Research Article

Morphometric study of accessory foramen transversarium and their clinical importance

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ABSTRACT

Aim: To determine the presence of accessory foramen transversarium of cervical vertebrae and to investigate them according to their size, shape, location, diameter, and their changes related to the vertebral artery and their clinical significance. **Material and Methods:** The study was done in Saveetha Medical College, Thandalam, and 120 cervical vertebrae were procured from the Department of Anatomy to find the presence of accessory foramen transversarium and investigate them according to their morphometry based on size, shape, location, classification, and diameter. The size were measured by digital vernier caliper. **Results:** Out of 120 cervical vertebrae, accessory foramen transversarium is found only in 39 cervical vertebrae. Of these, 20 were complete and 19 were incomplete foramen. Based on shape, 11 round, 18 oval, and 10 irregular shapes were seen. Unilaterally 28 and bilaterally 11 accessory foramen transversarium were found. About 28 accessory foramen transversarium were seen in front and 11 were seen at the back in relation to foramen transversarium. Antero-posterior and transverse diameter of 39 accessory foramen transversarium was measured and their mean and standard deviation were calculated. **Discussion:** The neck is the part of long vertebral column which has cervical vertebrae. There are seven cervical vertebrae and are identified by the presence of foramen in their transverse process called foramen transversarium, the cardinal feature of cervical vertebrae. The knowledge of the dimension of both foramen transversarium and accessory foramen transversarium may contribute as additional information for the clinical during any procedure around cervical region. **Conclusion:** The knowledge of the presences of accessory foramen transversarium is important for radiologist and clinicians during vascular surgeries and neurosurgeries.

KEY WORDS: Accessory foramen transversarium, Cardinal feature, Cervical vertebrae, Morphometry, Vertebral artery

INTRODUCTION

The vertebral column is a part of axial skeleton of man which has to protect the spinal cord and support the body. There are seven cervical vertebrae and are identified by the presence of foramen in their transverse processes called foramen transversarium - the cardinal feature of cervical vertebrae. Of these seven, third to six is typical and first, second, and seventh are atypical cervical vertebrae. Typical cervical vertebrae consist of two major parts, an anterior, cylindrically shaped vertebral body and a posterior, irregularly shaped neural arch. The body of the vertebrae is small, with a transverse diameter greater than its anteroposterior diameter in cervical vertebrae. To minimize the weight of the vertebrae and allow dynamic load bearing, the vertebral body is not a solid block of bone but a shell of cortical bone surrounding a cancellous cavity. The cortical shell is reinforced by trabeculae in the cancellous bone, which helps resist compressive forces.

The neural arch can be further divided into the pedicles and the posterior elements. The pedicle is short, stout pillars with thick walls that transmit tension and bending forces from the posterior elements to the vertebral bodies. The remaining posterior elements are the laminae, the spinous process, and the transverse process. The spinous process is the posterior projection of bone that originates from the central portion of the lamina, dividing into two. The transverse processes are lateral projections of bone that originates from the lamina. It is made up of two elements transverse element and costal element. The transverse element fuses with the costal element and forms the medial part

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of the posterior wall of the foramen transversarium. The costal element has anterior and posterior roots which end in anterior and posterior tubercles joined together by costotransverse bar. The vertebral artery is one of the two principal arteries which supply the brain.[1] It branches from the first part of subclavian artery. The vertebral artery is divided into four parts; of this, the third part enters its vertebral course at the foramen transversarium of six cervical vertebrae to the posterior aspect of lateral mass of the atlas, the first cervical vertebrae. The embryogenesis of the vertebral artery occurs between day 32nd and 40th day of gestation. They are formed from fusion of the longitudinal anastomoses which connect the cervical intersegmental arteries following the course of the two through eight cervical segmental nerves. The intersegmental arteries regress during the embryonal development. Only the 7th intersegmental artery does not regress and becomes the proximal portion of the subclavian artery which gives rise to the vertebral artery.[2] It has been speculated that persistence of a portion of the primitive dorsal aorta with two intersegment arteries may give rise to vertebral artery duplication. Failure on the regression of the intersegment arteries can result in vertebral artery fenestration.[3] This fenestration may contribute to the development of the double foramen transversarium, but it is not proven yet. The cause of variations on the size and shape of the foramen transversarium is not well known. It may be developmental or related to the variations of the course of vertebral artery.

