SSR Institute of International Journal of Life Sciences
ISSN (O): 2581-8740 | ISSN (P): 2581-8732
Hingmire *et al*., 2025
doi: 10.21276/SSR-IIJLS.2025.11.2.9

Original Article

open access

Morphological Study of Foramen Transversarium of Atlas Vertebrae and its Clinical Significance

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Received: 06 Oct 2024/ Revised: 05 Dec 2024/ Accepted: 08 Feb 2025

ABSTRACT

Background: Cervical vertebrae are characterised by foramina transversaria, which are found in transverse processes. Because they allow the sympathetic nerves, vertebral vein, and vertebral artery to pass through, these foramina are significant anatomically. To research the variability in the human atlas vertebrae's foramina transversaria (FT), their morphology, and their clinical significance.

Methods: 32 dry atlas vertebrae were studied. Bones were obtained from a bone library of the Department of Anatomy at a medical college in Mumbai. Each vertebra was studied morphologically for the presence of various shapes of FT, and the presence or absence of any morphological features like accessory foramen or incomplete foramen.

Results: Two shapes of foramina transversaria were observed. Type 1(rounded) was 55% and type 2 (oval) was 45%. Incomplete foramen transversaria were observed in 5 vertebrae. Accessory foramina in 3 vertebrae and incomplete accessory foramina were observed in 3 vertebrae.

Conclusion: The morphological knowledge of these types of variation is clinically essential as the course of the vertebral artery may be distorted. The artery may get compressed, causing neurological symptoms. Also, knowledge of these types of variations is necessary for neurosurgeons in the posterior surgical approach to the cervical spine. Similarly, it is useful for radiologists during CT and MRI scans.

Key-words: Atlas vertebra, Cervical vertebrae, Costotransverse bar, Foramen Transversarium, Morphology

INTRODUCTION

The head is supported by the first cervical vertebra, the atlas. It has a ring form and neither a body nor a spine. A small anterior arch and a lengthy posterior arch connect the two lateral masses that make up this structure. From the lateral masses, the transverse process extends laterally. The transverse process contains the foramina transversaria. These are the cervical vertebrae's defining characteristics [1]. According to embryology, FT is made up of the genuine transverse process of the vertebra and a vestigial costal element that is united to the body; the neural plexus and vertebral veins are trapped between the bony portions [2]. The "costotransverse bar," a plate of bone that joins the costal element to the genuine transverse process, closes the FT laterally [3].

A thick posterior bar in intrauterine life represents the transverse process in the atlas vertebrae. This bar subsequently fuses with a thin anterior bar that develops from the ventrolateral part of the articular pillar in the third or fourth year of life, completing the creation of FT [4]. Therefore, as the anterior and posterior bars pass around the vertebral artery at the age of three to four years, they fuse to create the FT in the atlas [5].

The vertebral venous plexus, sympathetic plexus, and the second segment of the vertebral artery are all accessible through the FT of the atlas vertebra. Numerous bone abnormalities have been reported in the third segment of the vertebral artery when it leaves the foramen transversarium and enters the sub-occipital triangle [6].

How to cite this article
Hingmire VK, Kokane KS, Pai NV. Morphological Study of Foramen Transversarium of Atlas Vertebrae and its Clinical Significance. SSR Inst Int J Life Sci., 2025; 11(2): 7059-7063.

Access this article online
https://iijls.com/

doi: 10.21276/SSR-IIJLS.2025.11.2.9

Due to the intricate anatomy of the occipital area, there is a dearth of research on changes in the foramen transversarium of the atlas [7].

Although the exact origin of the differences in foramina transversaria size and shape is unknown, it is thought to be developmental or connected to changes that occur during the creation of vertebral arteries [8]. According to reports, bone degradation and the extent of the foramina may be caused by the vertebral artery's tortuosity [9]. Head and neck position is associated with human atlas morphology [10]. Therefore, the investigation of foramina transversaria of the atlas is necessary due to the incidence of neck injuries and syndrome [11]. For posterior approaches to the cervical spine, the identification of such variation ensures safety and effectiveness [12].

