Original Article

DOI: 10.7860/JCDR/2023/63927.18035

Anatomy Section

Morphological and Morphometric Variations in Foramen Transversarium: A Cross-sectional Study in Dried Cervical Vertebrae of Western Odisha Origin

SARITA BEHERA[1], MAMATA SAR[2], SRIKANTA KUMAR MISHRA[3]

ABSTRACT

Introduction: Foramen transversarium refers to bilateral foramina found lateral to the vertebral body in the transverse process of the cervical vertebrae. Many variations are observed in these foramina which may lead to vertebrobasilar insufficiency, labyrinthine or hearing disturbances along with neurological symptoms due to compression or tortuosity of vertebral artery as it passes through the foramen.

Aim: To study the morphological and morphometric variations of the foramen transversarium in cervical vertebrae.

Materials and Methods: This cross-sectional study was conducted in Department of Anatomy, Veer Surendra Sai Institute of Medical Sciences and Research, Burla, Odisha, India, from June 2022 to August 2022. A total of 367 human cervical vertebrae were procured from the anthropology section of Department of Anatomy. Vertebrae with any damage to foramen transversarium were discarded. Each vertebra was observed for shape, size, symmetry, number of foramen transversarium and osteophytic encroachment. Distance of foramen transversarium from the medial margin of uncinate process was measured bilaterally in C3 to C7 vertebrae. Data collected was tabulated and analysed by Microsoft excel software 2019.

Results: Mean anteroposterior diameter and transverse diameter in left-side were 5.45 mm and 5.42 mm respectively and in right-side the measurements were 5.29 mm and 5.23 mm respectively. Double foramen transversarium was observed in 40 (10.9%) vertebrae. Among them 18 (4.9%) was bilateral and 22 (6.0%) was unilateral. In 2 (0.54%) vertebrae there was triplication of foramen transversarium. In 34 vertebrae (9.26%) there was incomplete duplication of which 9 (2.45%) were bilateral and 25 (6.81%) were unilateral. Six different shapes of foramen transversarium were observed out of which round shape (62.1%) was the most common finding. In 261 (71.1%) of vertebrae the main foramen transversarium was symmetrical in both sides but in 106 (28.9%) it was asymmetrical. Osteophytic encroachment was found in 14 (3.81%) vertebrae. The mean distance of the foramen from medial margin of uncinate process was 5.32 mm on the left and 5.42 mm on the right-side.

Conclusion: The morphological data like very narrow foramina and such a high number of accessory foramina produced through the present study definitely points towards the variations of vertebral vessels.

Keywords: Foramina, Morphometry, Osteophyte, Spine, Vertebrobasilar

INTRODUCTION

Foramen transversarium refers to bilateral foramina found lateral to the vertebral body in the transverse process of the cervical vertebrae. It is ventrally by ventral bar and dorsally by dorsal bar. Each of the bars end in a tubercle laterally which are connected by intertubercular or costal lamella that forms the lateral boundary of the foramen. Developmentally, it is formed between vestigeal costal element anteriorly and true transverse process posteriorly [1].

These foramina are found only in cervical vertebrae and serve as a good way to identify them. Vertebral artery, vertebral vein and sympathetic plexus arising from inferior cervical ganglion pass through these foramina. Vertebral vein passes through all the seven foramina transversaria whereas the vertebral artery does not pass through the foramen transversarium of the seventh cervical vertebra as it mostly enters at the 6th cervical vertebra level for its vertebral course. Ideally, each cervical vertebra should have two foramen transversaria. But many variations are observed in these foramina. Congenital absence of the transverse foramen and osteophyte formation are reported to be one of the causative factors for vertebrobasilar insufficiency caused by rotation of the head. Vertebrobasilar insufficiency is characterised by headache, migraine and fainting attack. Also, inner labyrinthine or hearing disturbances along with neurological symptoms [2,3].

It has been reported that vertebral vessels are responsible for formation of foramen transversarium. So variations in the course of the vertebral vessels may be one of the causative factors for variations in foramen transversarium. It is also noted that tortousity of vertebral artery may cause bone erosion or obstruct the complete formation of the foramen transversarium [4]. Now-a-days transpedicular screw fixation of cervical spine is preferred surgery for instability due to trauma, tuberculosis, neoplasia or degenerative conditions and screw is placed just medial to foramen transversarium, so the vertebral artery is at risk of injury [5].