The vertebral artery enters its course, nearly always at the foramen transversarium of the sixth cervical vertebrae. Due to this fact, the foramen transversarium of the seventh cervical vertebrae contains only vertebral vein along with nerve branches. Occasionally, in about 5% of the cases, the vertebral artery or vein may travel through the foramen transversarium of the seventh cervical vertebrae. This is why these seventh foramen transversaria are usually smaller than the sixth, or even sometimes absent. The tortuosity of the vertebral artery may cause bone destruction.[4] Thus, it may be a factor in the size of the foramina. It also described bony excavation on the anterior surface of the superior articular process by pressure of the vertebral artery. Since the vertebral vessels are a factor in the formation of the foramen transversarium, it can be assumed that variations in the presence and course of the vessels will be manifested in changes of the foramen transversarium. Conversely, variations of the foramen transversarium can be useful or estimating changes or variations of the vessels and accompanying nerve structures.[5] Similar correlation may be suggested for double foramen transversarium. One of the foramina may be occupied by the vertebral artery and the other by vertebral vein. The left foramen transversarium is larger than the right foramen transversarium.[6] It was reported that this vertebral artery enters the foramen transversarium of vertebral at C6 in 88% of cases, C7 in only 5%, and C5 in 7% of cases.[7] An accessory transverse foramen is seen smaller in size than the primary foramen generally found in the sixth cervical vertebrae and less frequently in the adjacent vertebrae.

Anatomy and morphology of foramen transversarium is useful to the operating spine surgeons and radiologist in the interpretation of radiographic films and computed tomogram scans.[8] The presence of accessory transverse foramen is a rare condition and this may have variations that affect the course of vertebral artery. The deformation and variations of the accessory foramen may affect the anatomical course of vital vascular and neural structures and consequently cause pathological conditions are small or even sometimes absent. Variations in the number and size of the foramen transversarium of the cervical vertebrae may result in headache, migraine, and fainting attack due to compression of the vertebral artery.[9] The vertebral vessels in such situations may be compressed by head movements and may give rise to vascular insufficiency. Clinically, this type of variations is important for the radiologist while doing computed tomographic and magnetic resonant imaging scan. These variations of foramina transversarium are also important for surgeon during posterior cervical surgery.[10]

MATERIALS AND METHODS

In our research, about 120 cervical vertebrae were collected from the Department of Anatomy, Saveetha Medical College, Thandalam, Tamil Nadu. Of which 39 bones were observed with the presence of accessory foramen transversarium. The details on age, sex, and race of the individuals from which these vertebrae were derived were not available. The following parameters were observed and measured using digital Vernier caliper.

- Size: Complete, and incomplete.
- Shapes: Round, oval, and irregular.
- Location: Unilateral, bilateral, anterior, posterior, right, and left.
- Diameter: Anteroposterior and transverse.
- Classification: Brachiomorph, mesomorph, and dolichomorph.

The shapes, size, and location were concluded based on the visual observation done in the vertebrae. Using a digital Vernier caliper, the anteroposterior and transverse diameters of accessory foramen transversarium were measured. The transverse and anteroposterior diameter of each foramen was calculated to estimate the mean diameter of each accessory foramen transversarium.

Statistical evaluations were performed for each measurement. The mean and standard deviation value was performed to determine if there was a significant difference between the right and left side.

OBSERVATION AND RESULTS

In this study, we observed 39 cervical vertebrae with the presence of accessory transverse foramen of 120 cervical vertebrae. As mentioned in the materials and methods, we classified the accessory foramen transversarium based on the following criteria.

Of 39 accessory foramen, 20 are complete (13 on the right side and 7 on the left side) and 19 are incomplete (13 on the right side and 9 on the left side). According to the shape, accessory foramen transversarium is classified into round, oval, and irregular. Round-shaped foramen is seen in 11 vertebrae, of which seven is seen on the right side and five on the left side, oval-shaped foramen, which is comparatively seen in more vertebrae, is seen in 18 vertebrae, of which 11 is seen on the right side and seven on the left side, and elliptical-shaped one is seen in 10 vertebrae, of which six right side and four left-sided foramen. Similarly, the accessory foramen transversarium is divided into complete and incomplete. In 28 vertebrae, accessory foramen is observed only on either of one side (17 on the right side and 11 on the left side) and 11 vertebrae are observed with bilateral presences of accessory foramen transversarium [Figure 1].

