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Variations in Foramen Transversarium in Typical Cervical Vertebra

Variaciones del Foramen transverso en una Vértebra Cervical Típica

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SUMMARY: In literature were described variations in foramen transversarium in cervical vertebrae, as well as their clinical importance, and the information about them boils down to the individual case reports or population morphological studies. The aim of this paper is to contribute to the knowledge of morphological characteristics of the transverse openings on vertebrae of the cervical region. The study was performed on 60 typical vertebrae that are part of the collection of the Department of Anatomy in Nis. The characteristics of permanent openings were measured and accessory foramina were recorded. It was found that the diameter of the openings on the left side was 5.595±0.92 x 5.390±1.507 mm, and on the right 5.766±1.201 x 6.101±1.401 mm. Unilateral completely separated accessory foramina were recorded in 10.17 % of cases, dominant on the left side, and incompletely separated cases in 5.09 %. The research has demonstrated a relatively high incidence of accessory foramina and deviations from circular shaped openings.

KEY WORDS: Cervical vertebrae; Foramen transversarium; Variations; Morphometry.

INTRODUCTION

The osteological elements of the neck are the cervical vertebrae, which form the cervical part of the spinal column (columna vertebralis). The cervical part of the spinal column is in a slight lordosis and is mobile. There are seven cervical vertebrae (CI-CVII) out of 33-34, which is the total number of vertebrae in the spinal column. These are the smallest vertebrae in the spinal column. Among the cervical vertebrae, the official name in anatomical terminology is the first (atlas), the second (axis) and the seventh (vertebra prominens) and they belong to the group of atypical vertebrae, and the other cervical vertebrae, which belong to the group of typical cervical vertebrae, are marked with a latin name and an additional with the corresponding roman number (Standring, 2016).

The foramen transversarium or transversum (FT) is located on both sides in the transverse axis of the vertebral body and in front of the articular processes. It is implanted on the outside of the lateral mass of the vertebral body, between the anterior and posterior roots of the transverse process. The FT is one of the characteristic structures of the cervical vertebrae. The presence of FT distinguishes the cervical vertebrae from the other vertebrae of the spinal column. In all cervical vertebrae, most often with exception of the seventh, the vertebral artery, vertebral vein and sympathetic nerve plexus of the lower cervical ganglion pass through this opening (Standring, 2016). FT shows variations both in its shape and size and in the number of openings on one (unilateral) or on both sides (bilateral). Deformations and variations of the double opening can affect the anatomical flow of vascular and neural structures, and therefore can cause various pathological conditions that reduce the quality of life (Chaudari *et al*., 2013).

The aim of this study is to contribute to the knowledge of its variations and their frequences by examining the morphological characteristics of the foramen transversum.

MATERIAL AND METHOD

The research was performed on 60 typical vertebrae (C3 - C6) of human origin, at the Department of Anatomy of the Faculty of Medicine in Nis, which are part of the collection of this Department. All the vertebrae were numbered and photographed next to the ruler, with a Canon camera. The research was performed in compliance with all ethical principles.

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Immediately before photography, all vertebrae were cleaned for more accurate measurements. The photos obtained in this way were processed in the photo processing and analysis program ImageJ (http://rsb.info.nih.gov/ij/index.html) and morphometric analysis was performed via that software. The largest anteroposterior (AP) and largest mediolateral (ML) diameters of FT on the left and right side were measured (Fig. 1). The largest AP and ML diameters of all FTs, variable openings on the transverse processes of the analyzed vertebrae were also measured. One vertebra with mechanical damage that would compromise proper measurement of observed parameters and interpretation of results was excluded from the analysis.

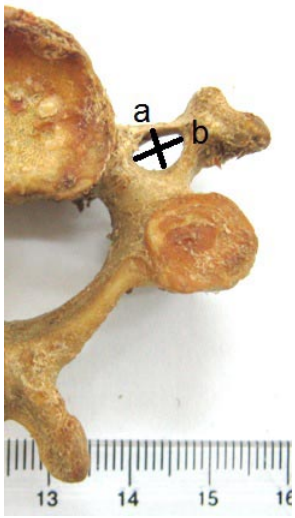

Fig. 1. Measured parameters of the foramen transversum (FT): a) the largest anteroposterior diameter of the FT; b) the largest mediolateral diameter of the FT.

