A cone beam computed tomographic study on foramen transversarium

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SUMMARY

The foramen transversarium is a vital feature found in the cervical vertebrae of the spine. It serves as a protective passageway for the vertebral artery and vertebral vein, supplying blood to the brain and spinal cord. Any compromise to these structures within the foramen can lead to severe neurological complications, emphasizing its clinical significance. The study was carried out on 83 subjects of typical cervical vertebrae. Among them were 42 males and 41 females. All the foramen transversaria were observed for any anatomical variations. The anteroposterior, transverse diameters of all the foramen transversaria and the distance between the medial margin of uncinate process to the foramen transversarium were measured. The average transverse diameter of typical cervical vertebrae and seventh cervical vertebrae were ± 0.84mm and 5.13 ± 1.22 mm respectively. The average anteroposterior diameters of typical and seventh cervical vertebrae were 4.84 ± 0.69 mm and 3.91 ± 1.17 mm respectively. The distance from medial border of uncinate process to foramen transversaria was 4.28 ± 0.77 mm in typical and 5.44 ± 1.28 mm in seventh cervical vertebrae. The incidence of double bubble foramen in typical cervical vertebrae was reported to be17.5%. The incidence of double foramen transversaria was 12.5% in the seventh cervical vertebrae. Osteophytes were obstructing the foramen transversarium and narrowing it in 25% of vertebrae. In cone beam computed tomography (CBCT), the foramen transversarium plays a pivotal role in precise imaging of the cervical spine. Its significance lies in providing clear visualization of anatomical structures and potential abnormalities, aiding in the accurate diagnosis and treatment planning for various spinal conditions, thus enhancing patient care.

Key words: Cone Beam Computed Tomography – Typical cervical vertebrae – Foramen transversarium – Osteophytes – Vertebrobasilar insufficiency

INTRODUCTION

A cluster of seven tiny bones, termed the cervical vertebrae, that are nestled in the neck area of the human spine are crucial to our daily existence and functional capacity. Given the extensive multitude of tasks they execute, these vertebrae are of paramount importance. The vertebral body, vertebral arch, vertebral foramen, articular facet, spinous process, and foramen transversarium

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(FT) are all defined by the CV as crucial anatomical adaption elements (Benzel, 2012). The foramen transversarium, also known as the vertebral artery foramen, is a recent structure that has garnered attention. It is a small but important anatomical feature, encountered notably in the first through sixth cervical vertebrae.

The foramen transversarium is a unique structure with bilateral openings, one on each side of the spine. It executes a multitude of necessary tasks. The sympathetic nerve plexus, vertebral artery, and vein all pass through the foramen transversarium. These blood vessels deliver oxygen-rich blood to the brain, supplying it with the resources it needs to function at its best. The sympathetic nerve fibres that travel via the foramen transversarium also assist in stabilising and supporting the cervical vertebrae, as well in regulating different bodily processes like blood pressure and heart rate (Chaiyamoon et al., 2021).

Any FT-related alterations can have a direct influence on the structure and shape of the neurovascular structures to which they are connected, resulting in vertebrobasilar ischemia, hearing impairment, and neurological symptoms inextricably linked to the vertebral artery or basilar artery (Zaw et al., 2021). The foramen transversarium in dry skulls is extensively discussed in the literature, albeit without the use of radiography. By using different imaging modalities, these variations of FT can be clearly seen radiographically. Cone beam computed tomography (CBCT) has recently attracted interest in this area.

In the entities of orthopaedics and radiology, cervical vertebral imaging using CBCT has become a useful diagnostic tool. Due to its high-resolution three-dimensional capabilities, CBCT has the unique advantage of rendering the cervical spine. This technique permits a comprehensive inspection of the cervical vertebrae, which is best suited for surgical planning, as it enables surgeons to precisely examine the anatomy and pathology of the cervical spine, impacting the precision of procedures and mitigating risk. Furthermore, cervical spine disorders, fractures, tumours, and degenerative changes can all be intercepted and monitored early with CBCT, which contributes to developing more effective and comprehensive treatment plans. So, the aim of the present study is to study the foramen transversarium from the stance of a radiologist in order to improve the process of diagnosis and therapy.

