Section: Anatomy

Original Research Article

VARIATIONS IN TRANSVERSE FORAMINA OF CERVICAL VERTEBRAE: MORPHOLOGY AND CLINICAL IMPORTANCE

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Abstract

Background: The cervical vertebrae are crucial for supporting the skull and protecting the spinal cord and vertebral arteries. Variations in their anatomical structures can have significant clinical implications. This study aims to investigate variations in the transverse foramina of cervical vertebrae and their morphological and clinical significance. **Materials and Methods:** A total of 200 human dried cervical vertebrae from the Department of Anatomy, B.J. Medical College, Ahmedabad, were examined for variations in the number and size of transverse foramina. The vertebrae were meticulously observed for any differences. **Results:** Among the 200 cervical vertebrae studied, complete double transverse foramina were present in 40 vertebrae (20%). Of these, 31 vertebrae (15.5%) exhibited unilateral double foramina, while 9 vertebrae (4.5%) had bilateral double foramina. Incomplete double transverse foramina were noted in 22 vertebrae (11%), with unilateral incomplete foramina found in 16 vertebrae (8%) and bilateral incomplete foramina in 6 vertebrae (3%). **Conclusion:** The occurrence of complete unilateral double transverse foramina in cervical vertebrae is more frequent than bilateral occurrences. Additionally, unilateral small-sized transverse foramina are also prevalent. These variations hold significant implications for neurosurgeons during cervical surgeries, as they can potentially distort the course of the vertebral artery. Understanding these variations is also crucial for radiologists when conducting CT and MRI scans to ensure accurate diagnosis and treatment planning.

INTRODUCTION

The cervical vertebrae, distinct in their anatomy, exhibit a unique relationship between their costal and transverse elements, particularly around the foramen transversarium located in the transverse process.[1] The costal element of the cervical vertebrae comprises the anterior root, anterior tubercle, costotransverse bar, and posterior tubercle, while the transverse element includes the posterior root.[2] These anatomical structures are crucial as the transverse foramina in the cervical vertebrae accommodate significant neurovascular structures, including the vertebral artery, vertebral vein, and sympathetic fibers from the inferior cervical ganglion.[3] Notably, the C7 vertebra typically transmits only the vertebral vein, with variations in the size or even the presence of its foramen.

The cervical vertebrae, being smaller and more delicate than vertebrae from other regions of the human spine, present a wide array of morphological variations, particularly in the foramen transversarium.[4,5] While a single foramen per transverse process is common, supernumerary foramina are not rare and can alter the pathways of the structures they transmit. These anatomical variations can have significant clinical implications6. For instance, changes in the number and size of the transverse foramina can lead to compression of the vertebral artery, potentially resulting in clinical symptoms such as headaches, migraines, and fainting spells.

Given these potential clinical outcomes, it is imperative to understand the variations in the transverse foramina of cervical vertebrae. This study aims to macroscopically analyze these variations and calculate their incidence, providing valuable insights for clinical practice. Understanding these variations is not only crucial for neurosurgeons during cervical spine surgeries but also for radiologists interpreting CT and MRI scans, ensuring accurate diagnosis and effective treatment planning.

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MATERIALS AND METHODS

Study Design and Sample Collection

This study was conducted over a one-year period from May 2023 to April 2024 to investigate variations in the number and size of transverse foramina in cervical vertebrae. A total of 200 human dried cervical vertebrae were obtained from the Department of Anatomy, B.J. Medical College, Ahmedabad. Defective vertebrae were excluded from the study to ensure accurate observations.

Inclusion Criteria

1. Intact human dried cervical vertebrae.
2. Vertebrae obtained from the Department of Anatomy, B.J. Medical College, Ahmedabad.
3. Vertebrae with clearly identifiable transverse foramina.

Exclusion Criteria

1. Defective or damaged cervical vertebrae.
2. Vertebrae with any structural anomalies not related to the transverse foramina.
3. Vertebrae with incomplete or missing transverse processes.

Observation and Data Collection

Each vertebra was meticulously examined for variations in the number and size of transverse foramina. Observations were documented, and vertebrae exhibiting variations were photographed for detailed analysis. Both the anterior and posterior tubercles, connected by the costotransverse bar, were scrutinized for any anomalies.

Statistical Analysis

The data collected from the observations were compiled and analyzed using Microsoft Excel software. The incidence of variations in the transverse foramina was calculated, and the results were categorized based on the type and location (unilateral or bilateral) of the variations.

