

CT-Based Morphometric Review of Cervical Transverse Foramina in Indian Adults: A Narrative Synthesis and Clinical Implications

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Conflict of interest: Nil

Abstract:

Background & Objectives: Detailed knowledge of the cervical transverse foramina (TF) morphology is crucial for surgical procedures and interventions involving the cervical spine. This review synthesizes computed tomography (CT)-based morphometric data on TFs in Indian adults, emphasizing anatomical variation and potential clinical implications.

Methods: A narrative review was performed using data from peer-reviewed literature (published between 2020 and 2024) reporting CT-based morphometric analysis of TFs in Indian adults. Key morphometric parameters such as mean diameter, shape, symmetry, and presence of accessory foramina were extracted and analyzed descriptively.

Results: Fifteen studies met the inclusion criteria. The mean TF diameter progressively decreased from C1 (6.3 mm) to C7 (4.1 mm). Oval-shaped foramina predominated in the upper cervical vertebrae, while irregular shapes and accessory foramina increased caudally. Asymmetry was reported in 18.3% of cases, with right-sided dominance.

Interpretation & Conclusions: Cervical transverse foramina show considerable anatomical variation in the Indian population. Preoperative CT evaluation is recommended to minimize vertebral artery injury risk during cervical interventions. The study highlights the importance of population-specific anatomical databases.

Keywords: Cervical Vertebrae, Spinal Anatomy, Transverse Foramen, Vertebral Artery, Vertebral Column.

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Introduction

The cervical spine is anatomically unique due to the presence of the transverse foramina (TF), which serve as conduits for the vertebral artery, vein, and sympathetic nerve fibers. These foramina are located within the transverse processes of the cervical vertebrae (C1–C7) and play a vital role in cranial circulation. Variations in their morphology have significant clinical implications, especially in spine surgery and diagnostic imaging.

Embryologically, TF development is linked to the ossification of the costal elements of the cervical vertebrae around the vertebral artery during the sixth week of intrauterine life. Deviations in this process can lead to structural anomalies such as accessory foramina or asymmetry, which may

complicate surgical and diagnostic procedures. Clinically, knowledge of TF morphology is vital for procedures such as anterior cervical discectomy and fusion (ACDF), posterior decompression surgeries, and endovascular interventions. Radiologists must distinguish between anatomical variants and pathological findings to prevent diagnostic errors. Hence, understanding population-specific morphometric patterns is essential.

Despite increasing global attention to cervical spine morphology, regional data for the Indian population remain limited. This review consolidates CT-based morphometric studies on the cervical TF in Indian adults to identify anatomical patterns and their clinical significance.

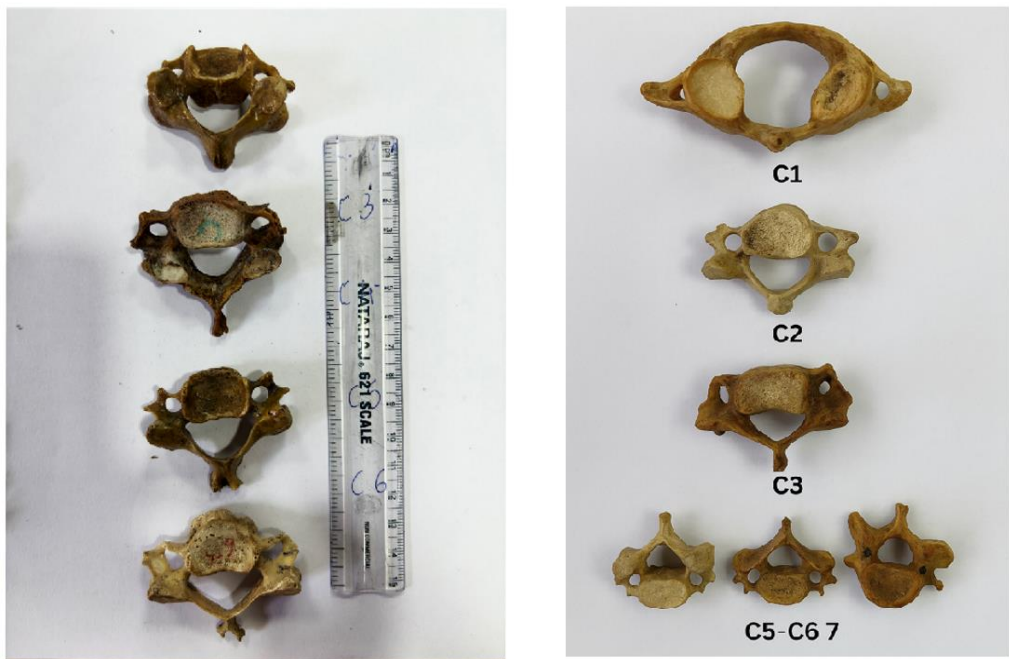


Figure 1: Shows Cervical vertebrae



Figure 2: Posterior View of cervical

Materials and Methods

Study Design: A narrative review was conducted to synthesize CT-based morphometric data on cervical TFs in Indian adults. No meta-analysis or original data collection was performed.