Anteroposterior diameter is measured and calculated in 39 cervical vertebrae. About 21 foramens are measured on the right side which is 1.46762 mm ± 0.5235 mm and on the left side about 18 foramen transversaria are measured which is 1.51277 mm ± 0.4318 mm. Likewise, transverse diameter measured in 21 foramina are measured on the right side and its value is 1.8181 mm ± 0.5863 mm and on the left side about 18 foramina are measured and its value is 1.821 ± 0.6363 [Figure 2].

DISCUSSION

The foramen transversarium develops from the fusion of two components, namely vestigial costal element and the true transverse process of the cervical vertebrae. The vertebral vessels and nervous plexus are caught between these two bony parts. The foramen transversarium is closed laterally by the costotransverse bar, a thin plate of bone connecting the costal element to the original transverse process. Accessory foramen transversarium might be due to double costal element on the same side fusing to the original transverse process resulting in unusual number of foramen transversarium.[11] The accessory foramen transversarium may also be due to variations in the vertebral vessels. The vertebral artery arises

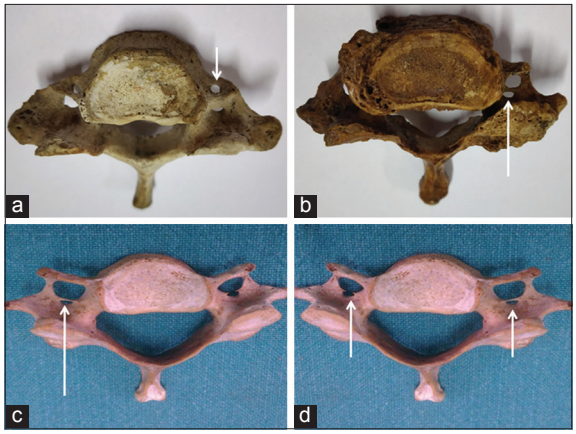

Figure 1: (a) Round-shaped foramen, (b) oval-shaped foramen, (c) elliptical-shaped foramen, (d) complete and incomplete foramen

Figure 2: (a) Unilateral foramen, (b) bilateral foramen, (c) transverse and anteroposterior diameter, (d) measuring the diameter using the digital Vernier caliper

from the subclavian artery and usually traverses through the foramen transversarium of all cervical vertebrae except the seventh.[12] The two vertebral arteries are solely responsible for posterior circulation of the brain. The tortuous course of vertebral artery and rarely medial position of transverse foramen in relation to the joint of Luschka may result in life-threatening iatrogenic injury following cervical decompression.[13] The two vertebral arteries are unequal in size in about 75% of cases. One of them may be extremely narrow, more so on the right side in 10% of cases. Bow hunter's stroke is a symptomatic vertebral-basilar insufficiency caused by stenosis or occlusion of the vertebral artery with head rotation.[14] It is a common finding on angiography that head rotation produces stenosis or occlusion of a contralateral vertebral artery. The narrowing of the transverse foramen may predispose patients to vertebral-basilar insufficiency and thrombus formation, especially with head rotation. Duplication of extracranial vertebral artery has been reported in literature.

Table 1: Based on size

Classification	Right side	Left side	Total number
Complete accessory foramen	13	7	20
Incomplete accessory foramen	13	6	19

Table 2: Based on shapes

Classification	Right side	Left side	Total number
Round	7	5	11
Oval	11	7	18
Irregular	6	4	10

Table 3: Based on location

Classification	Right side	Left side	Total number
Unilateral	17	11	28
Bilateral	11		

Vertebral artery develops from a fusion of longitudinal anastomoses that link the second to sixth cervical intersegmental arteries. Most of the intersegmental arteries regress except the seventh which forms the origin of vertebral artery. Failure of the occlusion of intersegmental arteries may be responsible for duplication fenestrations of vertebral artery. A duplicate vertebral artery may potentially serve to protect patients against chemical attacks to the brain and provide collateral blood flow to the basilar artery. However, fenestrated vertebral arteries have been demonstrated histological lyrics to be weak with irregular elastic fibers in the vessels wall.[15] Fenestrated/double vertebral arteries may carry more risk of thrombus formation and embolization, leading to serve transient ischemic attacks. It is easily understood that the course of vital vascular and neural structures, occupying the foramen transversarium, may be distorted due to variations like the presence of accessory foramen transversarium. Interestingly, it has been estimated that up to 10% of malpractice involving physicians may be due to a lack of knowledge of the anatomical variations. Thus, detecting and understanding anatomical variations of the vertebral artery, accompanying the variations of the foramina transversaria, are essential while performing the complex surgical procedures that involve the screw fixation, to avoid possible complications.