As per literature, most of the earlier studies have focused either on morphology or morphometry of foramen transversarium in different populations [6-10]. Study by Nayak G et al., which included the bones of eastern part of Odisha also describes only about the incidence of accessory foramen transversarium [11], they have not studied the morphometric details. Hence, the present study was undertaken to study both the morphological and morphometric variations of foramen transversarium in dry bones of western Odisha population in a comprehensive way, which will definitely be helpful for the neuro and orthopaedic surgeons and the radiologists of this part of India to increase the effectiveness of the surgical and diagnostic procedures and decrease the complications related to injury of vertebral artery.

MATERIALS AND METHODS

This cross-sectional study was conducted from June 2022 to August 2022 in Department of Anatomy, Veer Surendra Sai Institute of Medical Sciences and Research, Burla, Odisha, India. Study was commenced after obtaining approval from the Institutional Ethics Committee (IEC) (IEC no 009-2022/I-F-O/43/Dt.17-05-2022).

Inclusion criteria: Both typical and atypical cervical vertebrae were included in the study.

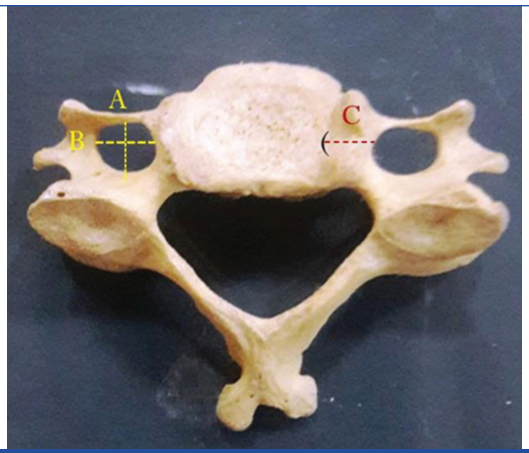
Exclusion criteria: Vertebrae with damaged foramen transversarium were excluded from the study.

Data collection: A total of 367 human cervical vertebrae of unknown age and sex, were procured from the anthropology section of Department of Anatomy, VIMSAR, Burla. Each vertebra was observed for shape, size, symmetry, osteophytic encroachment and number of foramen transversarium. In vertebrae having accessory foramen transversarium the larger foramen was taken as the main foramen and smaller one as accessory foramen.

The shapes of the foramina were classified into six categories using the criteria by Ambali MP and Jadhav SD with little modifications [12].

- Type-1 round,
- Type-2 elliptical with main diameter (length) anteroposterior,
- Type-3 elliptical with main diameter transverse (breadth),
- Type-4 elliptical with main diameter oblique, from right to left,
- Type-5 elliptical with main diameter oblique from left to right,
- Type-6 as irregular.

The widest anteroposterior and transverse diameters of main transverse foramina taken on the inner side were measured bilaterally using digital Vernier caliper [Table/Fig-1]. In C3-C7 vertebrae distance of medial margin of foramen transversarium from the medial margin of uncinate process was measured.



[Table/Fig-1]: Typical cervical vertebra showing measurements of the transverse foramen.
A: anteroposterior diameter, B: transverse diameter, C: distance from the medial margin of the uncinate process to the medial margin of the transverse foramen.

STATISTICAL ANALYSIS

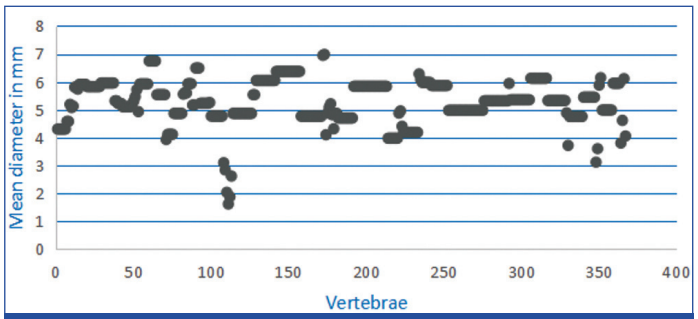
Data collected was tabulated and analysed by Microsoft excel software 2019. The range, mean and standard deviation of all the measurements like anteroposterior diameter, transverse diameter, mean diameter and distance of medial margin of the foramen transversarium from the uncinate process were calculated. The scatter chart for the mean diameters of foramen transversarium of the right and left-side was plotted.

