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Original Research Article

AN OSTEOLOGICAL STUDY OF FORAMEN TRANSVERSARIUM OF CERVICAL VERTEBRAE AND ITS CLINICAL SIGNIFICANCE

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ABSTRACT

Introduction: Seven cervical vertebrae constitute the skeletal framework of the neck. Along with the other identification points, the cardinal feature of a cervical vertebra whether typical or atypical is the presence of Foramen transversarium on the transverse process. This foramen transmits the Vertebral artery, Vertebral vein and Sympathetic nerves. These foramina are known to have variations in size, shape and numbers and may be absent, incomplete or duplicate, which may lead to various symptoms. Their etiology is related with the variations in the course of the Vertebral artery due to developmental reasons.

Materials and methods: Three hundred dry human cervical vertebrae were collected and studied in the department of Anatomy, PSG Institute of Medical Sciences and Research, Coimbatore. We included all the Cervical vertebrae including Atlas, Axis and all other cervical vertebrae. We observed the presence, size, shape and variations of Foramen transversarium of cervical vertebrae during our study.

Observations and results: Out of three hundred Cervical vertebrae, One hundred and twenty five cervical vertebrae (42%) had variations of Foramen transversarium like Complete / incomplete Accessory foramen, triple foramen on one side, absence of foramen on one side and unequal size of foramen on both the sides. The different types of shapes of foramen transversarium were also analysed and tabulated. The areas of foramen transversarium were measured after measuring all the diameters.

Conclusion: Variations in the Foramen transversarium may indicate, the variation in the course of the Vertebral artery. The present study was important clinical implications for Head and neck and vascular surgeries. These variations should be kept in our mind during surgeries on cervical spine.

KEY WORDS: Foramen transversarium, shape, cervical vertebrae, accessory, absent and variations.

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INTRODUCTION

The cervical spine is made up of first seven cervical vertebrae in the spine. It starts just below the skull and extends at the top of the thoracic spine. Approximately 8% of overall body length is accounted by the cervical spine [1], whereas for the cervical (neck) length, 80% is contributed by the cervical vertebral bodies and about 20% is provided by the intervertebral discs [2].

Presence of Foramen transversarium on their transverse process, small vertebral body with beveled edges and bifid spine are the characteristic features of typical cervical vertebrae while absence of body and spine is the peculiarity of atlas.

In cervical vertebrae, the costal and transverse elements are connected to each other around the foramen transversarium of the transverse process. The costal element is represented by the anterior root, anterior tubercle, costo - transverse bar and posterior tubercle. The transverse element is represented by the posterior root [3].

The cervical vertebrae are identified by transverse foramen in the transverse process. This foramen transmits Vertebral artery, Vertebral vein and Sympathetic fibres from inferior cervical ganglion. C7 vertebrae only transmits Vertebral vein. Sometimes this foramen is small or absent [4].

These transverse foramina are found to have variations in size, shape and numbers and may be absent, incomplete or duplicate, which may lead to various symptoms.

Vertebral vessels are responsible for formation of foramen transversarium. It can be assumed that variations in the course of the Vertebral vessels may cause variations in Foramen transversarium [5].

Variations in Foramen transversarium may be one of the causes for complaints like headache, migraine and fainting attacks due to compression of the Vertebral artery [6]. Knowledge of anatomic variations of the foramen transversarium is important for clinicians and radiologists during interpretation of radiographs and CT scans.

MATERIALS AND METHODS

Three hundred dry human cervical vertebrae were collected and studied in the department of Anatomy, PSG Institute of Medical Sciences and Research, Coimbatore. We included all the Cervical vertebrae including Atlas, Axis and all other cervical vertebrae. We excluded all broken and damaged cervical vertebrae. We observed the presence, size, shape and variations of Foramen transversaria of cervical vertebrae during our study. Specimens with variations of Foramen transversarium were photoghaphed. Data collected was tabulated and analysed.

OBSERVATIONS AND RESULTS

Out of three hundred cervical vertebrae studied, One hundred and twenty five cervical vertebrae were found to have variations in the foramen transversarium. Nine Atlas vertebrae, Eleven Axis vertebrae and one hundred and five other cervical vertebrae were found to have variations in the Foramen transversarium of cervical vertebrae.

