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The morphology and incidence of the accessory foramen transversarium in human dried cervical vertebrae as well as their clinical significance in the Eastern Indian population

Rakesh Ranjan[1], Md. Zahid Hussain[2], Soni Kumari[3], Vijay Kumar Singh[4], Rashmi Prasad[5]

[1]Assistant Professor, Department of Anatomy, Shri Krishna Medical College, Muzaffarpur, Bihar, India, [2,4]Tutor, [5]Professor and Head, Department of Anatomy, Nalanda Medical College, Bihar, India, [3]Tutor, Department of Anatomy, Patna Medical College, Patna, Bihar, India

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ABSTRACT

Background: A characteristic feature of the cervical vertebrae (C1–C7) is the presence of a foramen tranversarium on the transverse process. The cervical vertebrae are the smallest in size as compared to the thoracic and lumbar vertebrae and are characterized by a foramen in each transverse process, which is not found in any other vertebra. Except for the seventh cervical vertebra, which transmits only the vertebral vein, this foramen transmits the vertebral artery, vein, and sympathetic nerves (a branch from the cervicothoracic ganglion) in all cervical vertebrae. Any deviation in the development of the foramen transversarium (FT) causes changes in the course, relationships, and structure (stenosis and lumen narrowing) of the vertebral artery and its associated structures. **Aims and Objectives:** The aims of this study were to establish the location, shape, size, and incidence of accessory FT in dry human cervical vertebrae of Eastern Indian population. **Materials and Methods**: An observational cross-sectional study was conducted on 170 dry cervical vertebrae (Typical-123 and Atypical-47) of unknown sex and age after getting approval from the Institutional Ethics Committee. Range, frequencies, percentage, mean, standard deviation, and P value were calculated. $P<0.05$ was taken as significant. **Results:** The foramen tranversarium in the transverse process is present in all 170 cervical vertebrae examined. Of the 170 cervical vertebrae, the accessory FT is found in 24 (14.12%) of the vertebrae. In both typical and atypical cervical vertebrae, the accessory FT is more common on the right side. On the axis vertebra, no accessory FT was found. **Conclusion:** Understanding the accessary FT and the considerable variation in different cervical vertebrae (C1-C7) in terms of their size, shape, and number of FT are essential for routine spine surgical procedures in the cervical region to avoid post-operative complications. This study is also important for the teaching and acknowledgement of undergraduate and postgraduate students in anatomy as well as in orthopedics, neurosurgery, and radiology departments.

Key words: Accessary foramen transversarium; Foramen transversarium; Typical cervical vertebrae; Vertebral artery

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INTRODUCTION

In cervical vertebrae, the transverse process is morphologically composite around the foramen transversarium (FT). The cervical vertebrae are the smallest in size as compared to the thoracic and lumbar vertebrae and are characterized by a foramen in each transverse process, which is not found in any other vertebra. The 1st and 2nd cervical vertebrae are called the atlas and axis vertebrae, respectively. Except for the seventh cervical vertebra, which transmits only the vertebral vein, this foramen transmits the vertebral artery, vein, and sympathetic nerves (a branch from the

Address for Correspondence:
Dr. Vijay Kumar Singh, Department of Anatomy, Nalanda Medical College, Kankarbagh, Patna - 800 026, Bihar, India.
Mobile: +91- 8210725653. **E-mail:** vkspmc@gmail.com