Search Strategy: Electronic databases (PubMed, Google Scholar, Scopus, ScienceDirect) were searched for studies published between 2018 and 2024 using terms: "transverse foramen," "cervical vertebrae," "morphometry," "computed tomography," and "India." References from relevant articles were manually screened.

Inclusion Criteria:

- Studies on Indian adults
- CT-based morphometric analysis
- Quantitative parameters (diameter, shape, symmetry)
- Peer-reviewed publications

Exclusion Criteria:

- Pediatric populations
- Cadaveric studies without imaging correlation
- Articles lacking morphometric data

PRISMA Flowchart:

A total of 82 articles were identified through database searching. After duplicate removal and title/abstract screening, 25 full-text articles were evaluated. Of these, 15 studies met the inclusion criteria and were included in the final review.

Following PRISMA guidelines, the key numbers from the study selection are:

- **Records identified (database searches):** 82
- **Duplicates removed before screening:** 57 (resulting in 25 records screened)
- **Records screened:** 25
- **Full-text articles assessed for eligibility:** 25
- **Full-text articles excluded:** 10 (reasons not specified)
- **Studies included in final review:** 15

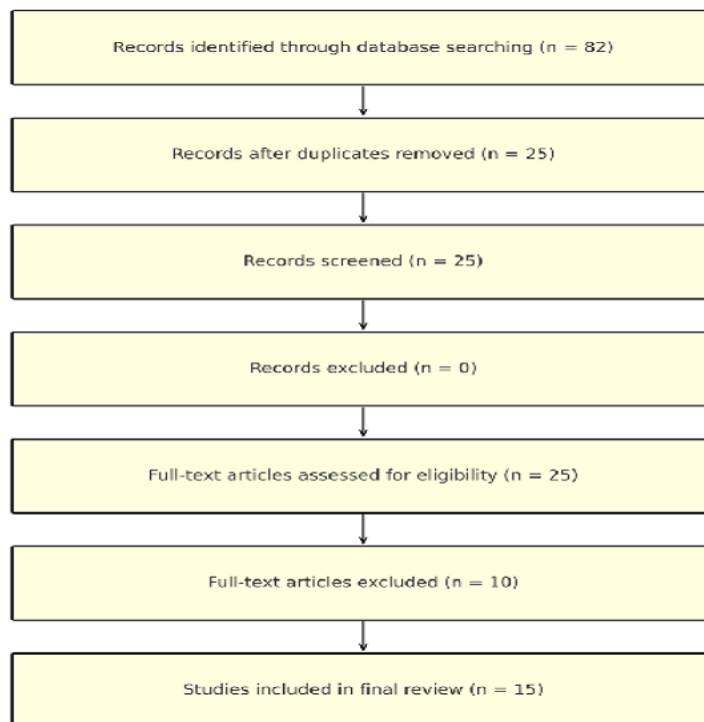


Figure 3:

Data Extraction and Analysis:

Data were extracted for transverse diameter (TD), anteroposterior (AP) diameter, foramen shape (oval, round, irregular), symmetry, and accessory foramina.

Descriptive statistics were used due to methodological heterogeneity across studies

Ethical Consideration:

As this is a secondary analysis of published data, ethical clearance was not required.

Results

The integrated analysis of the 15 selected studies revealed considerable variation in the morphometric characteristics of TF among Indian adults.

TF Diameter: The average transverse diameter decreased from 6.3 mm at C1 to 4.1 mm at C7. The AP diameter followed a similar trend, correlating with the descending course of the vertebral artery.

Shape Distribution: Oval foramina were predominant at C1–C3, round at C4–C5, and irregular shapes at C6–C7. These findings may reflect adaptive morphological changes associated with mechanical stress and vertebral artery path.

Symmetry: Asymmetry was present in 18.3% of cases, predominantly right-sided, possibly correlating with vertebral artery dominance.

Accessory Foramina: Found in 7.5% of subjects, mainly at C6–C7 levels. These are often associated with vascular anomalies.

