Original Article

Anatomical Assessment of Incidence and Structural Variations of Accessory Foramen Transversarium in Cervical Vertebrae Among the Garhwal Population

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Abstract

Background: The transverse process of the cervical vertebra contains the foramen transversarium, which transmits the vertebral artery (except in C7), vertebral veins, and the sympathetic plexus. Alterations in the morphology of this foramen may result from developmental variations, mechanical loading, or changes in the vertebral artery pathway. These foramina differ in size, configuration, and number. Accessory foramina transversaria may occur on one or both sides, and can be either complete or incomplete. The aim is to analyze the morphological patterns of the foramen transversarium and to assess the frequency and laterality of accessory foramina transversaria. **Material and Methods:** The study was carried out on 142 dry cervical vertebrae of undetermined sex and age. The bones were obtained from the osteology collection of the Department of Anatomy, Government Doon Medical College, Dehradun, Uttarakhand. Each specimen was carefully examined to document the shape of the foramen transversarium and the occurrence of accessory foramina with respect to side and completeness. **Results:** Out of 284 foramina observed in 142 vertebrae, 98 (35%) were classified as Type I (round), 30 (10%) as Type II (anteroposterior), 93 (33%) as Type III (transverse), and 63 (22%) as Type IV (oblique). Among the vertebrae, 15 (11%) exhibited bilateral complete accessory foramina, 3 (2%) had incomplete accessory foramina, while 3 (2%) showed a combination of complete on one side and incomplete on the opposite side. **Conclusion:** Anatomical variations in the foramen transversarium may lead to compression of nearby neurovascular structures, producing clinical symptoms such as headache, vertigo, or syncopal attacks. Recognition of these variations is important for clinicians, particularly surgeons, radiologists, otorhinolaryngologists, and orthopaedic specialists, to avoid complications during diagnostic and operative procedures.

Keywords: Cervical Vertebrae, Foramen transversarium, Frill Foramen Transversarium.

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Introduction

The foramen transversarium is a key identifying feature of cervical vertebrae, located within the transverse process. It transmits the vertebral artery (except at C7), vertebral vein, and sympathetic nerves. The morphology of this foramen varies in size, shape, and number—it may be complete, incomplete, duplicated, or occasionally absent. Such variations can result in compression of the neurovascular bundle, producing clinical manifestations. These differences must be carefully considered during posterior approaches to cervical spine surgery.[1]

Embryologically, the foramen forms by fusion of the vestigial costal element with the vertebral body and transverse process, which terminate laterally as anterior and posterior tubercles joined by an intertubercular lamella.[2] The cervical spine, consisting of seven vertebrae between the skull and thoracic spine, contributes nearly 8% of body length.[3] The foramen transversarium distinguishes cervical vertebrae from those of other spinal regions. While most cervical vertebrae transmit vertebral artery, vein, and sympathetic plexus, the foramen of C7 is typically smaller, transmitting only the vertebral vein, and may be rudimentary or absent.[4]

Morphological variations in these foramina are influenced by the vertebral vessels.[5] Such changes may produce symptoms like headache, vertigo, or syncope owing to vascular compression. The cause may be embryological or related to the vascular pathway.[6] Deviations may also lead to vertebrobasilar insufficiency. Thus, understanding the anatomy of these foramina is clinically important for surgeons and radiologists. During cervical spine surgery, preservation of the vertebral artery is essential, as even minor trauma may cause life-threatening hemorrhage.[7]

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Aim and Objectives

To examine the morphological variations of the foramen transversarium in cervical vertebrae and to determine the frequency of accessory foramina.

Materials and Methods

The study was conducted on 142 dry cervical vertebrae of unknown age and sex from the osteology collection of the Department of Anatomy, Government Doon Medical College, Dehradun, Uttarakhand.

Inclusion criteria

Intact vertebrae without deformity, trauma, or degeneration.

Exclusion criteria

Damaged or malformed vertebrae.

The shapes of foramina were classified according to Taitz et al.[8]

- Type I: Round
- Type II: Elliptical, anteroposteriorly elongated
- Type III: Elliptical, transversely elongated
- Type IV: Oblique, with diagonal axis (right-to-left or left-to-right)

Study design: Cross-sectional observational study.