MATERIALS AND METHODS

The JSSDCH IEC Research Protocol Number: 21/2023 was approved by the institutional ethics committee. The volumetric images produced in the large view modes were generated using Planmeca ProMax 3D. A convenient sampling technique was used, assuming an absolute precision of 5% and a confidence level of 95%. A total of 83 CBCT scans, 42 males and 41 females, were utilised between May 2022 and June 2023.

Inclusion criteria

1. Ideal axial section of optimum diagnostic CBCT images of cervical vertebrae and closely associated structures.
2. Patients who underwent CBCT evaluation of:
    a. Mixed dentition analysis.
    b. Maxillary and mandibular arch pathologies.
    c. Pre and post treatment evaluation for maxillofacial implant placement.
    d. Pre-surgical planning for orthognathic surgery.
    e. Trauma involving maxilla and mandible.

Exclusion criteria

1. CBCT of axial images do not clearly depict the cervical region and not cover the sixth cervical region.
2. Images with developmental defects or pathology involving the cervical region.
3. Inadequate image quality, including images with exposure artefacts, subject artefacts, and inherent artefacts.

Radiographical images satisfying this inclusion criteria will be further analysed for the transverse diameter, antero-posterior diameter, distance from the medial border of the uncinate process to the foramen transversarium, and the prevalence of any accessory foramina and osteophytes (Figs. 1-3).

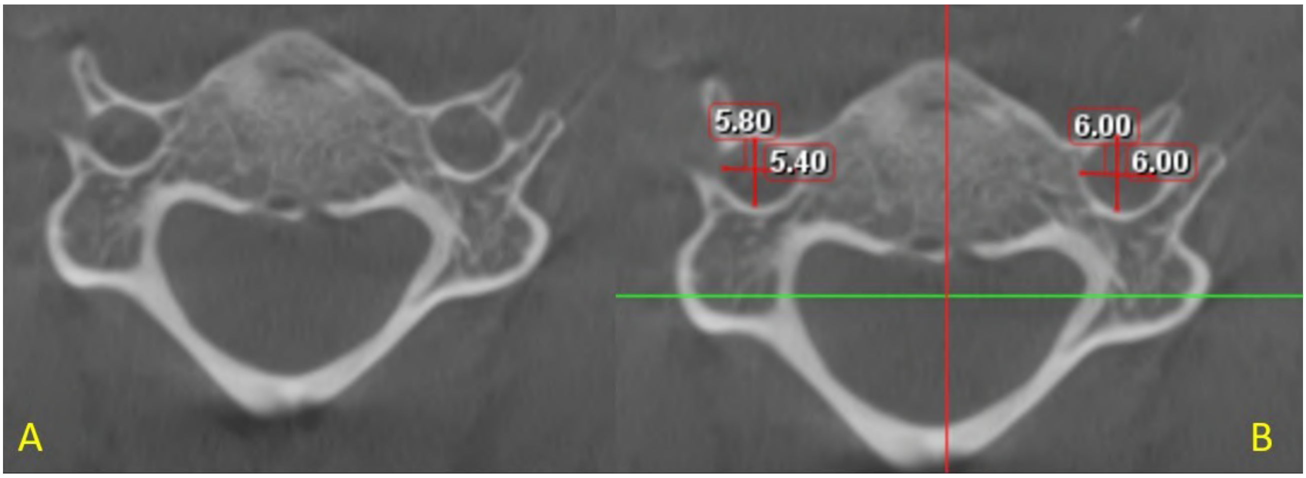

Fig. 1.- A: Transverse and anterior-posterior diameter of foramen transversarium in axial section. **B:** Transverse and anterior-posterior diameter of foramen transversarium measuring its dimension.