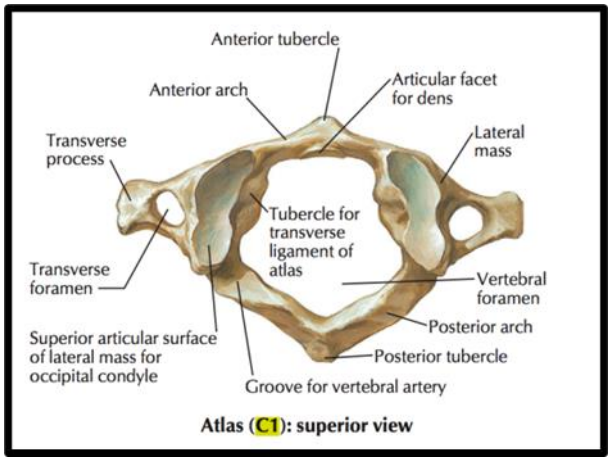

Fig. 1: Atlas (C1): Superior view

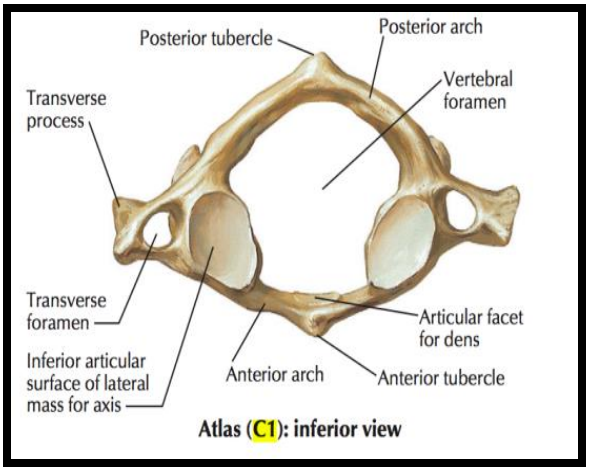

Fig. 2: Atlas (C1): Inferior view

Indicative of a neurological origin, occipital neuralgia is typically unilateral and characterized by short-lived, shock-like pain [13]. There have been reports in the literature of the vertebral artery's aberrant path compressing the nerve root [14]. Because of the aberrant vertebral artery path and joint instability, bony anomalies at the craniovertebral junction might result in occipital headaches [15].

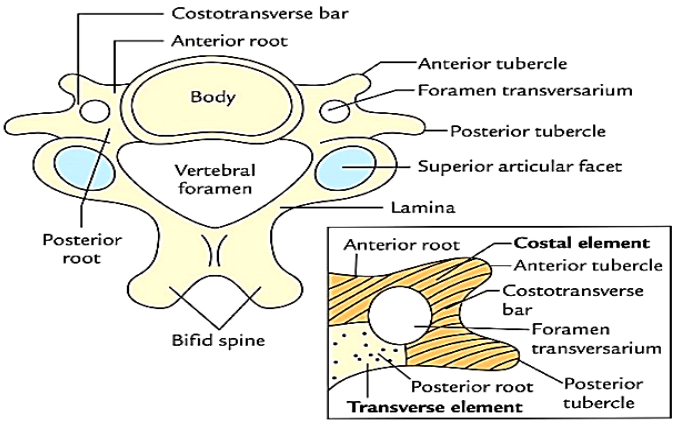

Fig. 3: Schematic cervical vertebra showing the foramen transversarium (FT)**.**
(Shaded portion of transverse process represents costal component

MATERIALS AND METHODS

Study Location- The study was conducted in the Department of Anatomy, Topiwala National Medical College & B.Y.L. Nair Charitable Hospital, Mumbai, India.

Sample Source- A total of 32 dry adult atlas vertebrae of unknown gender and age were obtained from the bone library of the Department of Anatomy.

Sample size- 32 dry adult atlas bones of unknown gender and age were obtained.

Study Design- A descriptive observational study was conducted to analyze the morphological variations of the foramen transversarium.

Data Collection- Each vertebra was examined macroscopically to identify different morphological variations of the foramen transversarium. The following parameters were studied:

- Shape of foramen transversarium.
- Presence of accessory foramen transversarium.
- Occurrence of incomplete foramen transversarium.
- Presence of incomplete accessory foramina.

Inclusion Criteria

- Dry, intact atlas vertebrae.
- Bones free from any visible pathological deformity.

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Exclusion criteria

- Damaged vertebrae
- Bones affected due to any pathology
- Bones of paediatric age group

Statistical Analysis- Data was analyzed using descriptive statistics, with results expressed in terms of frequency and percentage. Observations were recorded in tabular format to provide a comparative analysis.

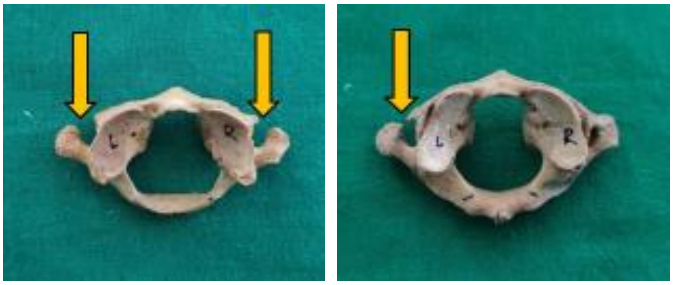
RESULTS

A total of 32 dry atlas vertebrae with 64 foramina transversaria were examined morphologically for the presence of variations.

Most of the foramina were of two distinct shapes: round and oval. Among the 58 complete foramina, round foramina were more prevalent than oval ones. Fig. 4 and Fig. 5 illustrate these variations. The study also identified cases of incomplete foramina transversaria, which were observed in 5 vertebrae (Fig. 6).

Fig. 4: Superior view of the atlas showing an oval foramen transversarium.

Fig. 5: Superior view of the atlas showing a round foramen transversarium.



A (Bilateral) B (Unilateral)

Fig. 6: Superior view showing an incomplete foramen transversarium (arrow indicating incomplete closure).