Vertebrae with complete accesssory foramen transversarium was found in 55 cervical vertebrae and vertebrae with incomplete accessory foramen was found in 14 cervical vertebrae. Triple foramen transversarium was found in the right side of one cervical vertebrae. Absence of right foramen transversarium was observed in three cervical vertebrae.

Vertebrae with one side complete accessory foramen transversarium and the other side with incomplete accessory foramen transversarium were found in 10 cervical vertebrae.

The number and percentage of complete and incomplete foramen transversarium in unilateral and bilateral cervical vertebrae was tabulated.

Table 1: Variations in transverse foramina (among 125 cervical vertebrae showing variations).

Variations in transverse foramina	Number in Unilateral variety	Number in Bilateral variety	Percentage among unilateral	Percentage among bilateral	Number in Total	Percentage in Total
Vertebrae with complete accessory transverse foramen	42	13	14	4	55	18
Vertebrae with incomplete accessory Transverse foramen	8	6	3	2	14	5
Vertebrae with triple foramen	1	-	-	-	-	0.003
Vertebrae with unequal size of the transverse foramen	42	-	-	-	-	14
Absent right transverse foramen	3	-	-	-	-	1
Vertebrae with one side complete foramen and the other side with incomplete foramen	10	-	-	-	-	3.3

Table 2: Incidence of different types of accessory transverse foramen observed in this study (among 125 vertebrae showing transverse foramen).

Number of vertebrae with accessory foramen transversarium	Number	Percentage
Number of vertebrae with unilateral accessory transverse foramen	50	17
Number of vertebrae with bilateral accessory transverse foramen	19	6
Number of vertebrae with incomplete unilateral accessory transverse foramen	8	3
Number of vertebrae with incomplete bilateral accessory transverse foramen	6	2
Number of vertebrae with complete unilateral accessory transverse foramen	42	14
Number of vertebrae with complete bilateral accessory transverse foramen	13	4
Number of vertebrae with unilateral triple foramen	1	0.003
Number of vertebrae with unequal size of transverse foramen	42	14
Absent right transverse foramen	3	1
Vertebrae with one side complete foramen & the other side with incomplete foramen	10	3

Comparison of Accessory transverse foramen with the other studies and Prevalence of Accessory transverse foramen also tabulated.

Table 3: Comparison of Accessory transverse foramen with other studies.

Authors	Number of vertebrae	Incidence of accessory transverse foramen (%)	Unilateral accessory transverse foramen (%)	Bilateral accessory transverse foramen (%)
Kaya et al	22	22.72	13.63	9.09
Katikiereddi et al	100	3	2	1
Chaudhari et al	133	23.75	14.7	8.42
Rathnakar et al	140	5.7	3.6	1.42
Chandravadiya et al	140	4.76	3.8	0.95
Sharma et al	200	8	3.5	4.5
Muralimanju et al	363	1.6	1.4	0.3
Taitz et al	480	7	---	---
Patra et al	150	22	10.6	11.3
Omar et al	315	9.8	7.3	2.5
Present study	300	23	16.6	6.4

Table 4: Showing the prevalence of accessory transverse foramen in different study populations.

Authors	Year	Prevalence of accessory transverse foramen	Study sample	Population
Taitz et al	1978	7	480	Indians
Nagar et al	1999	8.6	1388	Roman – Bynzanthine jews
Das et al	2005	1.5	132	Indians
Kaya et al	2011	22.7	262	Jewish
Karau PB, Oduia P	2012	3.9	102	Kenyan
Rekha et al	2013	6.54	153	Indians
Present study	2016	41.60%	300	Indians

Shape of Foramen transversarium was classified into five types using the criteria by Taitz.C et al 1978 [7]. According to the shape and direction of main diameter, transverse foramen were classified into five types:

Type 1 – round

Type 2 – elliptical with main diameter (length) anteroposterior

Type 3 – elliptical with main diameter(breath) transverse

Type 4 - elliptical with main diameter oblique from right to left

Type 5 – elliptical with main diameter oblique from left to right

All diameters were taken on the inner aspect of foramen.