Statistical analysis included the calculation of the mean, standard deviation (SD) and correlation coefficient (r). Values greater than mean+SD were treated as statistically significant increases, and values less than mean-SD as a statistically significant decrease in measured parameters. The correlation coefficient (r) was determined for the same parameters on the left and right sides to determine whether the growth of structures on one side follows the growth of structures on the other side. That parameter was also determined between the individual parameters on the right and then on the left side in order to determine their interdependence in order to determine FT circularity. One-Way ANOVA test was used to compare values between groups because it was previously established that values within groups had a normal distribution. Statistical analysis was performed in program IBM SPSS ver 25.0 (Armonk, NY: IBM Corp).

RESULTS

Figure 2 shows the mean values of the measured FT parameters on the left and right sides and their standard deviations (±SD). A statistically significant difference was noted between ML diameters, as well as between AP diameter on the left and ML diameter on the right side.

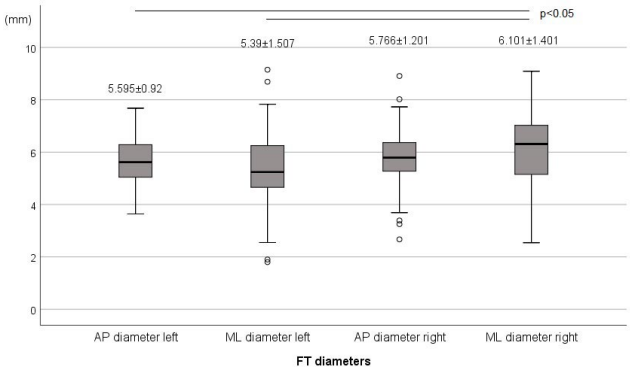

Fig. 2. Values of the FT diameters on both sides.

Table I shows the number of vertebrae that had parameters with statistically significantly increased (> mean+SD) or statistically significantly decreased (< mean-SD) values.

Table I. Number of vertebrae with significantly increased or decreased measured parameters.

		Left side		Right side	
		AP diameter	ML diameter	AP diameter	ML diameter
Number of vertebrae	> *X* - SD	11	9	8	9
	< *X* - SD	11	9	9	9

In the studied material, 6 (10.17 %) vertebrae were recorded with complete excess FT, of which 5 vertebrae had a variable foramen on the left side, and only one on the right side. Vertebrae with complete FT are shown in Figure 3, and the dimensions of the variable openings are given in Table II.

Table II. Values of the parameters of an excess foramens on transversal processes.

N° of vertebra	Left side [mm]		Right side [mm]	
	AP diameter	ML diameter	AP diameter	ML diameter
4	1.486	1.899	/	/
14	1.516	1.766	/	/
29	3.698	3.803	/	/
32	1.434	2.056	/	/
43	/	/	1.460	2.153
57	0.802	0.755	/	/

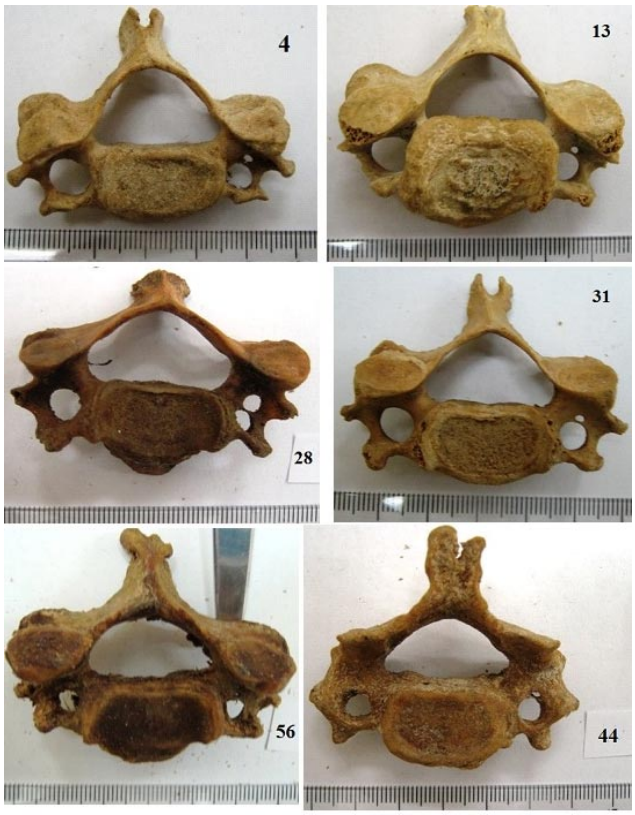

Fig. 3. Vertebrae with a complete excess foramen transversum: on the left side (vertebra No. 4, 13, 28, 31, 56 - view from above); on the right side (vertebra No. 44 - view from below).