The earliest known study was done by Taitz *et al.* (1978) who studied 480 foramina transversaria and found 34 vertebrae having accessory foramen transversarium in it. In Sharma *et al.* observed accessory foramen transversarium in 16 of 200 cervical vertebrae. Similarly, in 2014, Kattikireddi *et al.* studied three accessory foramen transversaria of 100 cervical vertebrates.[16,17] In our study, we observed about 39 cervical vertebrae with the presence of accessory transverse foramen of 120 cervical vertebrae. Out of these 13 complete accessory foramen transversarium seen in right side and 7 were on the left side and 13 incomplete accessory foramen transversarium seen on its right side and 6 were on the left side of cervical vertebrae Table 1. Laxmi *et al.* study observed the double foramen transversarium in 4.76% of the cases.[18] They studied about 210 cervical vertebrae, in which 10 vertebrae were found to haveorigin of vertebral artery. Among 10 vertebrae, eight vertebrae were found to have bilateral and two vertebrae were found to have unilateral double foramen transversarium. Magi and Suman study reported 19 (12.6%) vertebrae having bilateral double transverse foramina of 150 cervical vertebrae.[19] In our study, we have observed about 11 cervical vertebrae having the bilateral presence of accessory transverse foramen transversarium. Yadav *et al.* observed eight accessory foramen transversaria which includes three on unilateral and five on bilateral foramen of 120 cervical vertebrae.[20] In this study, of 120 cervical vertebrae, about 28 cervical vertebrae have the unilateral presence of accessory foramen transversarium and 11 having bilateral accessory foramen transversarium [Table 3]. Sangari *et al.* studied the mean diameter of the right transverse foramen varied from 2.54 mm to 7.79 mm in diameter (mean=5.55 mm ± 0.87 mm), whereas the mean diameter of the left transverse foramen varied from 2.65 mm to 7.35 mm (mean=5.48 mm ± 0.77 mm).[21] In our study, the mean diameter of the right accessory foramen transversarium varied from 0.5 mm to 2.00 mm, whereas the mean diameter of the left accessory foramen transversarium varied from 1.5 mm to 2.00 mm Table 4. Apart from transverse diameter, we also studied about anteroposterior diameter of accessory foramen transversarium which is not reported in any literature. The knowledge of the dimension of both foramen transversarium and accessory foramen transversarium may contribute as additional information for the clinical during any procedure around cervical region.

Taitz *et al.* and Aziz[22] observed the different shape of the accessory foramen transversarium such as round, oval, irregular, and quadrangular. They also reported that among the shapes, round-shaped foramen were the most common one (Taitz *et al.* - 54.8% and Aziz *et al.* -54.1%). In this study, we observed only round, oval, and irregular, we did not observe the quadrangular-shaped foramen in this study, but in this study, the common shape of foramen was oval which is 46%.Of these Oval shape were seen in 18 ,of which 11 were on the right side and 7 were on the left side.Round shaped

Table 4: Based on diameter (mean and standard deviation value)

Classification	Right side (total number of bones: 21)	Left side (total number of bones: 18)
Anteroposterior diameter	1.4676±0.5235 mm	1.5127±0.4318 mm
Transverse diameter	1.8181±0.5863 mm	1.8210±0.6363 mm

foramen were seen in 11 of which, 7 were on the right side and 5 were on the left side. Irregularly shaped foramen were seen in 10 of which 6 were on the right side and 4 were on the left side Table 2. Variations in the number and size of the foramen transversarium of the cervical vertebrae are important for the radiologist and also for neurosurgeon during posterior cervical surgery.

CONCLUSION

In this study, the presences of accessory foramen transversarium were found in 39 cervical vertebrae of 120 cervical vertebrae. The reasons for the presences of accessory foramen transversarium would be torturous passing of vessels through the cartilaginous development of cervical vertebrae or improper fusion of costal element and true transverse process of cervical vertebrae. The knowledge of the presences of accessory foramen transversarium is important for radiologist and clinicians during vascular surgeries and neurosurgeries.

