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Anatomy Section

Morphometric Study of Foramen Transversarium in Dried Cervical Vertebrae: A Cross-sectional Osteological Study in Eastern Indian Population

JAYA BANERJEE[1], PANCHALI DATTA[2], KESWARPURAMA RAO[3], SUBHRA MANDAL[4], PINAKI CHATTOPADHYAY[5], SHUBRATA GHOSH[6], SUDESHNA MAJUMDAR[7], PRABIR MANDAL[8]

ABSTRACT

Introduction: The Foramen Transversarium (FT), located in the transverse process of cervical vertebrae, is a key feature for the identification of cervical vertebrae. These foramina vary in size, shape and number, and they may even be absent. Accessory Foramen Transversarium (AFT) may be present due to developmental failure, along with variations in the course of the vertebral artery, which may predispose individuals to neurological symptoms.

Aim: To examine the morphometry of FT and the occurrence of AFT in dried cervical vertebrae.

Materials and Methods: A cross-sectional osteological study was conducted in the Department of Anatomy, Kalinga Institute of Medical Sciences (KIMS), Odisha, India, from January 2013 to August 2014. Five hundred dried human cervical vertebrae from C1 to C7 were studied for the morphometry of FT, considering parameters such as shape, Anteroposterior Diameter (APD), Transverse Diameter (TD) and the presence of accessory foramina. According to their shape, the foramina in the present study were classified into five types (type 1 to type 5) All measurements were taken using vernier callipers. The analysis was conducted using Statistical Package for Social Sciences (SPSS) software version 20.0.

Results: In the present study, type 3, which is the transversely elliptical FT, was the most common type, with 452 out of 1,000 (45.2%), followed by type 4, with 168 out of 1,000 (16.8%). The maximum APD of FT was found in the C1 vertebra, with mean values of 5.86±0.93 mm on the left and 5.83±0.92 mm on the right-side. The maximum TD was found in typical cervical vertebrae, with mean values of 5.37±0.91 mm on the left and 5.35±0.91 mm on the right-side. The incidence of accessory foramina was highest in the C6 vertebrae, with 21 out of 58 (36.2%), and lowest in the C2 vertebra (0%).

Conclusion: The present morphometric study shows a predominance of the transversely elliptical shape of FT. The maximum APD was observed in the C1 vertebra, while the maximum TD was noted in typical cervical vertebrae. The observations regarding the Eastern Indian population may be helpful for neurosurgeons to achieve better surgical outcomes.

Keywords: Accessory foramen transversarium, Morphology, Morphometry, Transverse process of cervical vertebrae

INTRODUCTION

The vertebral column of the human body consists of 33 vertebrae, of which the neck has seven cervical vertebrae. The transverse process of the cervical vertebra is morphologically composite and contains foramina on both sides, referred to as the FT. The FT is formed by the fusion of a vestigial costal element with the body and the true transverse process of the vertebra [1]. The FT in the upper six cervical vertebrae normally transmits the vertebral artery and vein, as well as, a branch from the cervicothoracic ganglion [2]. The first, second and seventh cervical vertebrae exhibit special features and are called atypical vertebrae, while the third, fourth, fifth and sixth cervical vertebrae are almost identical and are known as typical vertebrae. The sixth cervical vertebra, while typical in its general features, can be distinguished by a very prominent and elongated anterior root known as the carotid tubercle [3].

The FT shows variations with respect to shape, size and number. These variations may affect the anatomical course of vital vascular or nervous structures [4]. An accessory foramen, referred to as 'Double FT,' is one such variation. It may be unilateral or bilateral, depending on the course and tortuosity of the vertebral artery, and may be developmental [4]. The accessory foramen is most commonly found in the sixth vertebra and frequently lies in adjacent vertebrae [1]. Although the vertebral artery does not pass through the FT of the seventh cervical vertebra, it almost always contains vascular and nerve structures. The foramen of C7 is usually small and may even be absent [5].