Apart from the shown vertebrae in which completely separate supernumerary openings were recorded, three vertebrae (5.09 %) were also recorded in which there were supernumerary openings that were not completely separated from the basic opening on the transverse extension by bone tissue, but apparently continued on the basic opening. In such cases, the morphometry of additional openings was not performed, but they will be shown. In one case, such an opening was noted on the right side, in one case on the left side, and in one case bilaterally (Fig. 4).

The correlation coefficients between the measured parameters are shown in Table III. Correlation analysis compared parameters on the left with the same parameters on the right side, as well as parameters on the right side with each other and parameters on the left side with each other. The observed correlation coefficients indicate a more circular shape of the FT on the right side compared to a more elliptical shape on the left side. In addition, the size of the FT on one side has a very small, almost completely negligible effect on the size of the FT on the other side.

Table III. Correlation coefficient (r) between measured parameters.

r		Left side AP diameter	Left side ML diameter	Right side AP diameter	Right side ML diameter
Left side	AP diameter	0.413	0.387	0.25	
	ML diameter		0.116	0.051	
Right side	AP diameter			0.627	

DISCUSSION

The opening at the transverse process of the cervical vertebra is formed by the fusion of parts of the stunted cervical rib with the body and the true transverse process of the vertebra (Murugan & Verma 2014). The vertebral artery, vertebral vein and sympathetic nerve fibers pass through the opening on the transverse process. The spinal segment of the vertebral artery almost always begins at the level of the C6 vertebra (Kaya *et al*., 2011), but vertebral artery can begin its spinal course in other levels form C5 to even C2, and it also can be C7 (Murlimanju *et al*., 2011; Siedlecki *et al*., 2021; Yi *et al*., 2022).

Fig. 4. Vertebrae with incompletely separated excess foramen transversum (view from above): on the right side (vertebra No. 38); on the left side (vertebra No. 44); bilaterally (vertebra No. 46).

According to Shah *et al*. (2014), De Boeck *et al*. (1984) argue that the FT is anatomically described as an opening fronted by a fibrous or bony bridge, separating an artery from a vein. The most often described is a large anterior and small posterior opening through which the branch of the lower cervical ganglion and the vertebral vein pass (Shah *et al*., 2014). Spinal vessels, arteries and veins are responsible for the formation of the FT, and from this fact it can be assumed that the variations of the spinal vessels during their formation will be reflected in the variations of the FT, and that is precisely why the examination of variations considers this opening (its shape, size, doubling) important because it directly indicates the variations of the blood vessels that pass through it (Sharma *et al*., 2010). The narrower the opening itself, the smaller the caliber of the spinal vessels, because the variations of the vessels correspond to the variations of the opening and vice versa (Shah *et al*., 2014). However, as this opening is variable, not only in terms of shape and size, but can also be doubled, a logical question arises - will the artery also be doubled in this case? According to Sharma *et al*. (2010), Hashimoto *et al*. claim that such anomalies are very rare, but they have been reported. If they do exist, a duplicated artery will pass through the duplicated, auxiliary opening, which mostly parallels the main artery that passes through its FT, and the length of that variable artery is also variable. According to Sharma *et al*. (2010), Tran-Dinh claims that this variation is less than 1 % in anatomical dissections. In a study that analyzed geographic differences in the frequency of supernumerary FTs, a statistically significantly higher frequency of accessory FTs was noted in Caucasian Mediterranean subjects compared to sub-Saharan African subjects. Supernumerary FTs are most often noted on the C6 and C5 vertebra (Sanchis-Gimeno *et al*., 2019).

