplastic FT with osteophyte projecting in the FT from the body of vertebra (Fig.9). Shoja et al and Ikegami et al. mentioned that hypoplastic foramen may be due to hypoplastic vertebral artery or variation in its course [24&25]. These variations in course and position of vertebral artery are important in anterior approach during cervical spine surgeries to avoid injury to the extraosseous course of vertebral artery which may lead to severe haemorrhage [26].

Conclusion: The precise knowledge dimension and variation of foramen transversarium is important in case of planning any cervical spine surgery to prevent any unpleasant consequences to the patient during the surgeries. The variation in shape, size, agenesis, hypoplasia along with dimensions of FT are important for radiologist and spine surgeons for diagnosis surgical planning and treatment in neck regions.

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