Any variation in the FT may affect the structures passing through it and lead to neurological symptoms due to vertebrobasilar insufficiency [6]. Vertebral artery loop formation is one of the important causes of cervical radiculopathy [7]. An abnormal loop of the vertebral artery might compress both the cervicomedullary junction, as well as, the accessory nerve, which has been reported in the past [8]. Prior knowledge of such variations is important for neurosurgeons, orthopaedic surgeons and trauma surgeons during posterior cervical surgery on the upper cervical spine (occiput to C3), such as intralaminar screw or translaminar screw fixation. This information is also useful for radiologists during Computed Tomography (CT) and Magnetic Resonance Imaging (MRI) scans, aiding in the correct interpretation of variations in the foramina transversaria in radiography or computerised axial tomography [9].

In this context, the present study was aimed to investigate the morphometry of the FT in the Eastern Indian population. Additionally, the frequency of occurrence of accessory FT was also explored. While studies have been conducted in various parts of the world, including China, Japan, Thailand, Chile, South Africa, Spain, and both North and South Indian populations, no such study has been conducted in Eastern Indian populations, so far.

MATERIALS AND METHODS

A cross-sectional osteological study was conducted in the Department of Anatomy, KIMS, Odisha, India, from January 2013 to August 2014, after obtaining KIMS Ethics Committee approval (vide memo no. 768 dt 27-10-2012).

Inclusion criteria: A total of 500 cervical vertebrae are included in the study.

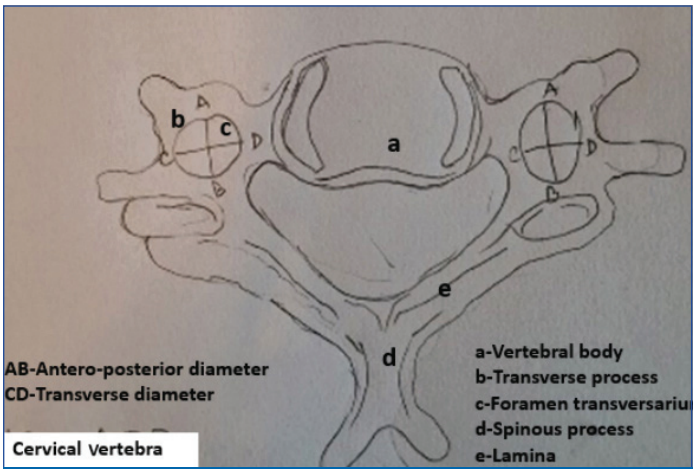
Exclusion criteria: Twelve damaged cervical vertebrae were excluded, and finally, five hundred (500) cervical vertebrae were included in the study.

Study Procedure

All the cervical vertebrae from C1 to C7 were studied, considering parameters such as shape, APD, TD and the presence of accessory foramina on both sides. According to their shape, the foramina in the present study were classified in accordance with the study conducted by Taitz C et al., into five types: Type 1- Round; type 2- Elliptical with the main diameter (length) anteroposterior; type 3- Elliptical with the main diameter transverse (breadth); type 4- Elliptical with the main diameter oblique from right to left; type 5- Elliptical with the main diameter oblique from left to right [10].

Tools used and procedure followed in the study: In the present study, 'M' type stainless steel vernier callipers with an accuracy of 0.01 mm were used to measure the Anteroposterior (APD) and Transverse (internal) Diameters (TD) of the foramina on both sides of all cervical vertebrae [Table/Fig-1,2]. In vertebrae with accessory foramina, the larger foramen was identified as the main foramen, while the smaller one was designated as the accessory foramen.

[Table/Fig-1]: Measurement taken by vernier callipers.



[Table/Fig-2]: Schematic diagram showing the measurements of the Foramen Transversarium (FT).

As the first step, after identifying the vertebrae, they were tied together with wire passing through the transverse foramina from cervical vertebra C7 to cervical vertebra C1 in a serial manner, and any missing numbers were noted to complete one set.

For each complete or incomplete vertebra set, the measurements of the internal diameter of the foramina were recorded. All measurements were taken by the same observer and with the same instruments to avoid any technical or interobserver bias and to maintain reproducibility. Each measurement was taken three times to reduce intraobserver bias, and the mean value was noted for estimating the diameters.