Measurements: Dimensions of accessory foramina were taken using a digital vernier caliper.

- **Width:** Caliper tips placed perpendicular to the transverse axis.
- **Depth:** Caliper aligned along the longitudinal axis.

Each dimension was measured thrice, and mean values calculated.

Limitations: Restricted sample size, natural anatomical variation, and manual measurement errors.

Results

A total of 284 foramina transversaria were examined from 142 cervical vertebrae.

- Type I (round): 98 (34%) [Figure 1], with 48 on the right and 50 on the left; most common type.
- Type II (anteroposterior): 30 (10%) [Figure 2], with 16 on the right and 14 on the left.
- Type III (transverse): 93 (33%) [Figure 3], with 44 on the right and 49 on the left.
- Type IV (oblique): 63 (22%) [Figure 4].

Asymmetrical foramina were observed in several vertebrae, including 34 (12%) on the right and 29 (10%) on the left [Figure 5].

Out of 142 vertebrae:

- Double foramina transversaria were present in 18 vertebrae (13%) [Figure 6]; of these, 10 were unilateral and 5 bilateral.
- Incomplete double foramina were found in 3 vertebrae (2%) [Figure 7]; 1 on the right and 2 on the left.
- Left-sided complete unilateral accessory foramina were present in 7 vertebrae [Figure 8].
- Left-sided incomplete unilateral accessory foramina were seen in 2 vertebrae [Figure 9].
- Right-sided complete unilateral accessory foramina were observed in 3 vertebrae [Figure 10].
- Right-sided incomplete accessory foramina were recorded in 1 vertebra [Figure 11].
- Mixed type (complete on one side, incomplete on the other) occurred in 3 vertebrae (2%) [Table-2]. Among these, 2 showed left-sided incomplete and right-sided complete foramina [Figure 12]

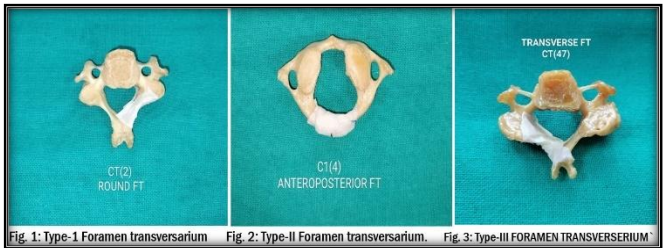


Fig. 1: Type-1 Foramen transversarium Fig. 2: Type-II Foramen transversarium. Fig. 3: Type-III FORAMEN TRANSVERSERIUM

Fig. 4: Type-IV Foramen transversarium Fig.5 ASSYMETRIC FORAMEN TRANSVERSERIUM Fig.6 COMPLETE BILATERAL ACCESSORY F

Fig. 7: Bilateral incomplete accessory FT Fig.8: LEFT U/L Complete Accessory FT Fig.9: Left U/L Incomplete Accessory FT