cervicothoracic ganglion) in all the cervical vertebrae. A FT is formed during the development of the cervical vertebra by the fusion of the costal element with the transverse element of the developing vertebra, entrapping the vertebral artery, vein, and sympathetic plexus. Any deviation in the development of the FT causes changes in the course, relationships, and structure (stenosis and lumen narrowing) of the vertebral artery and its associated structures. Bilateral stenosis of the vertebral artery and irritation of sympathetic nerves around it may present with basi-vertebral insufficiency and symptoms such as headaches, vertigo, and fainting attacks.[1] The cervical spine is comprised seven cervical vertebrae – C1–C7. It begins at the base of the skull and extends down to the thoracic vertebrae. The 1st, 2nd, and 7th cervical vertebrae are atypical, whereas the 3rd, 4th, 5th, and 6th cervical vertebrae are typical. The 7th cervical vertebra has vertebra prominens, the longest spinous process, and the process is not bifid. The cervical vertebrae are vertebral canals that enclose the spinal cord. The first cervical vertebra (atlas vertebra) is unique in that it is a ring-like structure that rotates around the second vertebral odontoid. The cervical vertebrae closest to the skull are the smallest.[2] The spine is small and bifid, the body is small and broad from side to side, whereas the vertebral foramen is large and triangular in shape.[3] Variation in the number, size, and shape of FT affects the anatomical course of the vertebral vessels, which may cause pathological conditions like vertebra-basilar insufficiency. This occurs as a result of compression of the vertebral artery during neck movements and is characterized by headaches, migraines, and fainting attacks.[4] The adult cervical vertebrae are characterized by the presence of a FT in the transverse process, which differentiates them from other vertebrae. The vertebral artery, vertebral vein, and sympathetic nerves from the inferior cervical ganglion pass through each of these foramen except the seventh. The vertebral artery enters its vertebral course at the level of the FT of the sixth cervical vertebra. The FT of the seventh cervical vertebra transmits only veins and is small or absent at times.[5] The vertabral foramen is at times divided into anterior (larger) and posterior (smaller) parts by a fibrous or bony bridge. The accessory vertebral foramen is the smaller posterior part of the FT. The larger anterior part encloses the artery, and the smaller posterior part encloses the vertebral nerve and vertebral vein.[6] The sixth cervical vertebra have an accessory FT, which is more common than the other vertebrae.[7] The variations of the FT in number, size and shape have an embryological basis and may be related to the course of the vertebral artery and very rarely, the cervical vertebra may be without the FT.[8]

Aims and objectives

The purpose of this research is to establish the location, shape, size, and incidence of accessory FT in dry human cervical vertebrae as well as its clinical significance in the Eastern Indian population and compares it with the incidence among various races in the world.

MATERIALS AND METHODS

An observational cross-sectional study was conducted on 170 dry cervical vertebrae (Typical-123 and Atypical-47) of unknown sex and age, which were available in the Departments of Anatomy, Orthopedics, and Forensic Medicine and Toxicology of Nalanda Medical College (Patna, Bihar, India) and Patna Medical (Patna, Bihar, India), Shri Krishna Medical College (Muzaffarpur, Bihar, India), Indira Gandhi Institute of Medical Sciences (Sheikhpura, Patna, Bihar, India). The study was pre-approved by the Institutional Ethics Committee (IEC) for the final permission. After obtaining the permission of IEC, the study was conducted. Among the 47 atypical cervical vertebrae, 18 are C1, 13 are C2, and 16 are C7. Each cervical vertebra is examined for the presence of an accessory FT. The study was carried out over a 3-year period, from September 2019 to July 2021. In each case where morphometric analysis was present and recorded, various observations were made. Representative photographs of different cervical vertebrae having accessory FT are taken using a digital camera.

Criteria for inclusion

The following criteria were included in the study:

The study will include dry and complete adult cervical vertebrae.

Criteria for exclusion

The following criteria were excluded from the study:

1. Partially broken or deformed specimens will be excluded from the study.
2. Specimens with osteoarthritis or evidence of past trauma or skeletal problems will be excluded from the study.
3. The cervical vertebrae of children were not included in the study.

Statistical analysis

Statistical analysis was carried out for 170 dry human cervical vertebrae. Microsoft Excel 16 is used to analyse data and create graphs. Version 22.0 of the SPSS (Statistical Package for the Social Sciences) Software was used for complex statistical data analysis like frequency analysis, percentage analysis, mean, standard deviation (SD), chi-square test, and P value. $P < 0.05$ was considered significant. An independent sample t-test was performed to compare the mean values of anteroposterior diameter and transverse diameter of FT between the right and left side.

RESULTS

A characteristic feature of the C1–C7 cervical vertebrae is the presence of a foramen tranversarium on the transverse process. The vertebral artery, veins, and sympathetic nerves are all transmitted through it. The foramen tranversarium in the transverse process is present in all 170 cervical vertebrae examined. Out of the 170 cervical vertebrae, the accessory FT is found in 24 (14.12%) of the vertebrae. Among these 24 vertebrae, 16 (9.41%) are typical and 8 (4.71%) are atypical cervical vertebrae. We observed in these 16 typical cervical vertebrae that 10 (5.88%) vertebrae have accessory FT on their right side, while 3 (1.76%) vertebrae have it on their left side and 3 (1.76%) vertebrae have bilateral accessory FT (Figures 1-3). Among eight atypical cervical vertebrae, 4 (2.35%) vertebrae have accessory FT on their right side, 3 (1.76%) vertebrae have it on their left side, and 1 (0.59%) vertebrae have bilateral accessory FT. In both typical and atypical cervical vertebrae, the accessory FT is more common on the right side. On the axis vertebra, no accessory FT was found (Figures 4-6). In typical cervical vertebrae, the accessory FT is much smaller than the main FT and is positioned posterior to it. The accessory foramen is separated from the main foramen by a thin bone bar. In atypical cervical vertebrae like atlas, the accessory FT is slightly smaller than the main FT, but in the seventh cervical vertebra, it is much smaller. The accessory FT is located posteriorly on the right side of the Atlas vertebra and laterally on the left side.