STATISTICAL ANALYSIS

The collected data was compiled in Microsoft (MS) Excel and codified for analysis. The data was summarised by estimating the mean and Standard Deviation (SD) for continuous variables, and percentages for categorical variables. The statistical test, such as the independent t-test for continuous variables, was used to draw inferences between the Independent Variable (IV) and the Dependent Variable (DV). Data analysis was conducted using SPSS software version 20.0. A statistical p-value of <0.05 was considered significant.

RESULTS

Among the 500 cervical vertebrae studied, 80 belonged to C1, 66 were C2, 269 were typical (C3, C4, C5, C6), and 85 were C7 vertebrae. Although C6 is considered a typical vertebra, it is examined separately due to its distinguished carotid tubercle.

Type 1 shows a notable presence in C2 and C6, with the highest counts in C6 (79.3% on the left) and a total of 165 occurrences, making up 16.5% of all foramina. Type 5 is notably present in C7 (58.8% on the right-side), totaling 153 occurrences, which constitutes 15.3% of the total [Table/Fig-3,4].

There was no significant difference between the mean APD and TD of the foramina on the two sides in C1 and the typical vertebrae C3, C4, and C5. The mean APD of the foramina in C2 is significantly greater on the left-side. The TD and APD of the foramina in C6 vertebrae are significantly greater on the left-side compared to the right-side. Although C6 cervical vertebrae are considered typical, they can be distinguished by the presence of the carotid tubercle; therefore, they are examined separately. In C7 vertebrae, the APD of the foramina is significantly greater on the right-side, while the TD is greater on the left-side [Table/Fig-5].

The incidence of accessory foramina was highest in C6 vertebrae (36.2%), followed by C7 (18.82%), and lowest in C2 (0%) [Table/Fig-6,7].

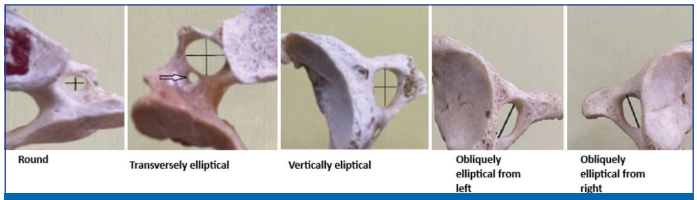
DISCUSSION

Many factors are involved in causing morphological variations of the FT, including developmental factors, mechanical stress, size and the number of anatomical structures passing through it [11]. In almost 90% of cervical vertebrae, the vertebral artery enters the FT of C6; however, it may also enter the cervical vertebral column through C1 (15%), C4 (2%), C5 (5%), or C7 (2%) [12]. The accessory foramen is likely associated with anatomical variants of the vertebral artery, which may include duplication or fenestration, and may be unilateral or bilateral depending on the course of the vertebral artery. Radiological studies have confirmed that when there is an absence of FT in such cases, the vertebral artery bypasses the vertebra [13]. Therefore, knowledge of the surgical anatomy of the FT, as well as, the presence of accessory FT, is useful for the preoperative evaluation by spine surgeons and radiologists when performing CT and MRI scans [14].

In the Japanese population, type 3 was seen as predominant, while the Chilean population showed a predominance of type 1. Two South African studies showed a predominance of both types 1 and

Type of foramen shape		C1		C2		C3, C4, C5		C6		C7		Total
		Right	Left	Right	Left	Right	Left	Right	Left	Right	Left	
Type 1		4 (5%)	5 (6.25%)	30 (45.45%)	27 (40.9%)	8 (3.8%)	14 (6.6%)	18 (31.0%)	46 (79.3%)	8 (9.4%)	5 (5.9%)	165 (16.5%)
Type 2		29 (36.25%)	28 (35%)	0	0	0	1 (0.5%)	1 (1.7%)	3 (5.2%)	0 (0%)	0	62 (6.2%)
Type 3		4 (5%)	0	0	0	203 (96.2%)	195 (92.4%)	37 (63.8%)	8 (13.8%)	4 (4.7%)	1 (1.2%)	452 (45.2%)
Type 4		36 (45%)	25 (31.25%)	19 (28.8%)	21 (31.8%)	0	0	0	0	23 (27.1%)	44 (51.7%)	168 (16.8%)
Type 5		7 (8.75%)	22 (27.5%)	17 (25.75%)	18 (27.3%)	0	1 (0.5 %)	2 (3.5%)	1 (1.7%)	50 (58.8%)	35 (41.2%)	153 (15.3%)
Total		80 (100%)	80 (100%)	66 (100%)	66 (100%)	211 (100%)	211 (100%)	58 (100%)	58 (100%)	85 (100%)	85 (100%)	1000 (100%)