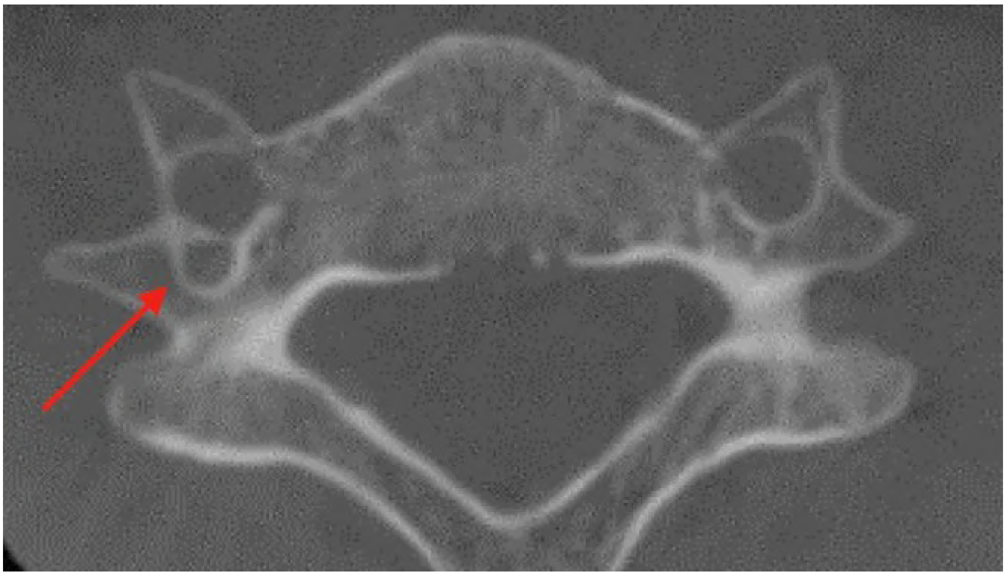

Fig. 2.- Accessory foramen transversarium (arrow).

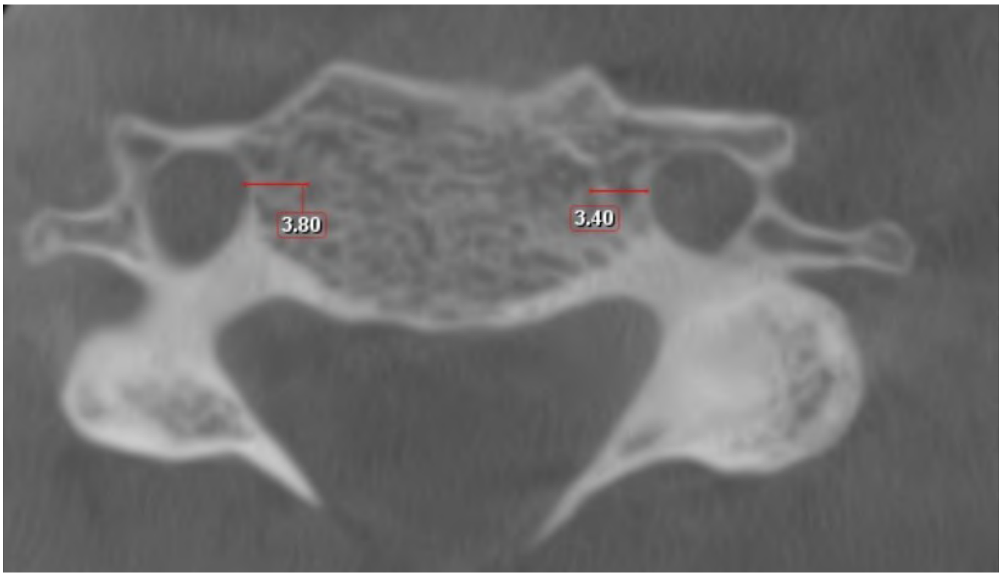

Fig. 3.- Distance from the medial process of the uncinate process to foramen transversarium.

Table 1. Mean and standard deviation.

Evaluated Parameters	Mean (mm)		Standard deviation (mm)	
	Right	Left	Right	Left
Transverse Diameter	5.993	6.066	0.747	0.707
Anterior- Posterior Diameter	5.363	5.488	0.656	0.660
Distance from the medial border of uncinate process to foramen transversarium	4.761	4.677	0.987	0.958

Statistical analysis

The SPSS 22.0 package was used to tabulate and analyse the gathered data. The application of descriptive statistics was rendered. A paired sample t-test was employed to assess the mean differences between the left and right sides or between the AP and transverse dimensions. It was done to calculate the mean, standard deviation, and P value. Also, the presence of the accessory foramen and the osteophytes obstructing the transverse foramen were qualitatively assessed.