The above parameters of distribution of accessory foramen transversarium shown in Table -1 in details and graphically presented in Graph-1.

Many studies have been done by different authors on the variation of the number, size, and shape of FT in past studies shown in Table-2 in details.

In typical cervical vertebrae, the accessory foramen transversarium is much smaller than the main

Figure 1: Unilateral (right-sided) accessory foramen transversarium in a typical cervical vertebra (C5)

Figure 2: Unilateral (left-sided) double foramen transversarium in a typical cervical vertebra (C4)

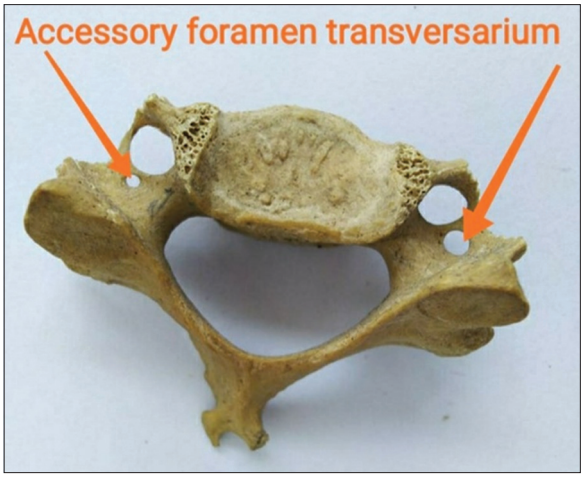


Figure 3: Bilateral accessory foramen transversarium in a typical cervical vertebra (C4)

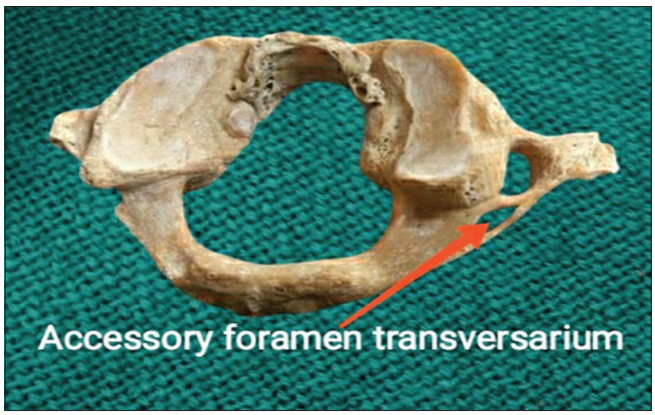
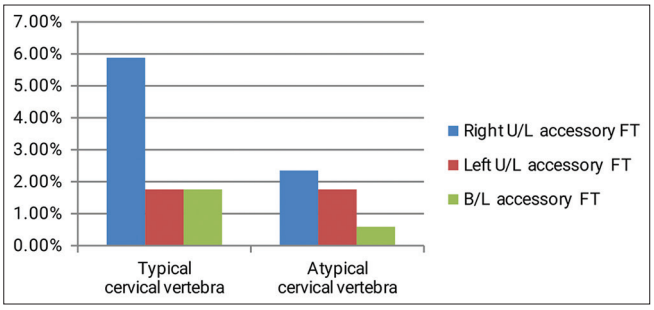


Figure 4: Unilateral (right-sided) accessory foramen transversarium in an atypical cervical vertebra (C1)

foramen transversarium and is positioned posterior to it. The accessory foramen is separated from the main foramen by a thin bone bar. In atypical cervical vertebrae like Atlas, the accessory foramen transversarium is slightly smaller than the main foramen transversarium, but in the seventh cervical vertebra, it is much smaller. The accessory foramen transversarium is located posteriorly on the right side of the Atlas vertebra and laterally on the left side.Individual cervical vertebrae from C1 to C7 showed a wide range of variations in the mean diameters of transverse foramina on the right and left sides.

