Original Article

Morphometric Study of Foramen Transversarium in Typical Cervical Vertebrae and Its Clinical Significance

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Abstract

Background: All cervical vertebrae have the property of having the foramen transversarium in the transverse process. It transmits the sympathetic plexus, the vertebral vein, and the vertebral artery (except at C7). The neurovascular structures that pass through the foramen transversarium may be impacted by variations in its size, number, and morphology. This could result in clinical conditions like vertebrobasilar insufficiency, which manifests as headache, migraine, vertigo, fainting attacks, and labyrinthine disorders. The objective is to examine the morphometry of the foramen transversarium in normal cervical vertebrae and evaluate its possible therapeutic uses. **Material and Methods:** Thirty dry, typical cervical vertebrae from the Department of Anatomy at the Government Medical College in Jammu were used in this investigation. The anteroposterior and transverse diameters of the foramen transversarium on both sides were measured using a digital vernier caliper. It was also observed that the auxiliary foramen transversarium was common. IBM SPSS Statistics version 26 and Microsoft Excel were used for statistical analysis. The independent t-test was used to compare the two groups, which were reported as means and standard deviations. Statistical significance was defined as a p-value < 0.05. **Results:** The right foramen transversarium's transverse width ranged from 1.30 to 3.60 mm, with a mean of 2.48 ± 0.57 mm, while its anteroposterior diameter ranged from 0.60 to 3.00 mm, with a mean of 2.40 ± 0.51 mm. On the left side, the anteroposterior diameter varied from 1.50 mm to 3.50 mm with a mean of 2.46 ± 0.51 mm, while the transverse diameter varied from 1.30 mm to 3.70 mm with a mean of 2.48 ± 0.51 mm. The right and left sides did not vary statistically significantly ($p > 0.05$). One vertebra on the right side had a double foramen transversarium, whereas there were none on the left. **Conclusion:** The present study demonstrates that typical cervical vertebrae do not show significant morphological variation in the dimensions of the foramen transversarium. However, the presence of an accessory foramen transversarium, although rare, may have important clinical implications during surgical and radiological procedures involving the cervical spine.

Keywords: Foramen transversarium, cervical vertebrae, morphometry, vertebral artery, anatomical variations, accessory foramen.

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Introduction

The cervical vertebrae are unique in their anatomical configuration, distinguished by the presence of the foramen transversarium in the transverse processes. This foramen serves as a passage for important neurovascular structures, including the vertebral artery, vertebral vein, and a sympathetic nerve plexus.[1] A major contributor to the posterior cerebral circulation, the vertebral artery normally enters the foramen transversarium at the level of the sixth cervical vertebra. It ascends via consecutive foramina to reach the cranial cavity.[2]

The structural integrity and dimensions of the foramen transversarium are therefore of considerable importance, as any variation may influence the course, caliber, or hemodynamics of the vertebral artery. Alterations in the size or shape of this foramen may compromise blood flow, potentially leading to vertebrobasilar insufficiency, which clinically manifests as vertigo, headaches, syncope, visual disturbances, and other neurological deficits.[3]

Morphological variations of the foramen transversarium are not uncommon and include differences in size, asymmetry between sides, absence, hypoplasia, or the presence of accessory (double) foramina. These variations are believed to arise from developmental anomalies during embryogenesis, particularly involving the costal elements of the cervical vertebrae and their fusion with the transverse processes.[4] The formation of accessory foramina may indicate duplication or fenestration of the vertebral artery or the persistence of additional venous channels.[5]

Several osteological and radiological studies have highlighted the variability in the dimensions of the foramen transversarium across different populations. These variations may be influenced

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by genetic, environmental, and ethnic factors, emphasizing the importance of region-specific anatomical studies.[6] Knowledge of such variations is particularly relevant in the Indian population, where limited morphometric data are available from certain regions, including Jammu.

From a clinical perspective, understanding the morphometry of the foramen transversarium is crucial for spine surgeons, radiologists, and clinicians. Surgical procedures such as anterior cervical discectomy, cervical spine fixation, and decompressive surgeries carry a risk of vertebral artery injury if anatomical variations are not adequately recognized.[7] Preoperative evaluation using imaging modalities like computed tomography and magnetic resonance imaging often relies on established morphometric parameters to distinguish normal anatomical variations from pathological findings.[8]

In addition, variations in the foramen transversarium have been associated with certain clinical conditions, including cervical spondylosis and traumatic injuries, where altered anatomy may exacerbate vascular compromise. Therefore, a detailed morphometric analysis of the foramen transversarium not only contributes to anatomical knowledge but also enhances diagnostic accuracy and surgical safety.