RESULTS

The transverse diameter of the right transverse foramen in a typical cervical vertebra exhibited considerable variation, with a mean value of 5.99 ± 0.74 mm, while the anteroposterior diameter of the right transverse foramen had a mean diameter of 5.36 ± 0.65 mm. The average transverse diameter of the left transverse foramen was found to be 6.06 ± 0.7 mm, while the average antero-posterior diameter was measured to be 5.48 ± 0.66 mm. The estimation of the distance between the right medial border of the uncinate process and the foramen transversarium exhibited variability, with an average value of 4.76 ± 0.98 mm. Similarly, the measurement of the distance between the left medial border of the uncinate process and the foramen transversarium also displayed variability, with an average value of 4.67 ± 0.958 mm (Table 1).

Table 2. Qualitative analysis of accessory foramina and osteophytes.

	Total Number (N = 83)	Percentage
Accessory transverse foramina	15	18.07
Osteophytes	7	8.43

The accessory transverse foramen was identified as the most prevalent anomaly, observed in 15 individuals, accounting for 18.07% of the total sample. Osteophytes, the second most prevalent anomaly, manifested in 7 patients, accounting for 8.43% of the sample (Table 2).

A paired t-test was performed on a sample comprising 83 individuals with the purpose of comparing four measurements pertaining to the architectural characteristics of the cervical spine, specifically focusing on the differences between the right and left sides. The transverse foramen exhibited a discernible discrepancy in both transverse diameter (t-test of difference, T-value = -0.948, P value = 0.346) and antero-posterior diameter (t-test of difference, T-value = -1.37, P value = 0.174) between the right and left sides. None of the aforementioned distinctions exhibit statistical significance, as none of the p-values fall below the threshold of This finding indicates that there are no statistically significant differences between the right and left sides of the foramen transversarium in the studied population (Table 3).

Table 3. Paired t-test.

	t value	*p value*
Right vs Left Anterior - Posterior Diameter	-1.37	0.174
Right vs Left Transverse Diameter	-0.948	0.346
Right vs Left Uncinate Process to FT	0.96	0.34

DISCUSSION

Studying the morphology of FT is indispensable for diagnostic applications in a variety of ways in light of the impairment that might occur in the vertebral artery pathway. Vertebral artery compression can manifest in neurological ailments like headaches, migraines, vertigo, and disturbances of the hearing. In any context, it's critical to understand the FT variations, especially for surgeons and neurosurgeons. The formation of the vertebral artery, the essential component of the FT, during embryogenesis may be substantially causally linked to the presence of these variations. The vertebral artery is developed by the fusion of the cervical intersegmentary arteries' longitudinal anastomosis with the primitive dorsal aorta. Furthermore, the disparities detected may be precipitated by developmental changes. According to the literature, stress and posture in the upright human figure the skeletal layout of the neck region (Taitz and Nathan, 1986).

As the angle of the head increases, vertebral artery stenosis, which induces the constriction, triggers Bow Hunter's stroke, a sign of vertebrobasilar insufficiency (Sarkar et al., 2014). The vertebrobasilar insufficiency (VBI), which provokes neck actions to nudge on the vertebral artery, is characterised by headache, migraine, and fainting spells (Kaya Özçora and Canpolat, 2017; Sangari et al., 2015). Cervical migraine, also known as Barré-Lieou syndrome, is a distinctive kind of migraine that originates in the neck. It is deemed that the causes of this condition comprise spasm of the vertebral artery and occlusion of the foramen transversarium (Tamura, 1989).

The two vertebral arteries are purportedly not of equal size in about 69% of cases; additionally, Sangari et al. (2015) report about 75% of unequal size. In the present study, the mean diameter of the right and left transverse foramen varied from the mean by 5.99 ± 0.74 mm and 6.06 ± 0.7 mm, respectively. Based on a study by Tellioglu et al. (2018), there is still a substantial positive association between the variation in C3-C6 vertebrae, despite the fact that there was no statistically significant difference between the dimensions of the right and left sides. The present study is concurrent with similar investigations by Cagnie et al. (2005), Taitz et al. (1978) and Zaw et al. (2021), all of which report that the left transverse foramen is larger than the right. The reason is that this is presumably because the arteries on the left side are frequently broader than those on the right side (Abd el-Bary et al., 1995; Gotlib and Thiel, 1985; Mitchell, 2004).

