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Original Article

Anatomy Section

Variations in Foramen Transversarium of Cervical Vertebrae-An Observational Study

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ABSTRACT

Introduction: Knowledge of the anatomical variations of the human body is important for us clinically both for diagnosis and treatment of diseases. Vertebral region also presents many variations. Foramen transversarium (FT) is the identification feature of cervical vertebrae and give way to neurovascular bundle, vertebral vessels and sympathetic plexus around them. Knowledge of the anatomical and surgical variations of the FT is very important for radiologists and neurosurgeons for reporting and planning for surgeries on cervical spine as ignorance of these may lead to injury of vertebral vessels that may cause headache, migraine, fainting and hearing disturbances.

Aim: To observe the incidence of double foramina transversarium in the cervical vertebrae and other variations of foramina transversarium. Also to make a note on it's clinical and morphological importance.

Materials and Methods: This was a retrospectively designed, single-center study. Total 148 human dried cervical vertebrae (80 typical and 68 atypical) were collected from the Osteology section of Department of Anatomy, Osmania Medical College, Telangana, India, during the year 2016. The collected vertebrae were observed for the presence of double FT and also for the other variations of FT. The descriptive statistics were calculated to define the sample.

Results: Out of 148 human dried cervical vertebrae 80 typical and 68 atypical vertebrae observed for variations in FT. Out of 148 human dried cervical vertebrae 17 (11.48%) vertebrae showed the accessory foramina. Out of 80 typical cervical vertebrae 13(16.25%) vertebrae showed the accessory foramina and out of 68 atypical cervical vertebrae 4(5.88%) vertebrae showed the accessory foramina.

Conclusion: These variations may be helpful for planning during neurosurgery for posterior approaches of the cervical vertebrae and to avoid post-operative complications. For the radiologist, the anthropologist and the anatomist, these variations are of importance and helpful in interpretation of the radiological films and also for the academic purpose.

Keywords: : Accessory foramen, Transverse foramen, Vertebral artery

INTRODUCTION

The cervical spine is formed by the first seven cervical vertebrae in the spine. Cervical spine extends between the base of the skull and the thoracic spine. Cervical vertebrae are the smallest movable vertebrae and are characterised by the FT, a foramen in each transverse process and a large vertebral canal to accommodate the cervical enlargement of the spinal cord. The first (atlas), second (axis) and seventh (vertebra prominens) cervical vertebrae are atypical. A typical cervical vertebra has a small, relatively broad vertebral body and a large roughly triangular vertebral foramen. The spinous process is short and bifid. The transverse process of cervical vertebrae has dorsal and ventral bars around the FT which terminate laterally as corresponding tubercles. These are connected lateral to the FT by costal or intertubercular lamella. The dorsal and ventral tubercles and the intertubercular lamella represent morphologically the capitellum, tubercle and neck of a cervical costal element. The morphological transverse process is represented by the attachment of the dorsal bar to the pediculolaminar junction [1]. The presence of a FT in the transverse process is the identification feature for cervical vertebrae. In all cervical vertebrae, the FT normally transmits the vertebral artery and vein and a branch from cervicothoracic ganglion (vertebral nerve) except seventh cervical vertebra where we do not see vertebral artery [1]. Normally, there is one FT on either side. Occasionally, it is either absent or duplicated unilaterally or bilaterally. Cervical spine also presents maximum mobility in contrast with dorsal and

lumbar segments. Variations of the FT of cervical vertebrae cause clinical conditions related with the compression of the vertebral arteries which lead to vertebrobasilar insufficiency during neck movements and may cause headache, migraine, fainting attacks and hearing disturbances [2].

The aim of the study is to identify the frequency of duplication of the FT in cervical vertebrae and other variations of foramina transversarium and to discuss the clinical importance of these variations.

MATERIALS AND METHODS

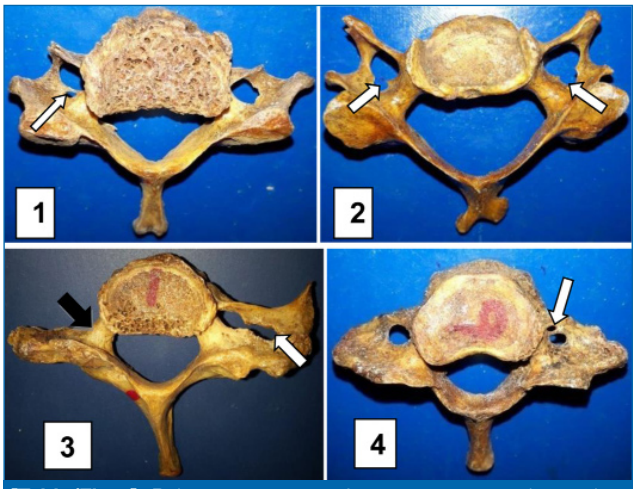
This was a retrospectively designed, single-center study. This study was conducted in Department of Anatomy, Osmania Medical College, Hyderabad, India, during the year 2016 from March to December around 10 months. 148 dried human cervical vertebrae were collected from the osteology section of the department; among them 80 were typical cervical vertebrae (C3, C4, C5, and C6) and 68 were atypical cervical vertebrae (C1, C2 and C7). The cervical vertebrae collected were from different skeletons not segregated according to age and gender. The broken vertebrae were excluded from the study. Each cervical vertebra was then segregated into typical and atypical group; among atypical again atlas, axis and seventh cervical vertebrae were separated. Then from each group all the cervical vertebrae were observed macroscopically for the variations of the FT-absence of FT, duplication of FT and also for the asymmetry of FT on both the sides. Vertebrae with variations of FT were photographed.