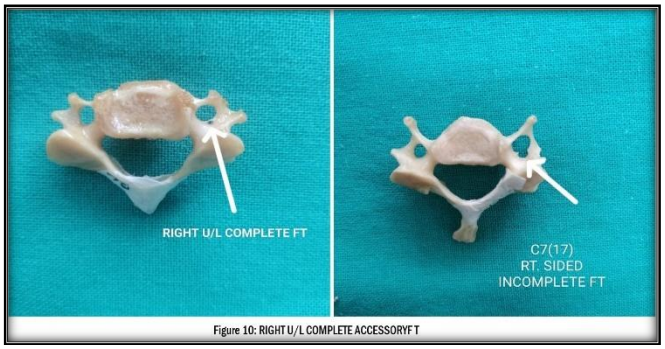


Figure 10: RIGHT U/L COMPLETE ACCESSORY F T

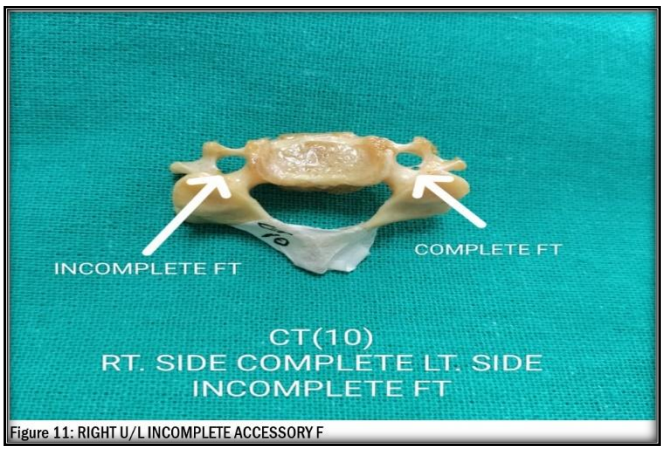


Figure 11: RIGHT U/L INCOMPLETE ACCESSORY F

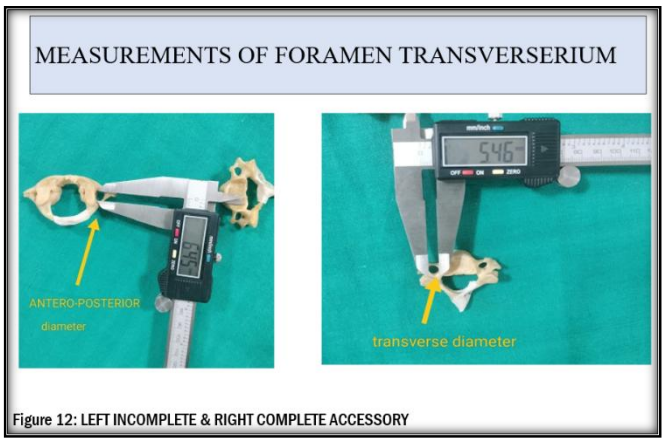


Figure 12: LEFT INCOMPLETE & RIGHT COMPLETE ACCESSORY

Table 1: Frequency of different types of foramen transverserium in each side of the vertebrae

Shape and direction foramen transverserium		Right (N)	Right Side %	Left Side (N)	Left Side %	Total No.	Total %
1	ROUND	48	17%	50	18%	98	35%
2	AP	16	6%	14	5%	30	11%
3	TRANS.	44	15%	49	17%	93	32%
4	OBLIQUE	34	12%	29	10%	44	22%

Table 2: Variation in the accessary foramen transversarium

Vertebrae with accessory ft	Unilateral	Percentage (%)	Bilateral	Percentage (%)	Total No.	Total (%)
Complete accessory ft	10	7.01%	5	3.5%	15	11%
Incomplete accessory ft	3	2%	0	0	3	2%
One side complete and other side incomplete	-	-	-	-	3	2%

Table 3: Vertebrae with unilateral accessary foramen transversarium

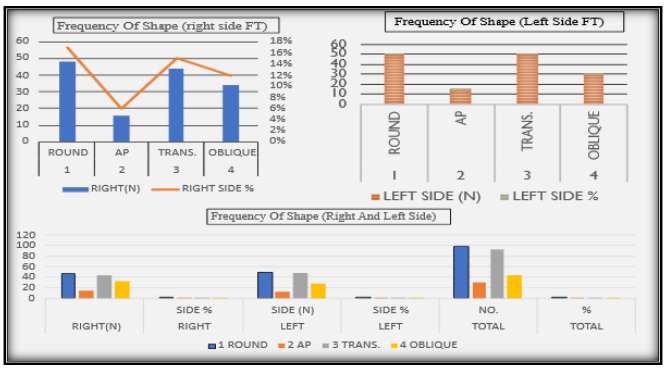
Number of Vertebrae with unilateral accessary foramen transversarium	RIGHT SIDED	LEFT SIDED
COMPLETE	3	7
INCOMPLETE	1	2