RESULTS

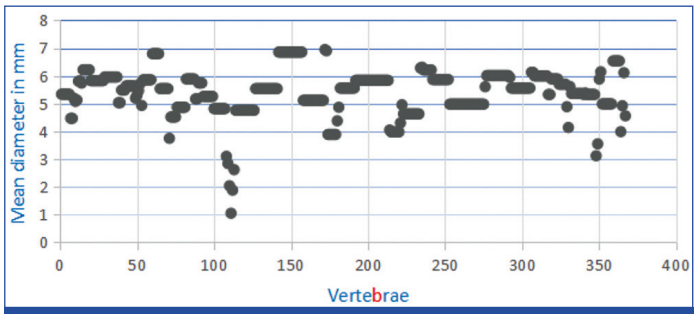
Mean anteroposterior diameter and transverse diameter in left-side were 5.45±0.81 mm and 5.42±0.79 mm, respectively and in right-side the measurements were 5.29±0.81 mm and 5.23±0.75 mm, respectively. The mean distance of the medial margin of the foramen from the uncinate process was 5.32±1.18 mm on the left and 5.42±1.33 mm on the right-side [Table/Fig-2]. Mean diameter of transverse foramen of individual vertebra showed wide range of variation ranging from 1.17-6.95 mm in the right-side and 1.05-6.95 mm in left-side [Table/Fig-3,4].

Dimension		Range (mm)	Mean±SD (mm)
Transverse diameter	Right	1.34-6.78	5.23±0.75
	Left	1.10-6.86	5.42±0.79
Anteroposterior diameter	Right	1.86-7.30	5.29±0.81
	Left	1.0-7.14	5.45±0.81
Mean diameter	Right	1.17-6.95	5.29±0.77
	Left	1.05-6.95	5.42±0.79
Distance of medial border of uncinate process-transverse foramen in C3-C6 vertebrae	Right	3.51-7.66	5.42±1.33
	Left	3.21-7.54	5.32±1.18

[Table/Fig-2]: Dimensions of foramen transversarium.



[Table/Fig-3]: Mean diameter of right foramen transversarium.



[Table/Fig-4]: Mean diameter of left foramen transversarium.

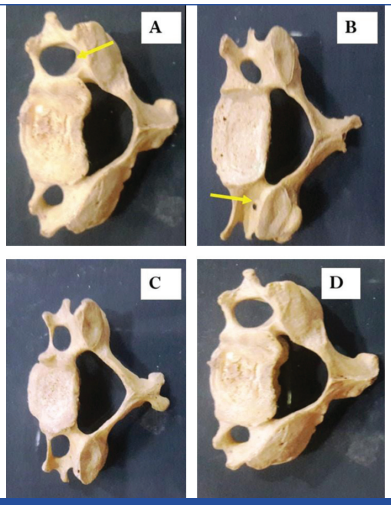
Double foramen transversarium were observed in 40 (10.9%) vertebrae. Among these 18 (4.9%) was bilateral and 22 (6.0%) was unilateral. In 2 (0.54%) vertebrae there was triplication of foramen transversarium. In 261 (71.1%) of vertebrae the foramen transversarium was symmetrical in both sides but in 106 (28.9%) it was asymmetrical. In 34 vertebrae (9.26%) there was incomplete duplication out of which 9 (2.45%) was bilateral and 25 (6.81%) was unilateral. Osteophytic encroachment was found in 14 (3.81%) vertebrae [Table/Fig-5-7]. Six different shapes of foramen transversarium were observed. Type-1 or round shape was the most common finding bilaterally [Table/Fig-8,9].