[Table/Fig-3]: Morphology of Foramen Transversarium (FT) in cervical vertebrae (n=1000).
*Table adopted from study by Taitz C et al., [10]



[Table/Fig-4]: Shape of Foramen Transversarium (FT).

Vertebrae		Diameter (mm)	Side (Right) (Mean±SD)	Side (Left) (Mean±SD)	Student t-test p-value
C1 (n=80)		APD*	5.83±0.92	5.86±0.93	0.81
		TD*	4.86±1.16	4.57±1.08	0.11
C2 (n=66)		APD	4.48±0.97	4.48±1.06	0.047+
		TD	3.92±0.71	3.77±0.72	0.76
C3, C4, C5 (n=211)	Typical	APD	4.36±0.76	4.54±0.81	0.15
		TD	5.35±0.90	5.37±0.91	0.81
C6 (n=58)		APD	4.47±1.27	5.07±1.12	0.005+
		TD	5.14±1.27	5.14±1.16	0.04+
C7 (n=85)		APD	4.07±1.15	3.81±1.28	0.016+
		TD	4.74±1.14	4.8±1.38	0.000021+

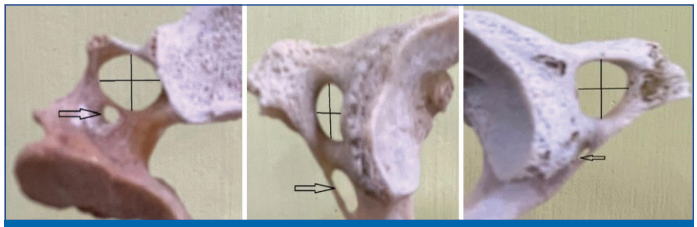
[Table/Fig-5]: Mean APD (length) and TD (breadth) of FT of both sides of cervical vertebrae (N=1000).
*APD: Anteroposterior diameter; *TD: Transverse diameter; +The p-value <0.05 was considered statistically significant

Cervical vertebrae	Total, n	Vertebra with unilateral Acc FT, n	Vertebra with bilateral Acc FT, n	Percentage of different cervical vertebrae having Acc FT, n (%)
C1	80	3	4	7 (8.75%)
C2	66	0	0	0 (0%)
C3, C4, C5	211	9	6	15 (7.10%)
C6	58	14	7	21 (36.20%)
C7	85	7	9	16 (18.82%)
Total	500	33	26	59 (11.8%)

[Table/Fig-6]: Incidence of accessory FT in cervical vertebrae (n=500).
Acc: Accessory

2. In contrast, an Indian study showed a predominance of types 1 and 4, which differs from the present study [Table/Fig-8] [15-22].

The mean APD and TD of the FT of cervical vertebrae were measured from C1 to C7. Taitz C et al., observed that the left FT was generally larger than the right one, which corroborates, to some extent, with the present study [10]. Additionally, Taitz C et al., reported that the mean values for the left FT from C3 to C7 levels were higher than



[Table/Fig-7]: Accessory Foramen Transversarium (FT).

those for the right, with the FT of C1 showing the highest mean values, whereas the FT of C7 showed the lowest mean values. This finding is also similar to the results of the present study. Sangari SK et al., showed a wide range of variation in the mean diameter of the FT on the left and right-sides in individual cervical vertebrae from C1 to C7, but these changes were found to be statistically insignificant [23]. Jaffar A et al., studied the area of the FT and found that the maximum area of the FT was seen in the C1 vertebrae, with mean values of 31.8 mm^2 on the left and 32.9 mm^2 on the right-side [24]. The distortion of the vertebral artery and its largest caliber at the level of C1 vertebrae could be considered a mechanical factor responsible for the maximum area of the FT in C1 vertebrae.