The C6 level was the most afflicted level in the present study, with 53% of the vertebrae having a duplicate foramen, followed by the C5 level with 31%; this is almost certain with Moreira et al. (2020) and Zibis et al. (2016). The primary anatomical difference most commonly noticed in our investigation was the double foramen, which Meckel first described in 1912. The double foramen transversarium is also known as foramen transversarium bipartitia. Relying on the vertebral artery's course, it could be unilateral or bilateral. The vertebral artery's tortuosity, along with embryological factors, is crucial in the development of FT bipartitia. However, the actual cause of the double FT is not well renowned (Ulusoy, 2019).

According to our report, the occurrence of the accessory foramen is approximately 18.07%, compared to 17.5% encountered by Yesender et al. (2017). At the level of C7, Taitz et al. (1978) presented three foramina in a single vertebra. No triple foramen was located during our analysis. This may well raise the probabilities of thrombus formation and embolisation in fenestrated or numerous vertebral arteries, which could lead to severe transient ischemic attacks (Ionete and Omojola, 2006).

Ostephytes, which are aberrant bone growths that can conceivably cause injuries to the sympathetic plexus, vertebral artery, and vein, are evidently existent inside the FT (Strek et al., 1998). The vertebral artery may get compressed as a consequence of elevated external constraint imposed by the cervical spine's deterioration (Cockerill et al., 2000). 8.43% of the vertebrae in the present study evinced osteophytes, which showed hardly a proclivity for the right or left side. Osteophytes were found in 5.7% of the vertebrae, predominantly in the C7 segment, according to a study, which is significantly less than the percentage reported (Das and Basu, 2022; Sanchis-Gimeno et al., 2019). Whenever the head revolves, the osteophyte triggers an inflammatory response that results in the development of a fibrous layer surrounding the VA, which hinders arterial advancement, compression or kinking are more likely to occur (Kuether et al., 1997).

The mean distance of the transverse foramen from the medial margin of the uncinate process in the present study was 4.76± 0.98 mm on the right side and 4.67± 0.95 mm on the left side, which was less than the study by Sangari et al. (2015), who reported it as 5.0 ± 0.87 mm on the right side and 5.0 ± 1.0 mm on the left. This is noteworthy because the medial edge of the uncovertebral joint may contribute as a robust landmark during anterior cervical disc surgery to prevent vertebral artery injury (Malik et al., 2010). It is possible to have a strong possibility of laceration of the vertebral arteries, particularly during lateral decompression to eliminate osteophytes from the uncinate process (Ebraheim et al., 1996).

Agenesis of the transverse foramen is often rare. However, our investigation did not find any evidence of the foramen transversarium being absent. Taitz et al. reported the absence of a foramen transversarium in four vertebrae. Kimura et al. (1985) recorded 18 instances, and Wysocki et al. (2003) reported one case.

CONCLUSION

This study concluded that, regardless of the lack of statistical significance, the left transverse foramen was larger than the right one. In 18.07% of the samples that were evaluated, an accessory foramen was located, and 8.43% of the samples revealed osteophytes. We opine that any values lower or higher may suggest abnormality. In this circumstance, it is posited to assess the foramen transversarium using cone-beam computed tomography (CBCT), an imaging modality that is embraced as the gold standard. The clinical significance of the foramen transversarium will be comprehended with further research in this field. This is pertinent to medical practitioners, since it exemplifies the value of detailed anatomical information when diagnosing and treating disorders involving the cervical spine. Recognising the importance of the foramen transversarium in vascular health, neurology, or orthopaedics is vital to delivering expedient patient treatment and ensuring people's livability.

DECLARATIONS

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper. The Institutional Ethics Committee authorised the work as a descriptive retrospective study after it was proffered to them. Only subjects' respective masked radiographs were evaluated from the archives maintained in the department; no patients actively participated in the study. Hence, patient consent is not applicable for the study.

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