Clinical Significance

Variations in the transverse foramina can potentially affect the course of the vertebral artery. Clinical symptoms such as headaches, migraines, and fainting attacks may result from compression of the vertebral artery due to these anatomical differences. Understanding these variations is crucial for radiologists during CT and MRI scans to ensure accurate diagnosis and effective treatment planning.

Photographic Documentation

Vertebrae showing variations in the transverse foramina were photographed to provide visual documentation of the anomalies. These photographs were used to support the data analysis and to facilitate a better understanding of the morphological differences observed.

Statistical Analysis

The compiled data were statistically analyzed to determine the prevalence and types of variations in the transverse foramina. The analysis aimed to identify patterns and correlations that could be relevant for clinical practice.

Ethical Considerations

All vertebrae were sourced from a pre-existing collection at B.J. Medical College, Ahmedabad, with institutionalethical approval, ensuring respectful handling of human remains and adherence to ethical standards for anatomical research.

RESULTS

Out of the 200 cervical vertebrae examined, significant variations in the transverse foramina were observed. The most notable finding was the presence of complete double transverse foramina in 40 vertebrae, accounting for 20% of the total sample. Within this subset, unilateral double foramina were notably more common, appearing in 31 vertebrae (15.5%). Bilateral double foramina were less frequent, observed in only 9 vertebrae (4.5%). These complete double foramina indicate the presence of fully formed, additional foramina that could potentially alter the anatomical course of critical neurovascular structures such as the vertebral artery and vein.

In addition to the complete double transverse foramina, incomplete double transverse foramina were identified in 22 vertebrae, representing 11% of the sample. Among these, unilateral incomplete foramina were observed in 16 vertebrae (8%), indicating a higher prevalence compared to bilateral incomplete foramina, which were found in 6 vertebrae (3%). Incomplete double foramina are characterized by partially formed additional foramina, which may still impact the pathways of the vertebral artery and vein but to a lesser extent than complete foramina. [Table 1]

The observed variations in both complete and incomplete transverse foramina are clinically significant. The unilateral dominance of these variations suggests a potential asymmetry in the anatomical structure of cervical vertebrae, which could have implications for neurosurgical procedures and radiological assessments. The presence of supernumerary foramina, whether complete or incomplete, could potentially lead to compression of the vertebral artery, resulting in clinical symptoms such as headaches, migraines, and fainting attacks.

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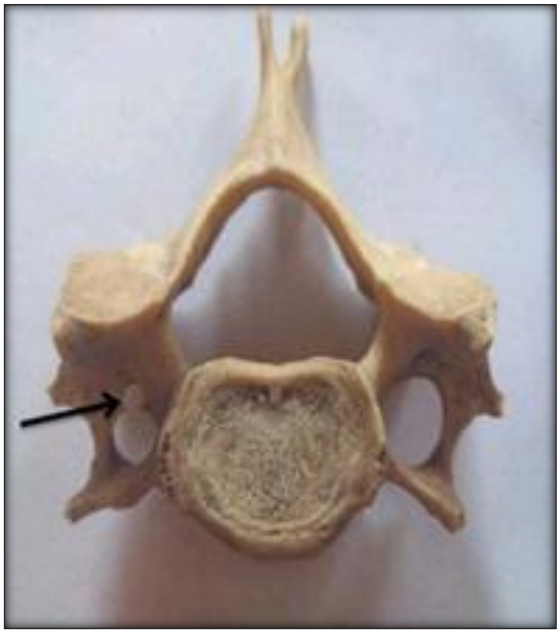