In this context, the present study aims to evaluate the morphometric characteristics of the foramen transversarium in typical cervical vertebrae from the Jammu region and to assess their potential clinical significance.

Aims and Objectives

Aim: To examine the morphometry of the foramen transversarium in normal cervical vertebrae and evaluate its possible therapeutic uses.

Objectives

1. To measure the anteroposterior diameter of the foramen transversarium on the left and right sides.
2. To determine the transverse diameter of the foramen transversarium on the left and right sides.
3. To contrast the morphometric characteristics of the left and right sides.
4. To determine the incidence of accessory (double) foramen transversarium in typical cervical vertebrae.
5. To analyze the statistical significance of differences observed between the two sides.
6. To correlate the morphometric findings with their possible clinical significance, particularly in relation to vertebral artery variations and surgical implications.

Materials and Methods

Study Design: The goal of this descriptive, cross-sectional osteological research is to examine the morphometric features of the foramen transversarium in normal cervical vertebrae.

Study Setting: The research was conducted in the Department of Anatomy at the Government Medical College in Jammu.

Study Material: A total of 30 dry adult typical cervical vertebrae (C3–C6) were obtained from the osteology collection of the Department of Anatomy. These vertebrae were used for detailed morphometric analysis.

Inclusion Criteria

1. Intact typical cervical vertebrae (C3–C6).
2. Vertebrae with clearly identifiable anatomical landmarks.

Exclusion Criteria

1. Bones of infants and children.
2. Vertebrae showing pathological conditions such as tumors, fractures, deformities, or any damage affecting their normal anatomical structure.

Methodology: Each vertebra was carefully examined for the presence of the foramen transversarium on both sides. The morphometric analysis was performed using a digital vernier caliper with the least count of 0.01 mm to ensure precision and accuracy.

The following parameters were measured:

1. Anteroposterior diameter (AP diameter): The maximum distance between the anterior and posterior margins of the foramen transversarium.

2. Transverse diameter (Transverse diameter): The maximum distance between the medial and lateral margins of the foramen transversarium.

All measurements were taken bilaterally (right and left sides) for each vertebra. Care was taken to ensure measurements were recorded consistently and accurately, minimizing observational errors.

In addition to morphometric measurements, the vertebrae were also observed for the presence of an accessory (double) foramen transversarium. Any such variation was noted and recorded.

Statistical Analysis: All the collected data were entered into a Microsoft Excel spreadsheet and subsequently analyzed using IBM SPSS Statistics version 26.

The data were expressed as mean and standard deviation. The comparison between the right and left sides was performed using an independent t-test. Statistical significance was defined as a p-value < 0.05. Every p-value has two tails.

Results

For morphometric examination of the foramen transversarium, thirty dry normal cervical vertebrae were examined. The anteroposterior and transverse widths on the left and right sides, as well as the existence of accessory foramina, were among the

factors assessed.

The present study was conducted on 30 dry adult typical cervical vertebrae obtained from the Department of Anatomy, Government Medical College, Jammu. Since the study was osteological, specific details on age and sex were not available. All vertebrae included were identified as typical cervical vertebrae (C3–C6) and were intact, fulfilling the inclusion criteria.

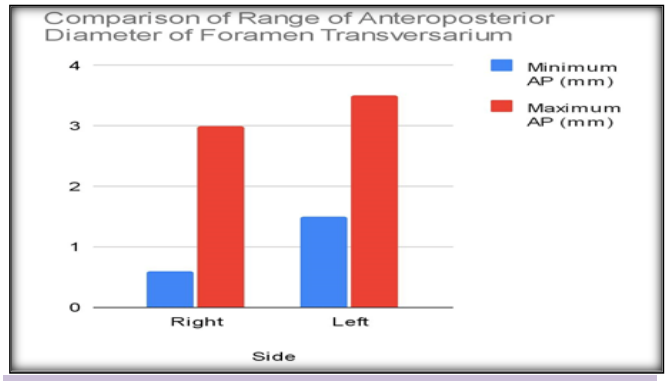

Figure 1: Comparison of the range of Anteroposterior Diameter of the foramen transversarium.