Type of variation	Number and percentage of vertebrae with the variation (%)
Double foramen transversarium	40 (10.9)
Triple foramen transversarium	2 (0.54)
Incomplete duplication	34 (9.26)
Asymmetric foramen transversarium in both sides	106 (28.9)
Osteophytic encroachment	14 (3.81)

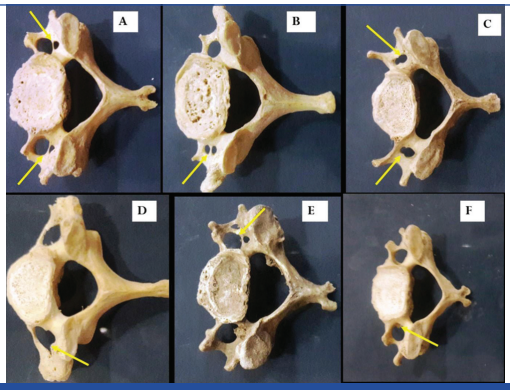
[Table/Fig-5]: Variations of foramen transversarium.

DISCUSSION

Anatomically foramen transversarium has been described to be divided by fibrous or bony ridge, separating artery and vein, the smaller posterior part that encloses a branch of vertebral nerve and



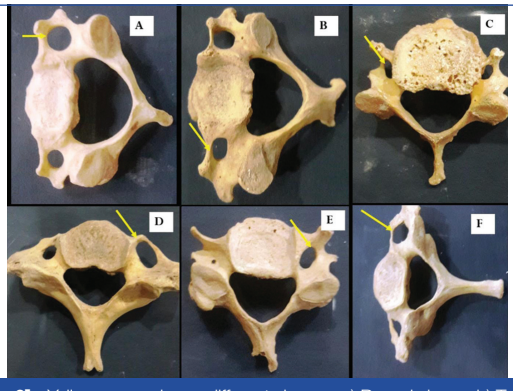
[Table/Fig-6]: a) Yellow arrow shows the largest diameter; b) Yellow arrow shows the smallest diameter; c) Shows symmetry of the foramen transversarium on both sides; d) Shows right and left foramen transversarium are asymmetrical.



[Table/Fig-7]: a) Yellow arrows show bilateral duplication of foramen transversarium; b) Yellow arrows show unilateral duplication; c) Yellow arrow shows bilateral incomplete duplication; d) Yellow arrow shows unilateral incomplete duplication; e) Yellow arrow shows triplication; f) Yellow arrow shows osteophytic encroachment.

Type of foramen	Shape	Right n=367	Left n=367	Total	Percentage (%) n=734
Type-1 (round)		220	236	456	62.1
Type-2 (Anteroposteriorly elliptical)		64	50	114	15.5
Type-3 (Transversely elliptical)		24	28	52	7.1
Type-4 (Elliptical and tilted to left)		13	11	24	3.3
Type-5 (Elliptical and tilted to right)		20	18	38	5.2
Type-6 (irregular)		26	24	50	6.8

[Table/Fig-8]: Shapes of main foramen transversarium.



[Table/Fig-9]: Yellow arrow shows different shapes: a) Round shape; b) Transversely elliptical; c) Anteroposteriorly elliptical; d) Anteroposteriorly elliptical and tilted to left; e) Anteroposteriorly elliptical and tilted to right; f) Irregular.

vein is called accessory foramen transversarium. Separate area in the form of complete accessory foramen transversarium for vertebral vein and nerve offers limited space. Any irritation or inflammation of nerve causes pressure effect on nerve and vein as well. Such duplication of foramen transversarium or accessory foramen transversarium may be suggestive of duplication of vertebral artery or separate area for vertebral vein and nerve. Awareness of such variation and its incidence is clinically important for spine surgeons to prevent intraoperative complications by damaging vertebral artery and vein [4].

Duplication of foramen transversarium may be associated with developmental anomalies of vertebral artery, such as duplication and fenestration or due to abnormality during formation of vertebra itself. Vertebral arteries are formed by fusion of the longitudinal anastomosis, connecting the cervical intersegmental arteries. The intersegmental arteries regress during the embryonal development except the 7th intersegmental artery, which forms the proximal portion of the subclavian artery and initial part of the vertebral artery. Persistence of a portion of primitive dorsal aorta with two intersegmental arteries results in duplication of vertebral artery. This may lead to accessory foramen transversarium [2].

Accessory vertebral arteries if present may potentially be protective against ischaemic attacks to the brain by providing collateral blood flow to the basilar artery. However, fenestrated vertebral arteries have been demonstrated histologically to be weak with irregular elastic fibres in the vessel wall. There may be a higher risk of thrombus development and embolisation leading to a severe transient ischaemic attack in people with fenestrated or duplicated vertebral arteries. [13].