Authors who also dealt with variations of the FT on typical cervical vertebrae, obtained different data on their incidence. In the work of Murlimanju *et al*. (2011), stated that in a study that included 363 cervical vertebrae, a supernumerary FT was recorded in 1.6 % of cases and only in 0.3 % bilaterally, but in 0.3 % of cases two supernumerary FT were recorded unilaterally. Rathnakar & Remya (2013), recorded a supernumerary FT in 5.7 % (8/140) of cervical vertebrae, in 3.6 % it was unilateral and dominant on the right side. Shah *et al*. (2014), studied 210 cervical vertebrae and observed a supernumerary FT in 16.19 % of cases (9.52 % unilateral). In two-thirds of the supernumerary FT, they were completely formed openings. Chaudhari *et al*. (2013), in a series of 133 cervical vertebrae, recorded a supernumerary FT in 23.15 % of cases (14.73 % unilateral). Patil *et al*. (2014), in a series of 175 (typical and atypical) cervical vertebrae recorded a supernumerary opening in 5.71 % of cases (3.42 % unilateral). Another study showed that in 150 cervical vertebrae, an accessory FT was observed in 19 (12.6 %) vertebrae, of which 15 were typical and 4 atypical. Among the typical ones, 12 vertebrae had supernumerary FT on the right side, one on the left side, and two vertebrae had bilateral supernumerary FT (Murugan & Verma, 2014). Sharma *et al*. (2010), in 8 % (16/200) of typical cervical vertebrae recorded a supernumerary FT, dominantly unilateral, where they pointed out that the appearance of a supernumerary opening is more common the lower the cervical vertebra is positioned. This statement is confirmed by the findings of Jaffar *et al*. (2004), who emphasize their finding that in 70 % of cases the supernumerary FT was located on the C6 vertebra. In the available literature, this work was the first that study the FT area, but only of permanent FT, and the circular shape of the openings is emphasized in the work. The other papers studied the areas of supernumerary FTs and found that in accessory FTs, the ratio of the area of the FT to the diameter of the vertebral artery is smaller. This is contrary to the claim that the diameter of the artery correlates with the diameter of the FT, but it also relates to the permanent FT. The authors state that the smaller ratio of the diameter of the accessory FT compared to the artery would be the reason why neurological symptoms related to the vertebrobasilar system appear more often in patients with an accessory FTs. (Sanchis-Gimeno *et al*., 2018; Tuncel Çini *et al*., 2023).

In our research, out of a total of 59 cervical vertebrae that were studied, 9 (15.25 %) supernumerary, accessory openings were found. The accessory FT occurred unilaterally in 8 (13.56 %) cervical vertebrae, predominantly on the left side, which deviates from the majority of findings in the available literature. In 6 (10.17 %) cervical vertebrae, the supernumerary FT was completely formed, and in 3 (5.09 %) cervical vertebrae, the accessory FT was not complete. Bilateral occurrence of accessory FT was found in 1 (1.69 %) cervical vertebra, where both openings were incomplete. Incomplete openings were "completed" in the living individuals with a fibrous bridge, which was destroyed after manipulation and cleaning of the vertebra.

In studies performed on CT scans, it was possible to analyze the differences between certain typical cervical vertebrae. In such studies, the possibility of a difference in the size of the opening on the same side of different cervical vertebrae was emphasized. In our research, the ordinal numbers of the cervical vertebrae were not defined, so it was not possible to compare vertebrae with different C numbers. In addition, if we analyze the average values of the size of FT in the studies of the population of Brazil, Jordan, North India and Turkey (Moreira Moreira & Herrero, 2020; El-Dwairi *et al*., 2021; Patra *et al*., 2022; Tuncer & Alkan, 2023), the results of our research do not differ

significantly. It could also be concluded that the average sizes of FT in people of different populations are very similar.

This research confirmed the findings available in the literature related to the dominant unilateral appearance of supernumerary FT of the cervical vertebrae, but also provided a unique morphometric analysis that refers to both permanent and supernumerary openings. Our results indicate a discrete deviation from the regular circular shape of the FT, with the fact that the permanent openings on the right transverse extension (which had a shape that most closely matched the circular one) had a discretely larger ML diameter, and on the left side, it was AP diameter. Supernumerary FTs, regardless of lateralization, had a discretely larger ML diameter. This study did not record three openings on one transverse processus, as well as the absence of the FT.

Knowing this morphological variation is very important in clinical practice because it can indicate a changed course of the vertebral artery. Compression or other pathological conditions on the vertebral artery can lead to neurological symptoms and sometimes hearing disorders. Knowledge of these variations is important for neurosurgeons during neck operations, especially the posterior region of the neck, as well as for radiologists during analysis of the CT or MRI images, but also for any other diagnostic procedure in this part of the body.

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RESUMEN: En la literatura se describen variaciones en el foramen transverso de las vértebras cervicales, así como su importancia clínica, y la información sobre ellas se reduce a informes de casos individuales o estudios morfológicos poblacionales. El objetivo de este trabajo fue contribuir al conocimiento de las características morfológicas de los forámenes transversos de las vértebras cervicales. El estudio se realizó en 60 vértebras típicas que forman parte de la colección del Departamento de Anatomía de Nis. Se midieron las características de los forámenes constantes y se registraron los forámenes accesorios. Se encontró que el diámetro de los forámenes del lado izquierdo era de 5,595±0,92 x 5,390±1,507 mm, y del derecho de 5,766±1,201 x 6,101±1,401 mm. Se registraron forámenes accesorios unilaterales completamente separados en el 10,17 % de los casos, dominantes en el lado izquierdo y casos incompletamente separados en el 5,09 %. La investigación ha demostrado una incidencia relativamente alta de forámenes accesorios y desviaciones de forma circular.