STATISTICAL ANALYSIS

The data was compiled and descriptive analysis was done using Microsoft Excel software.

RESULTS

Out of 148 human dried cervical vertebrae 80 typical and 68 atypical vertebrae observed for variations in FT. Out of 80 typical cervical vertebrae 13 (16.25%) vertebrae showed the accessory foramina. Among them unilateral duplication was found in 5 (6.25%) cervical vertebrae. Out of them right unilateral duplication was found in 3 (3.75%) and left duplication was found in 2 (2.5%) cervical vertebrae. While bilateral duplication was found in 8 (10%) cervical vertebrae. Thus, incidence of bilateral double FT was more common than the unilateral one. And asymmetrical FT found in 10 typical cervical vertebrae. In present study, out of 148, cervical vertebrae 68 were atypical- 38 C7, 15 C1 and 15 C2 vertebrae. Out of 38, C7 vertebrae unilateral FT found in 6 (15.78%), bilateral absent FT in 1 (2.63%), incomplete FT in 1 (2.63%), bilateral accessory FT in 1 (2.63%) and asymmetrical FT in 2 (5.26%). Out of 15 C1 vertebrae accessory FT found in 3 (20%) unilateral, incomplete FT in 1(6.66%), asymmetrical FT in 9 (60%), non union of costal element/transverse element in 1 (6.66%), retroarticular FT in 1 (6.66%) [Table/Fig-1]. Out of 15 C2 vertebrae asymmetrical FT found in 7 (46.66%) vertebrae. Thus, the incidence of absence FT was higher in C7 vertebrae. [Table/Fig-2,3]. Illustrates the variations of FT-accessory FT, asymmetry of FT and absence of FT.



[Table/Fig-1]: Points to accessory foramen transversarium points to absence of foramen transversarium 1, 3, 4 unilateral, 2 bilateral foramen transversarium in cervical vertebrae.

[Table/Fig-2]: Cervical vertebrae showing asymmetrical foramena transversaria. In a & b-L>R, in c-R>L

Variations of FT in Typical Cervical Vertebrae	No. of Vertebrae
Accessory FT	13
Asymmetrical FT	10
Total Typical Cervical Vertebrae Showing Variations	23

[Table/Fig-3]: Prevalence of variations of FT in typical cervical vertebrae.

DISCUSSION

Vertebrae are formed from the sclerotome portions of the somites, which are derived from paraxial mesoderm. A typical vertebra has a body, vertebral arch and a foramen, a transverse process and a spinous process [3]. In the cervical vertebrae vestigial costal element fused to the body and the true transverse process of the vertebra to form FT. The vertical part (second part) of the vertebral artery lying in the FT is formed from the post-costal anastomosis between the 1st to 6th cervical inter-segmental arteries [4]. This study dealt with the variations of FT-its presence, absence, asymmetry and presence of accessory FT whether unilateral or bilateral in typical and atypical cervical vertebrae. Among atypical

Variations of FT in C7 Vertebrae	No. of Vertebrae
Unilateral FT	6
Bilateral absent FT	1
Incomplete FT	1
Accessory FT-Bilaterally	1
Asymmetrical FT	2
Total C7 Vertebrae Showing Variations	11

[Table/Fig-4]: Prevalence of variations of FT in C7 vertebrae.

Variations of FT in C1 Vertebrae	No. of Vertebrae
Accessory FT	3
Incomplete FT	1
Asymmetrical FT	9
Non union of CE/TE	1
Retro articular FT	1
Total C1 Vertebrae Showing Variations	15

[Table/Fig-5]: Prevalence of variations of FT in C1 vertebrae.
CE-Costal Element; TE – Transverse Element

Variations of FT in C2 Vertebrae	No. of Vertebrae
Asymmetrical FT	7
Total C2 Vertebrae Showing Variations	7

[Table/Fig-6]: Prevalence of variations of FT in C2 vertebrae.

vertebrae atlas, axis and seventh cervical vertebrae were observed separately. These were depicted in the [Table/Fig-4-6].