During development of vertebra, double rib bone element may fuse to the original transverse process resulting in unusual number of foramen transversarium [12]. Study by Gupta M and Agarwal S on 319 foramen transversarium of 161 cervical vertebrae at Lady Hardinge Medical College, Delhi in 2019 found accessory foramen transversarium in 26.09% where majority were at C6 level and nil at C1 and C2 level [14]. Similar report was made by Patil NP et al., by their study on 175 cervical vertebrae at Ambjogai, Maharashtra in 2014 that the accessory foramen transversarium was more common in lower cervical vertebrae [15]. Present study found it to be 54.7% in C6 and nil in C1 and C2.

Vasuki AKM et al., in their study on 300 cervical vertebrae at Coimbatore in 2018 found triple foramen in right-side in one (0.003%) vertebra [4]. In the present study, in two (0.54%) vertebrae there was triplication of foramen transversarium.

Anatomical variations in the vertebral artery, embryological factors and functional conditions may play an important role in the formation of incomplete transverse foramen. It was noted that the tortousity of vertebral artery may cause bony erosion or obstruct the complete formation of foramen transversarium [4,16]. Vasuki AKM et al., found unilateral incomplete duplication in 3% and bilateral incomplete duplication in 2% out of 125 vertebrae showing variation [4]. Shah ST et al., in their study on 210 vertebrae at Gujarat in 2014 found unilateral incomplete duplication in 3.8% [6]. In the present study, in 34 vertebrae (9.26%) there was incomplete duplication out of which 9 (2.45%) was bilateral and 25 (6.81%) was unilateral.

Size of transverse foramen is directly proportional to the calibre of vertebral artery. Size of transverse foramen carries clinical significance as vertebrobasilar insufficiency may be seen in case of narrowing of foramen transversarium. During the development of bone, new layers are added to the pre-existing surfaces. Reduced foramen area of some cervical vertebrae may be attributed to periosteal growth at foramen margins to fit around their neurovascular and other contents [4].

Bow hunter's stroke is a symptomatic vertebrobasilar insufficiency caused by stenosis or occlusion of the vertebral artery with head rotation [7]. Ambali MP and Jadhav SD in their study on 163 cervical

vertebrae at Maharashtra in 2016 observed the average diameter of the foramen transversarium on the right-side to be 5.46 mm and on the left to be 5.80 mm [12]. In present study, the largest diameter was 7.30 mm and smallest was 1 mm. Previous studies had shown that the two vertebral arteries are not equal in size in 75% of people and of these,10% have quite narrow vertebral arteries in right-side [7]. Agrawal D et al., conducted a study on 160 cervical vertebrae of eastern Odisha origin in 2012 and reported asymmetrical foramen transversarium only in one specimen in typical vertebrae [17]. Ambali MP and Jadhav SD observed symmetrical foramen transversarium in 91 (55.82%) out of 163 vertebrae [12]. In the present study asymmetrical foramen transversarium were found in 106 out of 367 vertebrae (28.9%).

As per literature, as osteophytes are more common along the medial or lateral margins of the foramen transversarium reducing the transverse diameter, type 2 where the main diameter is along the anteroposterior direction is most likely to be involved in compression of the vertebral artery whereas type 3 where main diameter is along the transverse axis is at minimal risk [18,19]. Ambali MP and Jadhav SD found seven different shapes of foramen transversarium. Out of them oval and tilted to right was the commonest shape (44.78%) [12]. Vasuki AKM et al., found five different shapes out of which Type-1 or round shape was the most frequent (43.6%) [4]. Patra A et al., in their study on 200 cervical vertebrae of south central Asian cadavers in 2022 observed type 1 or round shape (27.13%) to be the most common in right-side and type-4 or elliptical with main diameter from right to left (27.63) in left-side [18]. In present study, six different shapes were observed and round shape was the most common (62.1%) in both sides. Most of the studies describe unilateral accessory foramen to be more common than bilateral which was consistent with present study [Table/Fig-10] [2,4,6-12,20-26].