Figure 1: -U/L Incomplete Double Transverse foramina

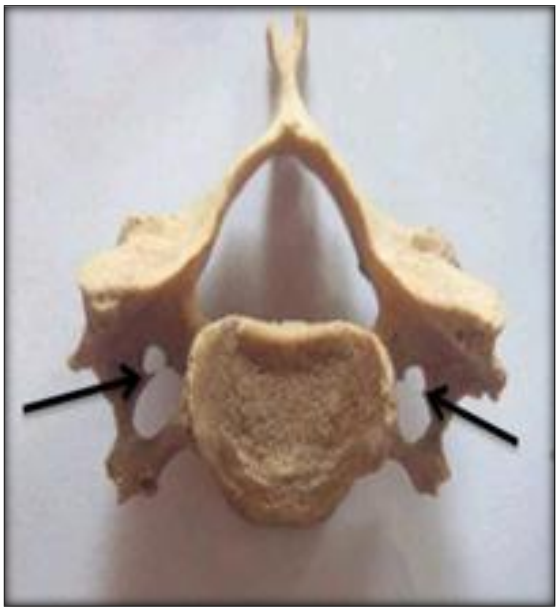

Image 2: B/L Incomplete Double Transverse foramina

Image 3: U/L Complete Double Transverse foramina

Image 4: B/L Complete Double Transverse foramina

Table 1: Variations in transverse foramina

Variations in transverse foramina	U/L	P Percentage (%)	B/L	Percentage (%)	Total (Percentage %)
Vertebrae with complete double transverse foramina	31	15.5	9	8	40 (20%)
Vertebrae with incomplete double transverse foramina	16	4.5	6	3	22 (11%)

U/L – unilateral, B/L- bilateral

DISCUSSION

The transverse foramen, a distinctive anatomical feature of the cervical vertebrae, is formed through the unique development of the cervical transverse processes. This formation involves the fusion of a vestigial costal element to the vertebral body and the true transverse process, laterally closed by the costotransverse bar (Taitz et al,[8] 1978). The morphological variations observed in this study underscore the complexity and clinical importance of understanding the anatomy of the transverse foramen.

One significant finding is the presence of complete and incomplete double transverse foramina. These anatomical variations can be attributed to

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developmental anomalies in the vertebral artery. During embryogenesis, portions of the primitive dorsal aorta may fail to degenerate, and intersegmental arteries connecting the vertebral artery may persist, leading to the double origin and duplication of the vertebral artery (Rahman and Das,[11] 2023). This anatomical variation can have substantial clinical implications. For instance, an aberrant or duplicated vertebral artery may alter the typical course within the transverse foramina, potentially leading to vascular compression or other pathologies that manifest as neurological symptoms, such as headaches, migraines, or even hearing disturbances (Zibis et al,[9] 2018).

The transverse foramen of the seventh cervical vertebra (C7) is particularly noteworthy. Unlike other cervical vertebrae, the transverse foramen in C7 primarily transmits branches of vessels and nerves, as well as fibrous and adipose tissues (Sim et al,[7] 2001). This anatomical peculiarity further complicates the clinical landscape, as variations in the size and presence of the transverse foramen in C7 can affect the surrounding neurovascular structures. Understanding these variations is crucial for neurosurgeons and radiologists, as the presence of extra foramina can indicate the multiplication of the structures passing through them, posing a risk during surgical interventions (Sangari et al,[12] 2015).

The clinical significance of these anatomical variations, although not completely clear, cannot be understated. The presence of supernumerary transverse foramina may lead to the compression of the vertebral artery, potentially causing significant clinical symptoms (Chaiyamoon et al,[13] 2021). Moreover, accurate identification of these variations is essential during diagnostic imaging and surgical procedures to prevent inadvertent damage to the vertebral artery and associated structures (Murugan and Verma,[14] 2014). For radiologists, recognizing these anatomical anomalies during CT and MRI scans can aid in the accurate diagnosis of conditions that may arise from these variations (Kaya et al6., 2011). For neurosurgeons, understanding the exact anatomy of the transverse foramina is critical to avoid complications during cervical spine surgeries (Tuncel Cini et al,[10] 2023).

The variations in the transverse foramina of cervical vertebrae, particularly the presence of complete and incomplete double transverse foramina, have significant clinical implications. These findings highlight the importance of detailed anatomical knowledge and careful preoperative planning to ensure patient safety and effective clinical outcomes. Further research is warranted to fully elucidate the clinical significance of these variations and to develop guidelines for their management in clinical practice.

CONCLUSION

In our study, complete double transverse foramina were observed in 20% of the cases, with unilateral double foramina being more common than bilateral. These findings contribute valuable information on the incidence and morphological basis of transverse foramina variations. This knowledge is particularly useful for radiologists during CT and MRI scans, aiding in the accurate imaging and diagnosis of neurological conditions. Additionally, understanding these variations is crucial for surgeons, particularly during posterior cervical surgeries, as it helps in planning and executing complex surgical procedures while minimizing the risk of damaging vital structures. Overall, recognizing and documenting these anatomical variations enhances clinical practice by improving diagnostic accuracy and surgical outcomes in the cervical region.

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