The cross sectional area of the Transverse foramen were calculated using the formula of an elipse

Area = pi(D1/2D2/2) where

D1 =horizondal length of the foramen

D2 =Vertical length of the foramen

Pi = 3.14

Accordingly, right area and left area were calculated and the results were tabulated. In this study, double foramen transversarium was observed in 34(7%) cervical vertebrae. Among them triple foramen was observed in one cervical vertebrae.

Table 5: Shape of Foramen transversarium (among 125 cervical vertebrae with 250 transverse processes).

Shape and direction of axes	Right side - Number	Right side - Percentage	Left side –Number	Left side – Percentage	Total - Number	Total –Percentage
Type - 1	55	22	54	21.6	109	43.6
Type - 2	2	0.8	4	1.6	6	2.4
Type - 3	30	12	27	10.8	57	22.8
Type - 4	16	6.4	21	8.4	37	14.8
Type - 5	20	8	18	7.2	38	15.2

Table 6: Showing the diameters and areas of Transverse foramen.

Diameters	Number	Minimum	Maximum	Mean	Standard Deviation
Right anteroposterior diameter	125	0.2	0.8	0.4	0.035
Right transverse diameter	125	0.2	1.2	0.6	0.0529
Left anteroposterior diameter	125	0.2	0.8	0.5	0.0268
Left transverse diameter	125	0.2	1.1	0.6	0.0447
Right area	125	0.785	1.18	1.18	0.0424
Left area	125	0.785	1.08	0.94	0.021

Fig.1: Shows Left (unilateral) complete accessory transverse foramen.

Fig. 2: Shows bilateral complete accessory transverse foramen.

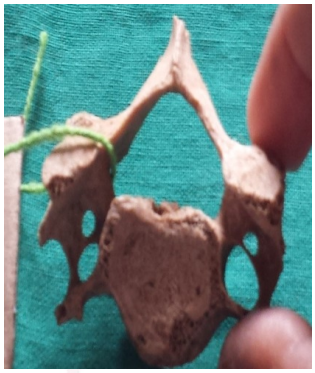

Fig. 3: Shows Left incomplete accessory (unilateral) transverse foramen

Fig.4: Shows bilateral incomplete accessory transverse foramen.

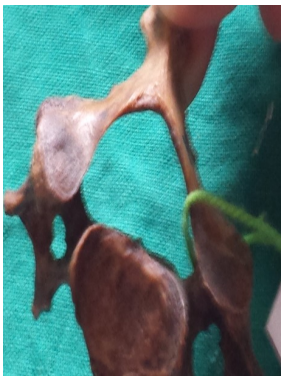

Fig. 5: Shows Right triple accessory transverse foramen.

Fig.6: Shows Absent right Transverse foramen.

Fig.7: Shows unequal size (Smaller and left larger) transverse foramen.

Fig. 8: Shows bilateral irregular transverse foramen.

Fig.9: Shows Type 1 – round transverse foramen.

Fig. 10: Shows Type 2 – eliptical (in Length) transverse foramen.

Fig.11: Shows Type – 3 (eliptical Transversely) transverse foramen.

Fig.12: Shows right – Type 5 and left – Type - 5 transverse foramen

DISCUSSION

Vertebrae develop from Sclerotome portion of Somites derived from Paraxial mesoderm which is regulated by HOX genes. Sclerotome undergoes resegmentation and caudal half of sclerotome grows and fuses with cephalic half of subsequent sclerotome. The caudal part of cervical sclerotome forms lateral masses and anterior and posterior arches of atlas. Foramen transversarium develops by vestigeal costal element anteriorly and true transverse process posteriorly. In Atlas vertebrae, true transverse process is represented by a thick posterior bar in intrauterine life which fuses eventually with thin anterior bar developed in 3 – 4th year of life from ventrolateral aspect of articular pillar and thus completes with formation of transverse foramen. Hence, in the Atlas, the transverse foramen is formed by fusion of anterior and posterior bars as they pass around the position of Vertebral artery at the age of 3 – 4 years [8]. Transverse foramen is the result of special formation of cervical transverse process. It is formed by a vestigeal costal element fused to the body and true transverse process of the vertebrae. Vertebral artery, vein and nerve plexus

are caught between the bony parts. The anatomy and morphology of accessory transverse foramen are helpful to both radiologists and neurosurgeons. Maintaining the vertebral artery intact constitutes an important concern during cervical spinal procedures. Incomplete transverse foramen was formed due to partially developed anterior bar of transverse foramen and never of posterior bar [9].