In typical cervical vertebrae presence or absence of accessory FT and asymmetry of FT of both sides observed. This can be explained by the variations on the development and course of the vertebral artery according to Das S et al., [5]. In seventh cervical vertebrae we have observed absence of FT unilateral and bilateral, incomplete FT, accessory FT and asymmetrical FT. Usually vertebral artery enters FT of C6 vertebra, sometimes FT of C7 vertebra. During its course vertebral artery does not have constant caliber within FT. FT of C7 cervical vertebra may be smaller or absent. Vertebral artery usually does not pass through the FT of C7 vertebra in that case it has vertebral vein and nerve or sometimes fibrous or adipose tissue may be present, which may be the cause for small FT [6]. Sometimes FT 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 FT and so widening of FT [7]. The duplication of the vertebral artery could account for the variations of the FT [8]. In the first cervical vertebrae we have observed the presence of accessory FT, incomplete FT, asymmetrical FT and also nonunion of costal element and transverse element. In the second cervical vertebrae we have observed only asymmetrical FT. In the present study the overall prevalence of accessory FT was 11.48%. These results

[Table/Fig-7]: Atlas showing retroarticular foramen.

coincide with the results of Murugan M et al., , who observed 150 cervical vertebrae and found 12.6% of the vertebrae with accessory FT [9]. In previous studies the overall prevalence of accessory FT varied from 1.5% to 23.75% as shown in [Table/Fig-7]. In many studies the prevalence of accessory FT was higher than the present study [10-15]. The other authors had lesser prevalence of accessory FT as compared with the present study [5,16-23]. Chaudhari ML et al., reported had highest prevalence of 23.75% [10] and Das S et al., had least prevalence of 1.5% [5]. The discrepancy among these studies could be caused by diverse ethnic origin of the samples studied and by the different methodologies used by the different authors. The C3-C6 segment had a higher

Study	Number of vertebrae	Incidence of Accessory Foramen	Incidence of Accessory Foramen-Unilateral	Incidence of Accessory Foramen-Bilateral
Chaudhari ML et al., [10]	133	23.75	14.70	8.42
Kaya S et al., [11]	22	22.72	13.63	9.09
Patra A et al., [12]	150	22	10.6	11.3
Sharma A et al., [18]	200	8	3.5	4.5
Pretty R et al., [19]	140	5.7	3.6	1.42
Chandravadiya L et al., [21]	140	4.76	3.8	0.95
Katikireddi RS et al., [22]	100	3	2	1
Muralimanju BV et al., [23]	363	1.6	1.4	0.3
Present Study	148	11.48	5.40	6.08

[Table/Fig-8]: Prevalence of variations of FT in different studies.

Study	Total
Das S et al.,[5] (2005)	1.5%
Murugan M et al., [9] (2014)	12.6%
Kaya S et al.,[11] (2011)	22.7%
Patra A et al.,[12] (2015)	22.0%
Gupta RV et al.,[13] (2014)	16.5%
Shah ST et al.,[14] (2014)	16.1%
Ramachandran K et al.,[15] (2014)	15.8%
Kumari M et al.,[16] (2015)	9.8%
Nagar Y et al.,[17] (1999)	8.6%
Sharma A et al.,[18] (2010)	8.0%
Pretty R et al.,[19] (2013)	5.7%
Patil NP et al.,[20] (2014)	5.7%
Chandravadiya L et al.,[21] (2013)	4.7%
Katikireddi RS et al., [22] (2014)	3.0%
Present Study	11.48%

[Table/Fig-9]: Prevalence of accessory FT in different studies.

frequency of accessory FT, with a 16.25%, similar to the results of El Shaarawy EA et al., who observed the incidence of accessory FT as being more common in the lower cervical spine (C5, C6 and C7) [24]. Regarding the laterality of the accessory FT, in the present study we have observed a higher unilateral presentation, consistent with the findings of other authors [10,21,22]. There were many authors who worked on variations of accessory FT in cervical vertebrae. A comparison of the results of those studies is depicted in [Table/Fig-8,9].

LIMITATION

The sample size was limited and collected from different skeletons and concentrated only on the presence or absence of FT.

CONCLUSION

The knowledge of this variation of FT is clinically important in many ways, due to the variations that can be present in the vertebral artery pathway. The compression of the vertebral artery can produce neurological symptoms, such as headache, migraine, fainting and hearing disturbance. Either way, it is crucial to know the variations of the FT, particularly for the surgeons and neurosurgeons, prior to a posterior cervical surgery. For the radiologist, the importance lies on the interpretation of the medical images, such as Computed Tomography (CT scan), Magnetic Resonance Imaging (MRI), and the right presentation of the information. This study provides the information about the variations of the FT.

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