Ambali MP and Jadhav SD found bony spicules in 12 (7.36%) out of 163 vertebrae [12]. Sangari SK et al., observed osteophytic encroachment in 21.3% of vertebrae studied [7]. Patra A et al., observed osteophytes in 21.3% [18]. In present study, authors observed osteophytic encroachment in 14 (3.81%) out of 367 vertebrae. The osteophytes encroaching the transverse foramina are potential sites of trauma to the vertebral artery which may also compress it resulting in its narrowing leading to vertebrobasilar insufficiency.

To avoid vertebral artery injury during anterior cervical disc surgery, the medial margin of the uncovertebral joint may be the safe landmark. The distance of foramen transversarium from uncinate process found in the present study which was consistent with findings of previous studies [Table/Fig-11] [7,14,16,18,23]. The risk of vertebral artery laceration may be increased, especially when osteophytes are removed from uncinate process by lateral decompression. So it is better to perform this procedure under direct visualisation with opening of the anterior walls of the transverse foramen and retracting the vertebral artery laterally [7].

Authors	Publication year	Study population	Type of cervical vertebrae studied	Number of vertebrae studied	Incidence of accessory foramen transversarium (%)	Unilateral accessory foramen transversarium (%)	Bilateral accessory foramen transversarium (%)
Kaya S et al., [2]	2011	Ancient Byzanthine	Typical and atypical	22	22.7	13.6	9.1
Murlimanju BV et al., [20]	2011	Indian (Mangalore)	Typical and atypical	363	1.6	1.4	0.3
Ratnakar P et al., [21]	2013	Indian (Mangalore)	Typical and atypical	140	5.7	3.6	1.42
Chandravadiya L et al., [22]	2013	Indian (Gujarat)	Typical and atypical	210	4.76	3.8	0.95
Rekha BS and Neginhal DD [23]	2014	Indian (South India)	Atlas	153	6.4	4.5	1.9
Katikireddi RS and Setty SNRS [8]	2014	Indian (Andhra Pradesh)	Typical and atypical	100	3	2	1
Murugan M and Verma S [24]	2014	Indian (Puducherry)	Typical and atypical	150	12.6	10.6	2
Shah ST et al., [6]	2014	Indian (Gujarat)	Typical and atypical	210	16.19	9.52	6.67
Patra A et al., [25]	2015	Indian (Punjab)	Typical and 7th	150	22	10.67	11.33
Akhtar MJ et al., [9]	2015	Indian (Bihar)	Typical and atypical	174	14.36	11.49	2.87
Sangari SK et al., [7]	2015	New York	Typical	71	24.01	24	0.01
Gujar SM et al., [10]	2015	Indian (Gujarat)	Typical and atypical	150	27.33	18	9.33
Ambali MP and Jadhav SD [12]	2016	Indian (Maharashtra)	Typical	163	14.72	4.90	9.81
Nayak G et al., [11]	2016	Indian (Eastern Odisha)	Typical and atypical	133	6.0	4.5	1.5
Vasuki AKM et al., [4]	2018	Indian (Coimbatore)	Typical and atypical	300	23	16.6	6.4
Shivaleela C et al., [26]	2021	Indian (Karnataka)	Typical and atypical	182	22	16	6
Present study	2023	Indian (Western Odisha)	Typical and atypical	367	11.44	6.54	4.90

[Table/Fig-10]: Comparison of studies about incidence of accessory foramen transversarium [2,4,6-12,20-26].

Authors	Population	Mean Anteroposterior diameter (mm)	Mean Transverse diameter (mm)	Range of mean diameter (mm)	Distance of foramen transversarium from uncinate process
Molinet GM et al., [16]	Chilean	_	_	Rt-4.40-5.60 Lt-5.57-5.92	_
Sangari SK et al., [7]	American	Rt-5.17±0.89 Lt-5.13±0.79	Rt-5.69±1.04 Lt-5.87±0.89	Rt-2.54-7.79 Lt-2.65-7.35	Rt-5.0±0.87 Lt-5.0±1.0
Gupta M and Agarwal S [14]	North Indian	Rt-5.21±1.15 Lt-5.26±1.12	Rt-5.78±1.10 Lt-5.84±1.03	-	-
Rekha BS and Neginhal DD [23]	South Indian	Rt-7.9±1.0038 Lt-7.78±0.98	Rt-6.328±0.99 Lt-6.325.±1.05	-	-
Patra A et al., [18]	North Indian	Rt-4.96±1.08 Lt-5.07±1.12	Rt-5.68±1.20 Lt-5.76±1.29	-	-
Present study	Western Odisha	Rt-5.29±0.81 Lt-5.45±0.81	Rt-5.23±0.75 Lt-5.42±0.79	Rt-1.17-6.95 Lt-1.05-6.95	Rt-5.42±1.33 Lt-5.32±1.18

[Table/Fig-11]: Comparison of morphometric data of foramen transversarium in different populations [7,14,16,18,23].