Figure 5: Unilateral (left-sided) accessory foramen transversarium in an atypical cervical vertebra (C1)

Figure 6: Bilateral accessory foramen transversarium in an atypical cervical vertebra (C7)



Graph 1: Side wise allocation of accessory foramen transversarium

1. Anteroposterior diameter- It was observed that maximum anteroposterior diameter was seen in C1 vertebrae with a mean value of 6.67±1.01 mm on left and 6.63±1.06 mm on right.
2. Transverse diameter- The widest range of transverse diameter was seen in C1 vertebrae with a mean value of 5.86±1.03 mm on left and 5.83±0.82 on right.

The variations in the mean diameters of anteroposterior diameter, transverse foramina on the right and left sides shown in Table-3 in details.

DISCUSSION

In the present study, we found that 14.12% (24) of cervical vertebrae were accessory foramen transversarium, which is very close to the findings of Patra Apurba et al.[10], Akhtar M. J. et al.[11], Ramachandran K et al.[12], Chaudhari et al.[13], and Murugan M et al[16].

Among 170 cervical vertebrae, we observed that 24 (14.12%) with accessory foramen transversarium, of which 16 (9.41%) are typical and 8 (4.71%) are atypical, which is very close to the findings of Chaudhari et al[13]. We observed that 11.76% (20) of cervical vertebrae were U/L accessory foramen transversarium, which is very close to the findings of Kaya et al.[4], Akhtar M.J. et al.[11], and Chaudhari et al[13]. We found that 2.35% (0.4) of the cervical vertebrae were B/L accessory foramen transversarium, which is very close to the findings of Sharma et al[6], Akhtar M. J. et al[11], Yadav Y et al[18], Murlimanju et al.[19] and Patil NP et al[20]. We observed that out of 16 typical cervical vertebrae, 10 (5.88%) were right U/L accessory foramen transversarium, and 3 (1.76%) were left with accessory

Table 1: Distribution of accessory foramen transversarium

Parameters	U/L accessory FT		B/L accessory FT	Total
	Right	Left		
Typical cervical vertebra	10 (5.88%)	3 (1.76%)	3 (1.76%)	16 (9.41%)
Atypical cervical vertebra	4 (2.35%)	3 (1.76%)	1 (0.59%)	8 (4.71%)
Total	14 (8.23%)	6 (3.52%)	4 (2.35%)	24 (14.12%)

FT- Foramen transversarium

foramen transversarium, whereas out of 8 atypical cervical vertebrae, 4 (2.35%) were right U/L accessory foramen transversarium, and 3 (1.76%) were left with accessory foramen transversarium, which matches the findings of Akhtar M. J. et al[11].

In the present study, the maximum anteroposterior diameter of FT was found in C1 vertebrae with a mean value of 6.77±1.01mm on left and 6.63±1.06 mm on the right side. The maximum transverse diameter was also found in C1 vertebrae with a mean value of 5.86±1.03mm on left and 5.83±0.82 on right side. The p value was found to be > 0.05, signifying that there was no effect observed. This implies that there was no statistical difference in the parameters of the FT between the two sides. Though the mean values of transverse and anteroposterior diameters were on a higher on left side, this difference was not found to be statistically significant. These findings are in consistence with the study of Taitz C et al[14], Gupta M [21] and Sangari SK.[22]

Taitz C et al[14] which showed that the maximum breadth was found in C1 vertebrae with mean value of 5.76 mm on left and 5.52 mm on the right side and also found that left FT was generally larger than the right. Another morphometric study of FT showed that anteroposterior diameter of left side had a mean value of 5.26 mm and right side 5.21 mm and the transverse diameter had a mean value of 5.84 mm on left and 5.78 mm on the right side.[21]

In a study on normal cervical vertebrae, FT showed a large variability in diameter in individual vertebrae. The anteroposterior diameter was 5.13 mm on the left side and 5.17 mm on the right, while the transverse diameter was 5.87 mm on the left and 5.69 mm on the right. [22] Jaffar AA et al.[23], was analysed that mean diameter of FT of left and right side showed wide range of variations in individual cervical vertebrae from C1 to C7, but when compared between the two sides, these changes were found to be statistically insignificant.