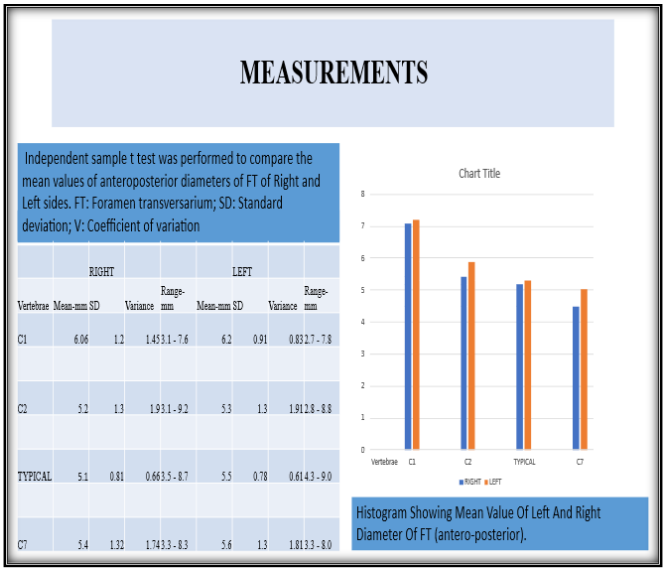
Table 4: Showing the prevalence of accessory foramen transversarium in different study populations

Author	Year	Prevalence	Study sample	Population
Taitz et al,[8]	1978	7%	480	Indian
Nagar et al,[11]	1999	8.6%	1388	Roman-Byzatine Jews
Das et al,[12]	2005	1.5%	132	Indian
Kaya et al,[5]	2011	22.7%	262	Jewish
Rekha et al,[13]	2013	6.5%	153	Indians
Manicka Vasuki A K et al,[9]	2016	41.6%	300	Indians
Shivaleela C et al,[14]	2020	37%	364	Indians
Present study	2023	12.6%	284	Indians

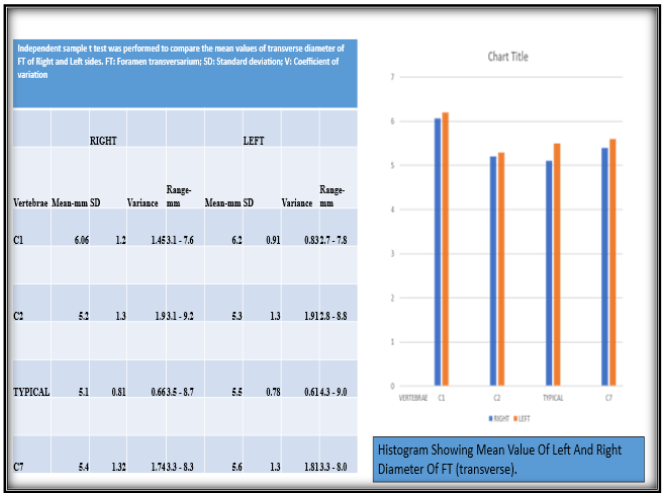
Table 5: Prevalence of variations of FT in different studies.

Study	Number of vertebrae	Incidence of Accessory Foramen Unilateral	Incidence of Accessory Foramen Bilateral
Chaudhari ML et al,[17]	133	14.70 %	8.42%
Kaya S et al,[5]	22	13.63%	9.09%
Patra A et al,[18]	150	10.6%	11.3%
Sharma A et al,[19]	200	3.5%	4.5%
Pretty R et al,[20]	140	3.6%	1.42%
Chandravadiya L et al,[21]	140	3.8%	0.95%
Katikireddi RS et al,[22]	100	2%	1%
Muralimanju BV et al,[23]	363	1.4%	0.3%
Sumalatha T et al,[24]	148	5.4%	6.08%
Present study	142	9.1%	3.5%





	RIGHT				LEFT			
Vertebrae	Mean-mm	SD	Variance	Range-mm	Mean-mm	SD	Variance	Range-mm
C1	6.06	1.2	1.45	3.1 - 7.6	6.2	0.91	0.83	2.7 - 7.8
C2	5.2	1.3	1.93	1.1 - 9.2	5.3	1.3	1.91	2.8 - 8.8
TYPICAL	5.1	0.81	0.66	3.5 - 8.7	5.5	0.78	0.61	4.3 - 9.0
C7	5.4	1.32	1.74	3.3 - 8.3	5.6	1.3	1.81	3.3 - 8.0



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C7	5.4	1.32	1.74	3.3 - 8.3	5.6	1.3	1.81	3.3 - 8.0

Observations and Description

In the present study, 35% of foramina transversaria were Type I (circular), followed by Type III (transverse), which accounted for 32%. Shivaleela C et al,[14] reported that 27% of foramina were Type I and 24% were Type III, while Manicka Vasuki A.K. et al,[9] documented 43.6% as Type I and 22.8% as Type III, findings that are broadly consistent with the current results.