PALABRAS CLAVE: Vértebras cervicales; Foramen transverso; Variaciones; Morfometría.

REFERENCES

Chaudhari, M. L.; Maheria, P. B. & Bachuwar, S. P. Double foramen transversarium in cervical vertebra: morphology and clinical importance. *Indian J. Basic Appl. Med. Res., 8(2)*:1084-8, 2013.

El-Dwairi, Q. A.; Abu Ghaida, J. H.; Isa, H. M.; Al-Mousa, A. A.; Marashdeh, W. & Al-Muqbel, K. M. Morphometric study of foramina transversaria in Jordanian population using cross-sectional computed tomography. *Anat. Sci. Int., 96(1)*:70-8, 2021.

Kaya, S.; Yilmaz, N. D.; 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., 21(4)*:534-8, 2011.

Moreira Moreira, J. J. & Herrero, C. F. P. S. Anatomical variations and morphometric features of the foramen transversarium in the cervical vertebrae of a latin american population: a brazilian study. *World Neurosurg., 137*:e18-e26, 2020.

Murlimanju, B. V.; Prabhu, L. V.; Shilpa, K.; Rai, R.; Dhananjaya, K. V. N. & Jiji, P. J. Accessory transverse foramina in the cervical spine: incidence, embryological basis, morphology and surgical importance. *Turk. Neurosurg., 21(3)*:384-7, 2011.

Murugan, M. & Verma, S. A study on variations of foramen transversarium of cervical vertebrae. *Natl. J. Clin. Anat., 3(1)*:4-7, 2014.

Patil, N. P.; Dhapate, S. S.; Porwal, S. & Bhagwat, V. B. The study of incidence of accessory foamen transversaria in the cervical vertebrae. *IOSR J. Dent. Med. Sci., 13(7)*:85-7, 2014.

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., 32(1)*:36-42, 2022.

Rathnakar, P. & Remya, K. Study of accessory foramen transversaria in cervical vertebrae. J. Health All. Sci. NU, 3(4):97-9, 2013.

Sanchis-Gimeno, J. A.; Blanco-Perez, E.; Llido, S.; Perez-Bermejo, M.; Nalla, S. & Mata-Escolano, F. Can the transverse foramen/vertebral artery ratio of double transverse foramen subjects be a risk for vertebrobasilar transient ischemic attacks? *J. Anat., 233(3)*:341-6, 2018.

Sanchis-Gimeno, J. A.; Quiles-Guiñau, L.; Llido-Torrent, S.; Aparicio, L.; Nalla, S. & Miquel-Feutch, M. Possible clinical implications of geographic differences in prevalence of double transverse foramen. *World Neurosurg,. 126:*e570-e572, 2019.

Shah, S.; Arora, K. & Shah, K. P. Study of accessory foramen transversarium in cervical vertebrae. *GCSMC J. Med. Sci., 3(2)*:21-4, 2014.

Sharma, A.; Singhp, K.; Gupta, V. & Srivastava, S. Double foramen transversarium in cervical vertebra an osteological study. *J. Anat. Soc. India, 59(2)*:229-31, 2010.

Siedlecki, Z,; Szostak, M.; Nowak, K. & S´niegocki, M. Atypical course of vertebral artery outside the cervical spine: case report and review of the literature. *World Neurosurg. 145*:405-8, 2021.

Standring, S. *Gray's Anatomy. The Anatomical Basis of Clinical Practice*. 41st ed. New York, Elsevier, 2016.

Tuncel Çini, N.; Nalla, S.; Mata-Escolano, F.; Blanco-Perez, E.; Valenzuela-Fuenzalida, J. J.; Orellana-Donoso, M. & Sanchis-Gimeno, J. A. Double transverse foramina-an anatomical basis for possible vertebrobasilar insufficiency risk and vertebral artery injury. *Diagnostics (Basel), 13(19)*:3029, 2023.

Tuncer, I. & Alkan, E. Morphometric study of cervical spinal canal and transverse foramen diameter using computed tomography: Sex difference and relationship to age in Turkish population. *Medicine (Baltimore), 102(49)*:e36155, 2023.

Yi, X.; Xie, P.; Zhang, L.; Lu, F.; Chen, H. & Liu, K. Entrance and origin of the extracranial vertebral artery found on computed tomography angiography. *Sci Rep. 12(1)*:15274, 2022.

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