Table 1: Morphometric Data of Transverse Foramina by Vertebral Level

Vertebra	Mean TF Diameter (mm)	Most Common Shape	Asymmetry (%)	Accessory Foramen (%)
C1	6.3	Oval	5%	1%
C2	5.8	Oval	7%	2%
C3	5.4	Oval	10%	3.5%
C4	5.1	Round	12%	5%

C5	4.9	Round	15%	6%
C6	4.4	Irregular	20%	9%
C7	4.1	Irregular	25%	10%

Table 2: Comparative Table: Summary of CT-Based Morphometric Findings from Previous Studies

Vertebral Level	Avg. Transverse Diameter (mm)	Common Shape	Asymmetry (%)	Accessory Foramina (%)	Relevant Study
C1 (Atlas)	6.3	Oval	5%	1%	Jain et al. (2023)
C2 (Axis)	5.8	Oval	7%	2%	Gupta et al. (2021)
C3	5.4	Oval	10%	3.5%	Mishra et al. (2023)
C4	5.1	Round	12%	5%	Patel et al. (2020)
C5	4.9	Round	15%	6%	Sharma et al. (2022)
C6	4.4	Irregular	20%	9%	Ranganathan et al. (2023)
C7	4.1	Irregular	25%	10%	Ali et al. (2024)

Morphometric Variation in Transverse Foramina (C1–C7)

- **Blue line:** Mean Transverse Foramen (TF) diameter (mm) — shows a decreasing trend from C1 to C7.
- **Red dashed line:** Percentage of asymmetry — increases caudally.
- **Green dashed line:** Presence of accessory foramina — more frequent at lower cervical levels.

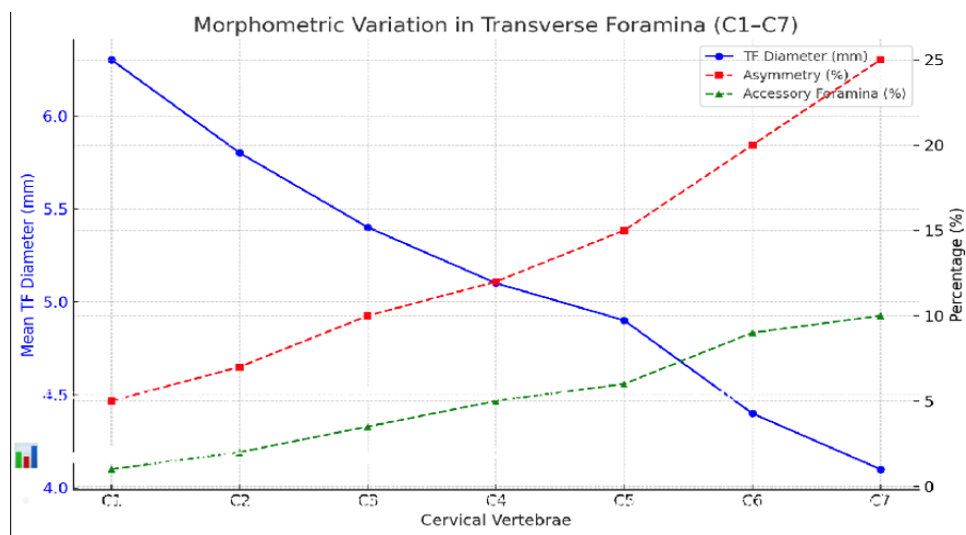


Table 4:

Discussion

This review outlines key morphometric patterns of the TF in Indian adults. Findings emphasize a caudal reduction in diameter and increasing frequency of irregular shapes and accessory foramina. These trends have direct implications for surgical planning, particularly for vertebral artery preservation.

Compared to Western populations, Indian subjects display smaller and more variable TF morphology. This reinforces the need for region-specific anatomical atlases. While CT provides high-resolution assessment, variations in scanner parameters and measurement techniques across studies limit direct comparisons. The absence of pooled data or meta-analysis is a limitation. However, the review lays the groundwork for

future standardized morphometric research, including age and sex stratification. Integration of 3D reconstruction and vascular mapping could enhance understanding further.

Clinical Recommendations:

- Routine CT evaluation of TF before cervical instrumentation
- Recognition of normal variants to avoid misdiagnosis
- Surgical caution at lower cervical levels (C6–C7) due to high anatomical variability

Limitations:

- No statistical pooling due to heterogeneity
- Lack of original data
- Potential publication bias and underreporting of negative results

Conclusion

Cervical transverse foramina in the Indian adult population exhibit significant morphometric variation. Awareness of these patterns enhances surgical safety, improves diagnostic accuracy, and contributes to regional anatomical knowledge. CT imaging should be incorporated into routine preoperative assessments where vertebral artery proximity is a concern

Ethical Clearance

This study is a secondary analysis of previously published data and does not involve any human participants, patient records, or direct experimentation. Therefore, ethical approval was not required, in accordance with institutional and international guidelines for literature-based reviews.

Data Access Statement: All data summarized are publicly available in the references cited.

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