Limitation(s)

As the study was done in dried vertebrae collected from the anthropology section, age and sex correlation could not be done.

CONCLUSION(S)

Finding of extremely narrow foramen transversarium as small as 1 mm in diameter and accessory foramina in such a good number of vertebrae in the present study raises questions about the integrity of the contained structures. This factor leading to vertebral artery compression should not be ignored while searching for the differential diagnosis of complaints like headache, migraine and fainting attacks. So the results generated through this osteological study should be correlated by undertaking radiological studies to confirm the variations of the vertebral vessels. Further, though the other morphometric details of foramen transversarium have been studied in different populations of India, the distance of uncinate process from its medial margin generated through this study will be first of its kind.

REFERENCES

[1] Standring S, Borley NR, Newell RLM, et al. editors.Gray's Anatomy- The antomical basis of clinical practice. 40th ed. Edinburgh: Churchill Livingstone/ Elsevier; 2008. Pp. 717,718, 449.
[2] Kaya S, Yilmaz ND, Pusat S, Kural C, Kirik A, Izci Y. Double foramen transversarium variation in ancient byzantine cervical vertebrae: Preliminary report of an anthropological study. Turk Neurosurg. 2011;21(4):534-38.
[3] Kotil K, Kilincer C. Sizes of the transverse foramina correlate with bloodflow and dominance of vertebral arteries. Spine J. 2014;14(6):933-37.
[4] Vasuki AKM, Jamuna M, Nirmaladevi M, Hebzibah DJ, Radhika K, Krishnan K. An osteological study of foramen transversarium of cervical vertebrae and its clinical significance. Int J Anat Res. 2018;6(1.2):4906-13.
[5] Gupta RP, Rai A, Gupta N. A study of anatomical variations in foramen transversarium and its clinical importance. Int J Contemp Surg. 2014;2(1):147.
[6] Shah ST, Arora K, Shah KP. Study of accessory foramen transversarium in cervical vertebrae. GCSMC J Med Sci. 2014;3(2):21-24.
[7] Sangari SK, Dossous PM, Heineman T, Mtui EP. Dimensions and anatomical variants of the foramen transversarium of typical cervical vertebrae. Anat Res Int. 2015:391823.
[8] Katikireddi RS, Setty SNRS. A study of double foramen transversarium in dried cervical vertebra. Int J Heal Sci Res. 2014;4(1):59-61.
[9] Akhtar MJ, Madhukar PK, Rahman S, Kashyap N. A morphometric study of foramen transversarium of dried cervical vertebrae. Int J Res Med Sci. 2015;3(4):912-16.
[10] Gujar SM, Oza SG, Shekhawat JP. A study of accessory foramen transversarium in dry cervical vertebrae and its clinical implications. Natl J Integr Res Med. 2015;6(6):27-30.
[11] Nayak G, Mohanty BB, Baisakh P, Das SR, Panda SK, Chinara PK. Study of accessory foramina transversaria in cervical vertebrae and their surgical and morphological importance. Res J Pharm Biol Chem Sci. 2016;7(3):1370-73.
[12] Ambali MP, Jadhav SD. Anatomical variations in foramen transversarium of typical cervical vertebrae and its clinical significance. Int J Anat Res. 2017;5(1):3426-29.
[13] Ionete C, Omojola MF. MR angiographic demonstration of bilateral duplication of the extracranial vertebral artery: Unusual course and review of the literature. Am J Neuroradiol. 2006;27(6):1304-06.
[14] Gupta M, Agarwal S. Morphometric study of foramina transversaria and the incidence of accessory foramina in cervical spine of Indian population. J Clin Diag Res. 2019;13(3):AC07-AC11.
[15] Patil NP, Dhapate SS, Porwal S, Bhagwat VB. The study of incidence of accessory foramen transversaria in the cervical vertebrae. IOSR J Dent Med Sci. 2014;13(7):85-87.
[16] Molinet GM, Robles FP, Roa I. Anatomical variations of the foramen transversarium in cervical vertebrae. Int J Morphol. 2017;35(2):719-22.
[17] Agrawal D, Mohanty BB, Shetty S, Parija B, Hazary SK, Chinara PK. Variations in foramen transversarium: An ostiological study in eastern India. Int J Curr Res. 2012;4(9):120-22.
[18] Patra A, Chaudhary P, Kaur H. Variations in the foramen transversarium of cervical spine and their surgical importance: An osteological study in dried cervical vertebrae of north Indian origin. Turk Neurosurg. 2022; 32(1):36-42.
[19] Aziz JN, Morgan M. Morphological study of the foramen transversarium of the atlas vertebra among Egyptian population and its clinical significance. Anatomy Physiol Biochem Int J. 2018;4(4):00163-67.
[20] Murlimanju BV, Latha VP, Shilpa K, Rai R, Dhananjaya KVN, Jiji PJ. Accessory transverse foramina in the cervical spine: Incidence, embryological basis, morphology and surgical importance. Turk Neurosurg. 2011;21(3):384-87.
[21] Rathnakar P, Remya K, Swathi B. Study of accessory foramen transversaria in cervical vertebrae. J Heal Allied Sci NU. 2013;3(4):97-99.
[22] Chandravadiya L, Patel S, Goda J, Chavda V, Ruparelia S, Patel S. Double foramen transversarium in cervical vertebra: Morphology and clinical importance. Int J Res Med. 2013;2(1):103-05.
[23] Rekha BS, Neginhal DD. Variations in foramen transversarium of atlas vertebra: An osteological study in South Indians. Int J Res Heal Sci. 2014;2(1):224-28.
[24] Murugan M, Verma S. A study on variations of foramen transversarium of cervical vertebrae. Natl J Clin Anat. 2014;3(1):04-07.
[25] Patra A, Kaur H, Chhabra U, Kaushal S, Kumar U. Double foramen transversarium in dried cervical vertebra: An osteological study with its clinical implications. Indian J Oral Sci. 2015;6(1):07-09.
[26] Shivaleela C, Khizer Hussain Afroze M, Ramesh P, Lakshmiprabha S. An osteological study of anatomical variations of foramen of cervical vertebrae and its clinical implications. Int J Anat Res. 2021;9(4):8145-50.