The largest anteroposterior (AP) diameter was observed at the C1 vertebra, measuring 7.1 ± 1.26 mm on the right and 7.2 ± 0.91 mm on the left. Similarly, the greatest transverse diameter was also found at C1, with 6.06 ± 0.81 mm on the right and 6.2 ± 0.78 mm on the left. In typical cervical vertebrae, the AP diameter averaged 5.2 ± 0.76 mm on the right and 5.3 ± 0.77 mm on the left.

Accessory foramina transversaria were noted in 18 vertebrae (13%). Among these, complete double foramina were found in 15 vertebrae: 10 unilateral (7%) and 5 bilateral (4%). Incomplete accessory foramina occurred in 3 vertebrae (2%), of which 1 was on the right (0.7%) and 2 were on the left (1%). Additionally, 3 vertebrae (2%) displayed a complete accessory foramen on one side and an incomplete on the other.

Murlimanju et al,[10] reported accessory foramina in 6 vertebrae (1.6%) out of 363, with bilateral presence in 1 (0.3%) and unilateral in 5 (1.4%). The overall prevalence in the present study was 14.7%, which aligns with prior research [Table 4]. Vaishakhi G et al,[15] found accessory foramina in 20% of vertebrae, with incomplete forms in 11%, while Singh A.P. et al,[16] observed accessory foramina in 20% and incomplete forms in 6% of vertebrae. Our findings show agreement with these studies.

Discussion

Taitz C et al,[4] reported the maximum AP diameter of the foramen transversarium at C1, measuring 7.23 mm on the left and 7.26 mm on the right, with the largest transverse diameter also at C1 (5.76 mm on the left and 5.52 mm on the right). Their observation that the left foramen tends to be larger is consistent with our findings.

Maqbool A et al,[5] similarly found the largest AP diameter in C1 (7.42 mm left, 7.44 mm right) and the greatest transverse diameter also in C1 (6.03 mm left, 5.95 mm right), supporting our results.

Gupta M et al,[6] measured mean AP diameters of 5.26 mm (left) and 5.21 mm (right), and transverse diameters of 5.84 mm (left) and 5.78 mm (right). Their findings of larger dimensions on the left side mirror the present study.

Sangari S.K. et al,[7] observed AP diameters of 5.13 mm (left) and 5.17 mm (right), with transverse diameters of 5.87 mm (left) and 5.69 mm (right). Again, the left side was larger, in agreement with our results.

Conclusion

Out of 284 foramina transversaria studied in 142 cervical vertebrae, 98 (35%) were Type I (round), 30 (10%) were Type II (anteroposterior), 93 (33%) were Type III (transverse), and 63 (22%) were Type IV (oblique). Accessory foramina were present in 18 vertebrae (13%): 15 with complete double foramina, 3 with incomplete foramina, and 3 with one side complete and the other incomplete.

The occurrence of double foramina transversaria may increase the risk of thrombus formation and embolic events. Such anatomical variations are clinically significant, as the vertebral and basilar arteries supply the brain and inner ear; compression of these vessels can manifest with neurological or auditory symptoms. Awareness of these variations is crucial for clinicians, neurologists, otorhinolaryngologists, orthopaedicians, radiologists, and spine surgeons.

In particular, incomplete accessory foramina may make the

second segment of the vertebral artery vulnerable to injury in posterior cervical trauma or surgical interventions. Recognition of these anomalies is essential in CT and MRI interpretation, neurological evaluation, and planning of complex cervical spine surgeries.

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Conflicts of interest
There are no conflicts of interest.

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