Along with embryological factors, other factors like anatomical variations in the Vertebral artery and functional conditions may play important role in the formation of incomplete transverse foramen. It was noted that the tortuousity of Vertebral artery may cause bony erosion or obstruct the complete formation of foramen transversarium [10].

Size of transverse foramen is directly proportional to the caliber 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 preexisting 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 [11].

The size of Foramen transversarium indicates the size of Vertebral artery. Small foramen transversarium means small calibre of Vertebral artery. This may be a risk for Vertebrobasilar insufficiency or thrombus formation. Also compression of Vertebral artery as a result of stenosis of Foramen transversarium may also lead to clinically important consequences for patients at risk [12].

Vertebral artery develops from longitudinal anastomosis that links 2nd and 6th cervical intersegmental arteries. Most intersegmental arteries regress except 7th intersegmental artery which forms origin of Vertebral artery. Failure of occlusion of intersegmental artery may be responsible for duplication or fenestrations of Vertebral artery. Duplication of Vertebral artery offers collateral blood flow so becomes protective but such artery may carry more risk of thrombus formation and embolization leading to severe ischaemic attacks [12].

Usually Vertebral artery enters Foramen transversarium of C6 vertebrae, sometimes foramen transversarium of C7 vertebrae. During its course Vertebral artery does not have constant caliber within foramen transversarium. The foramen transversarium of C7 cervical vertebrae may be smaller or absent. When foramen transversarium of C7 cervical vertebrae is not found to contain Vertebral artery then branches of vessels or nerves, fibrous and adipose tissue may present. This may be the reason for having small foramen transversarium [13].

Sometimes foramen transversarium can be wider as compared to other side. This may be due to the tortuosity of Vertebral artery. Tortuosity reported to cause erosion and enlargement of foramen transversarium and so widening of foramen transversarium [14].

Anatomically Foramen transversarium is described to be divided by fibrous or bony ridge, separating artery and vein [15], the smaller posterior part that encloses a branch of vertebral nerve and vein is called Accessory foramen transversarium [16].

If bony bridge develops incompletely then accessory foramen transversarium can form. Branches of vertebral nerve pass thro' 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. In Vaishaki Gonsai et al [17] study, complete double foramina were observed in 20% vertebrae, among them unilateral double foramina were found in 15% vertebrae and bilateral double foramina were found in 5%. Incomplete double foramen transversarium were observed in 11% vertebrae, among them unilateral double foramina were observed in 8% and bilateral double foramina were observed 3%vertebrae. In Anjali sabnis study [18], among 114 cervical

vertebrae, unilateral incomplete accessory foramen transversarium was found in 6 vertebrae and bilateral incomplete accessory foramen transversarium was found in 1 vertebrae. Bilateral complete accessory foramen transversarium was observed in 2 cervical vertebrae and unequal size of foramen transversarium was found in 2 cervical vertebrae.

Study by Rekha et al [19] found 10 complete double foramina. Out of which, 3 were on the left side and 4 were on the right side and 3 were on both sides. Six incomplete foramen transversarium were observed, 3 on the right, 2 on the left and one bilateral foramen transversarium were also observed.

Mamta kumari et al [20] observed unilateral accessory foramen transversarium in 23 vertebrae, among them complete unilateral accessory transverse foramen was found in 14 vertebrae and incomplete unilateral accessory transverse foramen was found in 9 vertebrae. Complete bilateral accessory transverse foramen was observed in 8 cervical vertebrae.

Shital T.Shah et al [21] found complete accessory transverse foramen in12 vertebrae, unilateral incomplete accessory transverse foramen was observed in 8 vertebrae and bilateral accessory transverse foramen was observed in 14 vertebrae among 210 cervical vertebrae.

Md.Jawad Akhtar et al [22] observed 25(14.3%) vertebrae with accessory foramen transversarium among 174 cervical vertebrae.