REFERENCES

1. Collinis P, Wigley C, Gieeson M. Grays Anatomy, the Anatomical Basis of Clinical Practice. 40th ed. New York: Churchill Livingston Elseiver; 2008. p. 652-7.
2. Fitzgerald MJ. Human Embryology: A Regional Approach. 1st ed. New York, USA: HarperCollins College Div.; 1978. p. 38-56.
3. Sim E, Vaccaro AR, Berzlanovich A, Thaler H, Ullrich CG. Fenestration of the extracranial vertebral artery: Review of the literature. Spine (Phila Pa 1976) 2001;26:E139-42.
4. Hyyppä SE, Laasonen EM. Erosion of cervical vertebrae caused by elongated and tortuous vertebral arteries. Neuroradiology 1974;7:49-51.
5. Taitz C, Nathan H, Arensburg B. Anatomical observations of the foramina transversaria. J Neurol Neurosurg Psychiatry 1978;41:170-6.
6. Epstein NE, Silvergleid R. Magnetic resonance angiographic diagnosis of ecstatic vertebral artery. J Spinal Disord 1995;8:308-10.
7. Kubikova E, Osvaldova M. A variable origin of vertebral artery. Bratislaske Lekarske Listy 2008; 109, 28-30.
8. Divya A, Sunita S, Bijaylaxmi P, Kumar HS, Kumar CP. Variations in foramen transversarium: An osteological in Eastern India. Int J Curr Res 2012;4:120-2.
9. Caovilla HH, Gananca MM, Silva ML. Sindrome Cervical Quadros Coto Neurologices Maid Comuns. Vol. 3. Sao Paulo: Atheneu; 2000. p. 95-100.
10. Kaya S, Yilmaz ND, Pusat S, Kural C, Kirik A, Izci Y, *et al.* Double foramen transversarium variation in ancient byzantine cervical vertebrae: Preliminary report of an anthropological study. Turk Neurosurg 2011;21:534-8.
11. Veeramani R, Shankar N. An unusual origin of the right vertebral artery from the thyrocervical trunka case report. Int J Basic Med Sci 2011;2:2-6.
12. Frazer JE. Cervical vertebrae. In: Anatomy of Human Skeleton. 6th ed. London: J and A Churchill liv td; 1965. p. 21-8.
13. Curylo LJ, Mason HC, Bohlman HH, Yoo JU. Tortuous course of the vertebral artery and anterior cervical decompression: A cadaveric and clinical case study. Spine (Phila Pa 1976) 2000;25:2860-4.
14. Seki T, Hida K, Akino M, Iwasaki Y. Anterior decompression of the atlantoaxial vertebral artery to treat bow hunter's stroke: Technical case report. Neurosurgery 2001;49:1474-6.
15. Takasato Y, Hayashi H, Kobayashi T, Hashimoto Y. Duplicated origin of right vertebral artery with rudimentary and accessory left vertebral arteries. Neuroradiology 1992;34:287-9.
16. Sharma A, Singh K, Gupta V, Srivastava S. Double foramen transversarium variation in cervical vertebra an osteological study. J Anat Soc India 2010;59:229-31.
17. Reddi RS, Setty SN. A study of double foramen transversarium in dried cervical vertebrae. Int J Health Sci Res 2014;4:59-61.
18. Laxmi C, Shailesh P, Jatin G. Double foramen transversarium in cervical vertebrae: And clinical importance. Int J Res Med 2013;2:103-5.
19. Magi M, Suman V. A study on variations of foramen transversarium of cervical vertebrae. Natl J Clin Anat 2014;3:4-7.
20. Yadav Y, Goswami P, Bharihoke V. An osteological study of foramen transversarium variations and clinical aspects. J Evol Med Dent Sci 2014;3:14562-6.
21. Sangari SK, Doussous PM, Heineman T. Dimensions and anatomical variations of the foramen transversarium of typical cervical vertebrae. Anat Res Int 2015;39:18-23.
22. Aziz JN. Michel Morgan morphological study of the foramen transversarium of the atlas vertebra among Egyptian population and its clinical significance. Anat Physiol Biochem Int J 2018;4:1-5.

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