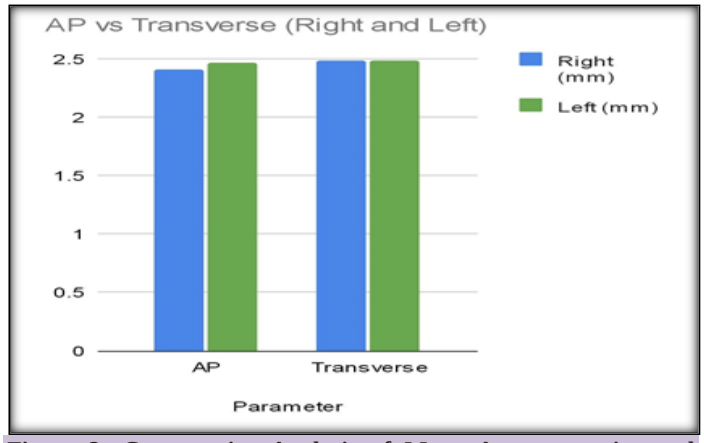

Figure 2: Comparative Analysis of Mean Anteroposterior and Transverse Diameters of Foramen Transversarium Between Right and Left Sides

The anteroposterior diameter of the foramen transversarium was measured on both sides. The readings for the right side had a mean of 2.4067 ± 0.51857 mm and ranged from 0.60 mm to 3.00 mm. The readings for the left side had a mean of 2.4667 ± 0.51148 mm and ranged from 1.50 mm to 3.50 mm. [Table 2].

Table 1: Demographic Distribution of Specimens

Parameter	Description
Total number of vertebrae	30
Type of vertebrae	Typical cervical vertebrae (C3–C6)
Source	Department of Anatomy, GMC Jammu
Nature of specimens	Dry adult bones
Sex distribution	Not determined
Age distribution	Not determined

Table 2: Distribution of Anteroposterior Diameter of Foramen Transversarium

Parameters	N	Minimum	Maximum	Mean	Std. Deviation
Right AP	30	0.60	3.00	2.4067	0.51857
Left AP	30	1.50	3.50	2.4667	0.51148

The transverse diameter of the foramen transversarium was also measured bilaterally. On the right side, it ranged from 1.30 mm to 3.60 mm with a mean of 2.4833 ± 0.57481 mm. On the left side, the range was 1.30-3.70 mm, with a mean of 2.4867 ± 0.51040 mm [Table 3].

Table 3: Distribution of Transverse Diameter of Foramen Transversarium

Parameters	N	Minimum	Maximum	Mean	Std. Deviation
Right TRAN	30	1.30	3.60	2.4833	0.57481
Left TRAN	30	1.30	3.70	2.4867	0.51040

The comparison between right and left sides for both anteroposterior and transverse diameters was carried out using the independent t-test. The results showed no statistically significant difference between the two sides for either parameter, with p-values greater than 0.05 [Table 4].

Table 4: Comparison of Anteroposterior and Transverse Diameters Between Right and Left Sides

Parameters	Side	N	Mean	Std. Deviation	t-value	P-value
AP	Right	30	2.4067	0.51857	-0.451	0.654
	Left	30	2.4667	0.51148		
TRAN	Right	30	2.4833	0.57481	-0.024	0.981
	Left	30	2.4867	0.51040		

The vertebrae under study have supplementary (double) foramen transversarium. One vertebra on the right side had a twin foramen transversarium, whereas the left side showed no such difference. [Table 5].

Table 5: Incidence of Accessory Foramen Transversarium

Parameter	Right Side	Left Side
Number of accessory foramina	1	0
Percentage	3.33%	0%

Summary: Anteroposterior and transverse widths were almost identical on the right and left sides of the foramen transversarium in normal cervical vertebrae, according to a morphometric study. The statistical analysis confirmed that the differences observed were not significant. The presence of an accessory foramen transversarium was rare, observed in a single vertebra on the right side.

Discussion

The goal of the current osteological investigation was to assess the clinical importance of the morphometric features of the foramen transversarium in normal cervical vertebrae. The study's results showed that there was no statistically significant difference between the right and left sides of the foramen transversarium, and the mean anteroposterior and transverse dimensions were almost similar on both sides. Additionally, an accessory foramen transversarium was identified in one vertebra on the right side.

Because it conveys the vertebral artery, vertebral vein, and sympathetic plexus, the foramen transversarium is an essential anatomical feature. The hemodynamics of the vertebral artery, which supplies blood to the back of the brain, may be affected by variations in its size and shape. Therefore, morphometric studies of this foramen are important for understanding both anatomical variations and their clinical implications.

In the present study, the mean anteroposterior diameter of the foramen transversarium was 2.40 ± 0.51 mm on the right and 2.46 ± 0.51 mm on the left. Similarly, the mean transverse diameter was 2.48 ± 0.57 mm on the right and 2.48 ± 0.51 mm on the left. These findings are in close agreement with those of Murlimanju and colleagues, who also reported minimal differences between the right and left sides in their morphometric analysis of cervical vertebrae.[9]

Chandravadiya and coworkers conducted a study on cervical vertebrae and reported that the transverse diameter was slightly greater than the anteroposterior diameter, although the difference was not statistically significant. This observation is consistent with the findings of the present study, where both diameters were nearly equal, indicating a relatively symmetrical morphology of the foramen transversarium.[10]

Taitz and Nathan, in their classical anatomical study, emphasized that variations in the size and shape of the foramen transversarium are common and may be attributed to developmental factors affecting the vertebral artery and surrounding structures.[11] The present study also supports this observation, as minor variations in the measurement range were noted, although they were not statistically significant.