Table 2: Comparison of studies about incidence of accessory FT by different authors

AuthorsAAA of study)	Year of study	No. of specimen studied	Incidence of accessory FT (in %)
Taitz et al.[14]	1978	480	07%
Das S et al.[7]	2005	132	1.5%
Sharma et al.[6]	2010	200	08%
Kaya et al.[4]	2011	22	22.7%
Laxmi C et al.[15]	2013	210	4.76%
Chaudhari el al.[13]	2013	133	23.15%
Rathnakar P et al.[9]	2013	140	5.7%
Ramachandran K et al.[12]	2014	120	15.8%
Murugan M et al.[16]	2014	150	12.6%
Katikireddi RS et al.[17]	2014	100	03%
Yadav Y et al.[18]	2014	120	6.67%
Akhtar M J et al.[11]	2015	174	14.36%
Patra Apurba et al.[10]	2015	150	22%
Present study	2020	170	14.12%

Limitations of the study

In the beginning of our study, we wanted to incorporate radiological images of cervical spines along with dry cervical vertebrae to make this a comparative study. But, we later on limited our focus only on dry cervical vertebrae as the data was already extensive. Still, we believe that morphometric data of dry cervical vertebrae can be compared with data collected taking similar parameters from radiological images of cervical spine so

Table 3: Comparison of dimensions of foramen transversaria on right and left side in different cervical vertebra (C1-C7)

Vertebra	No.	Diametes (mm)	Right side		Left side		P Value
			Mean±SD	Range	Mean±SD	Range	
C1	18	APD	6.63±1.03	4.70-8.60	6.77±1.01	4.90-8.46	>0.05
		TD	5.83±0.82	4.70-7.50	5.86±1.03	4.05-8.55	
C2	13	APD	5.27±0.86	4.02-7.45	5.47±0.68	4.34-6.95	>0.05
		TD	5.06±0.81	3.80-6.80	5.32±0.83	3.76-7.08	
C3	31	APD	5.04±0.60	3.90-6.50	5.73±0.49	3.99-5.71	>0.05
		TD	6.21±0.93	4.08-7.55	6.34±0.53	5.50-7.65	
C4	31	APD	4.90±0.90	3.30-6.70	5.04±0.84	2.70-6.80	>0.05
		TD	6.01±0.91	4.04-7.90	6.03±0.74	3.80-7.71	
C5	31	APD	5.00±0.92	1.90-6.20	5.28±0.91	2.10-7.22	>0.05
		TD	5.95±1.16	2.40-7.62	6.01±1.01	2.74-7.16	
C6	30	APD	5.20±1.02	2.94-6.96	5.21±1.26	2.26-725	>0.05
		TD	5.66±1.11	2.51-8.02	5.21±1.33	2.52-7.40	
C7	16	APD	4.03±1.40	0.00-6.91	4.11±1.76	0.00-6.76	>0.05
		TD	5.16±1.86	0.00-8.75	5.26±2.04	0.00-8.20	

APD=Anteroposterior diameter, TD=Transverse diameter

that a complete morphometric data is obtained for future references.

CONCLUSION

In the present study, we observed that 24 (14.12%) of the cervical vertebrae were accessory FT, which are more common on the right side of both typical and atypical cervical vertebrae, and also that the incidence of bilateral accessory FT is less common than unilateral accessory FT. Clinicians must be aware of the accessory FT, because its presence can alter the path of vertebral vessels and nerves, resulting in a variety of complications for patients. Understanding the accessary FT and the considerable variation in different cervical vertebrae (C1-C7) in terms of their size, shape, and number of FT are essential for routine spine surgical procedures in the cervical region to avoid post-operative complications. Orthopedic surgeons, neurosurgeons, radiologists, physiotherapists, and many other clinical surgeons must understand the incidence, variation, and clinical importance of the accessory FT to avoid misdiagnosis in their clinical practice. This study is also important for the teaching and acknowledgement of undergraduate and postgraduate students in anatomy as well as in orthopedics departments.

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Authors Contribution:
RR- Concept and design of the study, prepared first draft of manuscript; **MZH-** Interpreted the results; reviewed the literature and manuscript preparation; **SK, VKS-** Concept, coordination statistical analysis and interpretation, preparation of manuscript and revision of the manuscript, **RP-** Help at various steps for study and for preparation of manuscript.

Work attributed to:
Department of Anatomy, Shri Krishna Medical College, Muzaffarpur - 842 004, Bihar, India.

Orcid ID:
Dr. Rakesh Ranjan - https://orcid.org/0000-0002-0156-5623
Dr. Md. Zahid Hussain - https://orcid.org/0000-0002-6085-6551
Dr. Soni Kumari - https://orcid.org/0000-0003-2359-6073
Dr. Vijay Kumar Singh - https://orcid.org/0000-0002-7919-8800
Dr. Rashmi Prasad - https://orcid.org/0000-0001-5881-4822

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