PARTICULARS OF CONTRIBUTORS:

1. Assistant Professor, Department of Anatomy, Veer Surendra Sai Institute of Medical Sciences and Research, Burla, Sambalpur, Odisha, India.
2. Professor, Department of Anatomy, Veer Surendra Sai Institute of Medical Sciences and Research, Burla, Sambalpur, Odisha, India.
3. Associate Professor, Department of Anatomy, Veer Surendra Sai Institute of Medical Sciences and Research, Burla, Sambalpur, Odisha, India.

NAME, ADDRESS, E-MAIL ID OF THE CORRESPONDING AUTHOR:

Dr. Sarita Behera,
Assistant Professor, Department of Anatomy, Veer Surendra Sai Institute of Medical Sciences and Research, Burla, Sambalpur-768017, Odisha, India.
E-mail: drsaritabehera81@gmail.com

PLAGIARISM CHECKING METHODS: [Jain H et al.]

- Plagiarism X-checker: Mar 11, 2023
- Manual Googling: May 01, 2023
- iThenticate Software: May 20, 2023 (20%)

ETYMOLOGY: Author Origin

EMENDATIONS: 7

AUTHOR DECLARATION:

- Financial or Other Competing Interests: None
- Was Ethics Committee Approval obtained for this study? Yes
- Was informed consent obtained from the subjects involved in the study? No
- For any images presented appropriate consent has been obtained from the subjects. No

Date of Submission: **Mar 09, 2023**
Date of Peer Review: **Apr 04, 2023**
Date of Acceptance: **May 23, 2023**
Date of Publishing: **Jun 01, 2023**