Accessory foramina were found in 3 vertebrae, and incomplete accessory foramina were also present in 3 vertebrae. These variations may have clinical implications as they can influence vertebral artery passage and potential compression. Fig. 7 and Fig. 8 depict these accessory and incomplete accessory foramina, respectively.

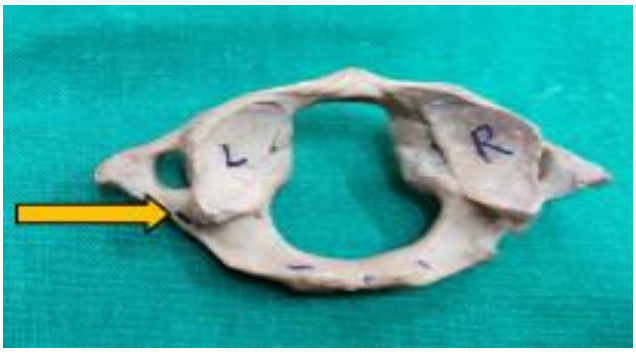


Fig. 7: Superior view showing an accessory foramen transversarium (arrow indicating additional foramen).

Fig. 8: Superior view showing an incomplete accessory foramen transversarium (arrow indicating partial formation).

The distribution of different types of foramina transversaria observed in this study is summarized in Table 1**.**

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Table 1: Distribution of variations in foramen transversarium observed in the study.

Foramen transversarium	No. of vertebrae	No. of foramen	percentage
Complete	27	54	84.4
Incomplete	5	6	15.6
Accessary	3	3	9.3
Incomplete Accessary	3	3	9.3

Additionally, the study observed that incomplete foramina were more common on the right side than on the left, with one case of bilateral occurrence. Accessory foramina and incomplete accessory foramina were also more frequently found on the left side. These findings indicate potential anatomical variations that could be of significance in clinical and surgical settings.

DISCUSSION

The morphological variations in the foramen transversarium of the atlas vertebra observed in this study have significant clinical implications. The presence of variations such as incomplete and accessory foramina can affect the course of the vertebral artery, leading to vascular compression and neurological symptoms [1]. Previous studies have reported that the size and shape of the foramen transversarium are influenced by factors such as genetic predisposition and mechanical stresses on the cervical spine [2].

The findings of this study align with previous research, which has noted that incomplete foramina transversaria are relatively common and can be associated with vertebral artery variations [3]. In particular, the higher occurrence of incomplete foramina on the right side in our study is consistent with earlier findings that suggest an asymmetric development of the vertebral artery [4]. Such anatomical variations are crucial for neurosurgeons and radiologists, as they may impact surgical approaches to the cervical spine and interpretation of radiological images [5,6].

Furthermore, the presence of accessory foramina transversaria suggests the possibility of duplicated or anomalous vertebral arteries. Some authors have linked these variations with an increased risk of vertebrobasilar insufficiency and cerebrovascular disorders [7,8]. It has also been suggested that changes in the morphology of the foramen transversarium may be associated with degenerative changes and age-related bone remodeling [9,10].

Similar studies have reported variations in the foramen transversarium among different populations. A study on 150 cervical vertebrae noted unilateral and bilateral accessory foramina, incomplete foramina, and asymmetrical foramina, reinforcing the importance of understanding these variations in clinical practice [11]. Another study on 175 cervical vertebrae identified double foramina in 24 specimens, highlighting the prevalence of these anomalies [12].

Clinical implications of these variations extend to patients experiencing cervicogenic headaches and vertebrobasilar insufficiency, where compression of the vertebral artery due to bony anomalies may contribute to symptoms [13,14]. Understanding these variations can aid in preoperative planning, particularly for posterior cervical surgical interventions [15,16].

Overall, the morphological knowledge of foramen transversarium variations is essential for clinicians, anatomists, and radiologists. Future studies incorporating larger sample sizes and advanced imaging techniques may further clarify the functional impact of these variations [17,18].

CONCLUSIONS

The morphological variations in foramina transversaria of the atlas vertebra hold significant clinical importance, particularly in neurosurgery and radiology. Variations such as incomplete or accessory foramina may alter the course of the vertebral artery, potentially leading to neurological symptoms or vascular compression. A thorough understanding of these anatomical variations is crucial for safe posterior cervical spine surgeries and accurate radiological interpretations.

Future studies using larger sample sizes and advanced imaging techniques like 3D CT and MRI can provide deeper insights into FT variations. Understanding their correlation with vertebrobasilar insufficiency may aid in early diagnosis and improved surgical planning.

CONTRIBUTION OF AUTHORS

Research concept- Vivek K. Hingmire, Kavita S. Kokane

Research design- Kavita S. Kokane, Nagaraja V. Pai

Supervision- Vivek K. Hingmire, Kavita S. Kokane

Materials- Kavita S. Kokane, Nagaraja V. Pai

doi: 10.21276/SSR-IIJLS.2025.11.2.9

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Data analysis and Interpretation- Vivek K. Hingmire
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Critical review- Kavita S. Kokane, Nagaraja V. Pai
Article editing- Vivek K. Hingmire, Kavita S. Kokane
Final approval- Kavita S. Kokane, Nagaraja V. Pai

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