In the present study, the prevalence of accessory FT was 11.8%, which is close to the findings of Mehta G and Mokhasi V, (15%) and Akhtar MJ et al., (14.36%), both of which are Indian studies [21,25]. The incidence of accessory FT was highest in C6 vertebrae (36.2%), followed by C7 (18.82%) and C1 (8.75%). Various studies indicating the percentage of cervical vertebrae with accessory FT in different populations have been presented in [Table/Fig-9] [4,10,16,18,21,25-28].

The FT allows the vertebral artery, sympathetic plexus and nerve to pass through it; therefore, any deviation from the normal size and pattern of the foramen may cause clinical symptoms such as tinnitus, vertigo, and even hearing loss. The anthropometric knowledge gained from the present study will complement the existing anatomical knowledge. Further studies on the pattern of the vertebral artery should be pursued in the future. Additionally, radiological correlation in patients presenting with neck symptoms due to morphometric variations of cervical vertebrae may be stimulated by the findings of the present study in the near future.

Limitation(s)

The unknown age and sex of the bony specimens examined in the present study limited the range of observations made. The vertebrae were collected randomly from different skeletons obtained from various medical colleges in Odisha. The authors plan was to

Author and year of the study	Study population	Vertebrae included	Number of specimen	Total number of FT	Type of shape of FT	Total number & Percentage on right-side	Total number and Percentage on left-side	Total percentage	Predominant type
Kimura K et al., (1985) [15]	Japanese	C1-C7	700	1400	1 2 3 4 5	152 (10.85%) 41 (2.92%) 265 (18.9%) 180 (12.85%) 170 (12,14%)	170 (12,14%) 38 (2,71%) 212 (15.14%) 159 (11.35%) 194 (13.85%)	22.99 5.63 28.04 24.2 25.99	Type 3
Karau PB and Odula P (2013) [16]	South African (Kenya)	C1	102	204	1 2 3 4 5	10 (4.9%) 30 (14.7 %) 5 (2.45%) 41 (20.09%) 16 (7.84%)	12 (5.88%) 40 (19.6%) 2 (0.98%) 8 (3.92%) 40 (19.6%)	10.78 34.3 3.43 24.01 27.44	Type 2
Ambali MP and Jadhav SD (2017) [17]	Indian	C3-C6	163	326	1 2 3 4 5 Others	33 (10.12%) 14 (4.29%) 10 (3.06%) 35 (10.73%) 32 (9.81%) 39 (11.96%)	37 (11.34%) 15 (4.6%) 9 (2.76%) 38 (11.65%) 31 (9.5%) 33 (10.12%)	21.46 8.89 5.82 22.38 19.31 22.08	Type 4
Guerra MM (2017) [18]	Chilean	C3-C7	121	242	1 2 3 4 5	NA (90.08% same shape bilaterally,9.91% is of different shape)		41.3 4.1 18.8 14 12.3	Type 1
Vasuki AKM et al., (2018) [19]	South Indian	C1-C7	125	250	1 2 3 4 5	55 (22%) 2 (0.8%) 30 (12%) 16 (6.4%) 20 (8.0%)	54 (21.6%) 4 (1.6%) 27 (10.8%) 21 (8.4%) 18 (7.2%)	43.6 2.4 22.8 14.8 15.2	Type 1
Abdul RS et al., (2018) [20]	South African Kwazulu-natal	C1-C7	126	252	A B C D E	26.19 3.97 9.52 15.87 8.73	29.37 1.59 12.70 8.73 14.29	55.56 5.56 22.22 4.6 23.02	Type 1
Mehta G and Mokhasi V (2021) [21]	South Indian	C1-C7	750	1500	I II III IV V	144 (9.6%) 71 (4.73%) 171 (11.4%) 288 (19.2%) 76 (5.06%)	141 (9.4%) 68 (4.53%) 165 (11%) 85 (5.66%) 291 (19.4%)	18.98 10.26 22.98 24.86 24.46	Type 4
Patra A et al., (2021) [22]	North Indian	C3-C7	200	400	1 2 3 4 5	54 (13.5%) 35 (9.5%) 41 (10.25%) 39 (9.75%) 31 (7.75%)	38 (9.5%) 39 (9.75%) 36 (9%) 55 (13.75%) 32 (%)	23.35 18.78 19.54 23.85 15.75	Type 4
Present study (2024)	Eastern Indian	C1-C7	500	1000	1 2 3 4 5	68 (6.8%) 30 (3%) 248 (24.8%) 78 (7.8%) 76 (7.6%)	97 (9.7%) 32 (3.2%) 204 (20.4%) 90 (9 %) 77 (7.7%)	16.5 6.2 45.2 16.8 15.3	Type 3