Das et al [23] studied on 132 cervical vertebrae and reported only 2 case of accessory foramen transversarium.

Kaya et al [24] studied on 22 Byzantine cervical vertebrae and observed the accessory foramen transversarium in 5(22.7%) vertebrae,in which 3 cases were unilateral and 2 cases were bilateral.

Karau PB et al [25] studied 102 cervical vertebrae and found 3.9% of accessory foramen transversarium.

Muralimanju et al [26] observed only six(1.6%) vertebrae with accessory foramen transversarium among 363 cervical vertebrae, in which five had bilateral accessory transverse foramen and one had unilateral accessory transverse foramen.

But in our study, among 300 cervical vertebrae, we found Variations in 125 (42%) cervical vertebrae. We observed accessory transverse foramen in 69(23%) cervical vertebrae, in which complete accessory foramen was observed in 55(18%) vertebrae and incomplete accessory transverse foramen was found in 14(5%) vertebrae. Triple foramen was observed on the right side of transverse foramen in one (0.003%) cervical vertebrae. Among them, unilateral incomplete accessory foramen was observed in 8(3%) cervical vertebrae, bilateral incomplete accessory transverse foramen was found in 6(2%) vertebrae, unilateral complete accessory transverse foramen was found in 42(14%) vertebrae and bilateral complete accessory transverse foramen was found in 13(4%) vertebrae. One side complete and the other side incomplete accessory transverse foramen was observed in 10(3%) vertebrae. Absent foramen transversarium was observed in 3(1%) Vertebrae. Unequal size of foramen transversarium was observed in 42(14%) vertebrae. Totally 125(42%) cervical vertebrae were found to have variations like accessory transverse foramen, absent transverse foramen and unequal size of transverse foramen. The presence of variations were observed to be higher in our study (especially the presence of accessory transverse foramen) than the previous studies.

Rekha B.S. et al [19] studied the shapes of transverse foramen. Type 4 was the highest on the right side and Type 5 was highest on the left side. In that study, diameters and mean area of transverse foramen on either side were also calculated. Mean area was found to be approximately equal on both the sides.

Athar Maqbool [27] observed Type 4 was higher in C1 vertebrae, type -1 was higher in C2 vertebrae, type – 3 was higher in C3 – C6 vertebrae and type – 5 was higher in C7 verterae. Right and left areas were calculated and both of them were approximately equal on both the sides.

In our study, shape of Foramen transversarium among 125 abnormal cervical vertebrae, we found type 1 was higher on both right and left sides. Right and left area also found to be approximately equal which was similar to the previous studies. The morphological knowledge of this type of variation is clinically important

because the course of vertebral artery may be distorted .The compression of vertebral artery may lead to neurological symptoms and at times hearing disturbances.

CONCLUSION

In our study, we observed variations of 125(42%) cervical vertebrae among 300 cervical vertebrae studied. We observed the complete accessory foramen transversarium in 55(18%) cervical vertebrae and incomplete accessory foramen transversarium in 14(5%)cervical vertebrae. The unilateral accessory foramen transversarium were more common than the bilateral foramen. We also found absent foramen transversarium on one side, unequal size of foramen transversarium on both the sides in our study. This study provides the information on incidence and morphological basis of foramen transversarium.

Incomplete foramen transversarium, unequal size of foramen transversarium on both the sides may be related to vertebral artery insults.

The presence of accessory foramen transversarium increases the risk of thrombus formation and embolization. Hence variations in Foramen transversarium carry a lot of clinical significance and should not be ignored.

It should be remembered that the vertebral and basilar artery contribute blood supply not only to the brain and also to the inner ear, so compression or spasm of the vertebral artery may be manifested by neurological symptoms and hearing problems.

Knowledge of such variations is important for Physicians, Neurologists Otorhinolaryngologists and Orthopedicians. Due to the presence of accessory foramen transversarium especially incomplete variety, the second part of vertebral artery may be dislodged and prone to get damaged easily during posterior cervical injuries. It is useful for the radiologists during CT and MRI scan. It helps in radiological imaging, neurological diagnosis and complex surgical procedures in the cervical area. This variation of foramen transversarium is also important for the surgeons during posterior cervical surgery.

Conflicts of Interests: None

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