The absence of significant side differences in the present study suggests that the vertebral artery likely maintains a relatively symmetrical course through the cervical vertebrae. This finding is consistent with the study by Bruneau and colleagues, who reported that symmetrical foraminal dimensions are generally associated with normal vertebral artery anatomy. In contrast, marked asymmetry may indicate vascular anomalies.[12]

The presence of an accessory foramen transversarium is an important anatomical variation. In the present study, a double foramen transversarium was observed in one vertebra on the right side, accounting for 3.33 percent of the sample. Similar findings have been reported by Das and Suri, who observed accessory foramina in a small percentage of cervical vertebrae and suggested that these may be associated with duplication or fenestration of the vertebral artery.[13]

Murlimanju and colleagues also reported the presence of accessory transverse foramina. They emphasized their embryological basis, stating that these variations may arise from incomplete regression or persistence of intersegmental arteries during development.[14] The identification of such variations is clinically important, as they may alter the course of the vertebral artery and increase the risk of vascular injury during surgical procedures.

From a clinical perspective, variations in the foramen transversarium are particularly significant in conditions such as vertebrobasilar insufficiency. Narrow or asymmetrical foramina may lead to compression or reduced blood flow through the vertebral artery, resulting in symptoms such as dizziness, vertigo, headaches, and syncope. Studies by Cacciola and Goel have highlighted the importance of understanding vertebral artery anatomy in relation to cervical vertebrae to prevent complications during surgical interventions.[15]

Radiological evaluation of the cervical spine frequently reveals variations in the foramen transversarium. Computed tomography and magnetic resonance imaging are commonly used to assess these variations. Knowledge of normal morphometric values, as established in the present study, is essential for distinguishing anatomical variants from pathological conditions.[16]

Furthermore, the findings of the present study are comparable with those reported in other population-based studies, suggesting that while minor variations exist, the overall morphology of the foramen transversarium remains relatively consistent. However, regional differences may persist, underscoring the importance of conducting such studies across different populations.[17]

The lack of statistically significant differences between the right and left sides in the present study may indicate that the foramen transversarium maintains functional symmetry, supporting uniform blood flow through the vertebral arteries. This observation is supported by the findings of Patel and colleagues, who also reported symmetrical dimensions in their morphometric analysis.[18]

The current study's limitations include its small sample size and the lack of demographic information, such as age and sex, despite providing insights into the morphometry of the foramen transversarium. Future studies with larger sample sizes and radiological correlation may provide a more comprehensive understanding of these variations and their clinical implications.[19]

Overall, the present study highlights that although the foramen transversarium generally exhibits symmetrical dimensions, the presence of accessory foramina, though rare, is of important clinical relevance. Clinicians, radiologists, and surgeons who treat cervical spine problems must have a thorough understanding of the anatomy of these variants.

Conclusion

The present osteological study provides a detailed morphometric analysis of the foramen transversarium in typical cervical vertebrae. The findings demonstrate that the mean anteroposterior and transverse diameters of the foramen transversarium on the right and left sides are nearly equal, with no statistically significant difference between them. This indicates that the foramen transversarium maintains a relatively symmetrical morphology in typical cervical vertebrae.

The study also revealed minimal variation in the size of the foramen transversarium, suggesting a consistent anatomical pattern that supports the normal course and function of the vertebral artery. However, the presence of an accessory (double) foramen transversarium in one vertebra on the right-side highlights that anatomical variations, although infrequent, do occur.

Such variations are of considerable clinical importance, as they may be associated with alterations in the course or branching pattern of the vertebral artery and accompanying venous structures. These variations can have implications in surgical procedures involving the cervical spine, particularly in anterior approaches, instrumentation, and decompressive surgeries, where there is a risk of vascular injury.

Furthermore, knowledge of the morphometric characteristics of the foramen transversarium is essential for accurate interpretation of radiological images and for differentiating normal anatomical variations from pathological conditions. It also helps clinicians understand the possible anatomical basis of symptoms associated with vertebrobasilar insufficiency, such as dizziness, vertigo, and headache.

In conclusion, although the foramen transversarium in typical cervical vertebrae shows consistent and symmetrical morphology, the presence of accessory foramina should be carefully considered during clinical evaluation and surgical planning. The findings of this study contribute to the existing anatomical knowledge and may serve as a useful reference for anatomists, radiologists, and spine surgeons.

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Conflicts of interest

There are no conflicts of interest.

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