[Table/Fig-8]: Comparison of different studies regarding variations in shape (morphology) of FT in cervical vertebrae [15-22].

Name of authors with year of study	Total number of Cervical Vertebrae (CV) studied	Number of CV with accessory FT	Incidence of accessory FT (Percentage)	Population
Taitz C et al., (1978) [10]	480	34	7.8	Indian
Kaya S et al., (2011) [4]	22	5	22.7	Jewish
Karau PB and Odula P, (2013) [16]	102	4	3.9	Kenya
Akhtar MJ et al., (2015) [25]	174	25	14.36	Indian
Guerra MM et al., (2017) [18]	121	21	17.35	Chilean
Mehta G and Mokhasi V, (2021) [21]	750	113	15	South Indian
Medeiros PM et al., (2021) [26]	165	36	21.82	North Eastern Brazil
Yalçın A et al., (2023) [27]	125	22	17.6	Eastern Turkey
Kaur S et al., (2023) [28]	100	22	22	North Indian
Present study (2024)	500	59	11.8	Eastern Indian

[Table/Fig-9]: Comparison of various studies showing the incidence of accessory FT in cervical vertebrae in different races [4,10,16,18,21,25-28].

include cervical vertebrae from intact vertebral columns to research exclusively the variations in foramina transversaria and the presence of accessory foramina transversaria.

CONCLUSION(S)

The morphometry of the FT in cervical vertebrae in the Eastern Indian population shows a predominance of type 3, followed by type 4. The present study recommends increasing awareness regarding variations in the morphometry of the FT, which will help neurosurgeons and spine surgeons with better preoperative planning for cervical spine surgery, thereby avoiding catastrophic intraoperative complications. Nevertheless, a multidisciplinary study could be conducted in which physiatrists, radiologists and anatomists work collaboratively to research the morphometric variations of cervical vertebrae in patients with neck symptoms attending the physical medicine and rehabilitation Outpatient Department (OPD).

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PARTICULARS OF CONTRIBUTORS:
1. Assistant Professor, Department of Anatomy, Prafulla Chandra Sen Government Medical College and Hospital, Arambagh, West Bengal, India.
2. Assistant Professor, Department of Anatomy, NRSMC and Hospital, Kolkata, West Bengal, India.
3. Professor, Department of Anatomy, KIMS, Bhubaneshwar, Odisha, India.
4. Professor, Department of Anatomy, NRSMC and Hospital, Kolkata, West Bengal, India.
5. Associate Professor, Department of Microbiology, Midnapore Government Medical College and Hospital, Midnapore, West Bengal, India.
6. Professor, Department of Anatomy, KIMS, Bhubaneshwar, Odisha, India.
7. Professor, Department of Anatomy, NRSMC and Hospital, Kolkata, West Bengal, India.
8. Medical Officer In-charge, Department of Physical Medicine and Rehabilitation (PMR), MR Bangur Superspeciality Hospital, Kolkata, West Bengal, India.

NAME, ADDRESS, E-MAIL ID OF THE CORRESPONDING AUTHOR:
Subhra Mandal,
Flat 5B, Shishir Apartment, 122 A Lake Gardens, Kol-45, Kolkata-700045, West, India.
E-mail: mandalsubhra67@gmail.com

PLAGIARISM CHECKING METHODS: [Jain H et al.]
- Plagiarism X-checker: Sep 25, 2024
- Manual Googling: Dec 24, 2024
- iThenticate Software: Dec 31, 2024 (21%)

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- Financial or Other Competing Interests: None
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- Was informed consent obtained from the subjects involved in the study? No
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