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Anatomical Variations of the Foramen Transversarium in Cervical Vertebrae

Variaciones Anatómicas del Foramen Transverso en Vértebras Cervicales

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SUMMARY: The cervical vertebrae are recognized mainly by the presence of the foramen transversarium, which is crossed by the vertebral artery and vein, accompanied by sympathetic fibers. The main objective of this study was to observe and describe the anatomy and variations in the foramen transversarium. 121 cervical vertebrae were analyzed, including the macroscopic characteristics, shape and diameter and presence of the foramen transversarium, as well as the accessory foramen transversarium. All cervical vertebrae presented the foramen transversarium, with a mean diameter of 5.60 mm and a mean diameter of 4.40 mm on the right and 5.92 mm - 5.56 mm on the left, respectively. With regard to shape classification according to Taitz *et al*. (1978), 90.08 % presented the same shape on both sides, and 9.91 % had different shapes. The presentation of the different shapes was as follows: shape 1 41.32 %; shape 2 4.13 %; shape 3 18.8 %; shape 4 14.04 %; and shape 5 12.39 %. Regarding the presence of accessory foramen transversarium, 17.35 % of the vertebrae presented it, 66.6 % unilateral, 57.14 % on the right side and 42.85 % on the left side. Osteophytes, were presented in 5.7 %. The anatomical knowledge of these variations is useful for spine surgeons in preoperative planning and for preventing vertebral vessel and sympathetic nerve injuries during cervical surgical approaches.

KEY WORDS: Cervical vertebra; Foramen transversarium; Accessory foramen; Vertebral artery.

INTRODUCTION

The cervical vertebrae are mainly recognized by the presence of the foramen transversarium (FT), located in the transverse process and inside it the course the vertebral artery and vein, accompained by the simpathetic plexus (Sanchis-Gimeno *et al*., 2005). The variations are mainly associated with the width and path of the vascular elements (Das *et al*., 2005), and this may cause alterations like vertebrobasilar insufficiency (Kaya *et al*., 2011), or modify the blood flow, due to a strong link between the diameter of the FT and the blood flow of the vertebral artery (Kotil & Kilincer, 2014).

The anatomical details in the FT variations are important for physicians, and radiologist in the interpretation of the medical images (Murlimanju *et al*., 2011). This importance is that the lesions in both the FT and the vertebral artery may be produced by penetrating injuries, trauma lesions, and overall after vascular compression secondary to fractures or luxations (Dalgic *et al*., 2009).

It is possible to observe the presence of abnormal bony outgrowths (ostephytes) inside the FT, which theoretically can produce lesions to the vertebral artery, vein, and the sympathetic plexus (Strek *et al*., 1998). The external pressure generated by the degenerative changes in the cervical spine, can produce compressión of the vertebral artery (Cockerill *et al*., 2000).

The aim of this study is to ascertain the incidence of the alterations of the FT in the cervical vertebrae, analyze then mophologically emphasizing in its surgical and clinical relevance.

MATERIAL AND METHOD

One hundred and twenty-one cervical vertebrae from a Chilean population were obtained from the Department of

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Basic Biomedical Sciences of the Universidad de Talca, Chile. All of the vertebrae included were in good condition, with no signs of trauma, infectious or neoplastic diseases, and with no apparent deformities. All measurements were bilaterally conducted by three independent observers using a digital Vernier caliper (Fowler Sylvac) to an accuracy of 0.01 mm precision. The sex and age of the bones are unknown. For the analysis, every vertebra was indentified and numbered.

The FT were observed macroscopically in each vertebra on both sides, as well as the presence of the accesory foramen transversarium (AFT). The maximum and minimum diameters of the FT were measured bilaterally using a digital caliper. We also studied the presence of ostephytes in the unciform process. The FT shape was recorded according to the parameters of Taitz *et al*. (1978).

RESULTS

A total of 121 cervical vertebrae were analyzed, 30 for each level (C3, C4, C5, C6, C7). Of the 121 cervical vertebrae, all presented FT with a mean maximum and minimum diameter media of 5.60 mm and 4.40 mm on the right side respectively, and 5.92 mm and 5.57 mm on the left side. The values by segment are shown in Table I.

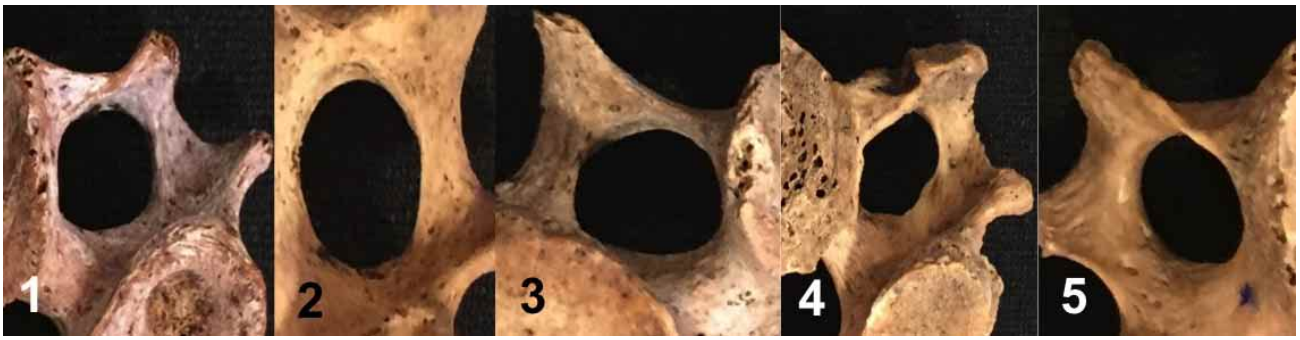

Fig. 1. Classification of the foramen transversarium according to Taitz *et al*., 1978.

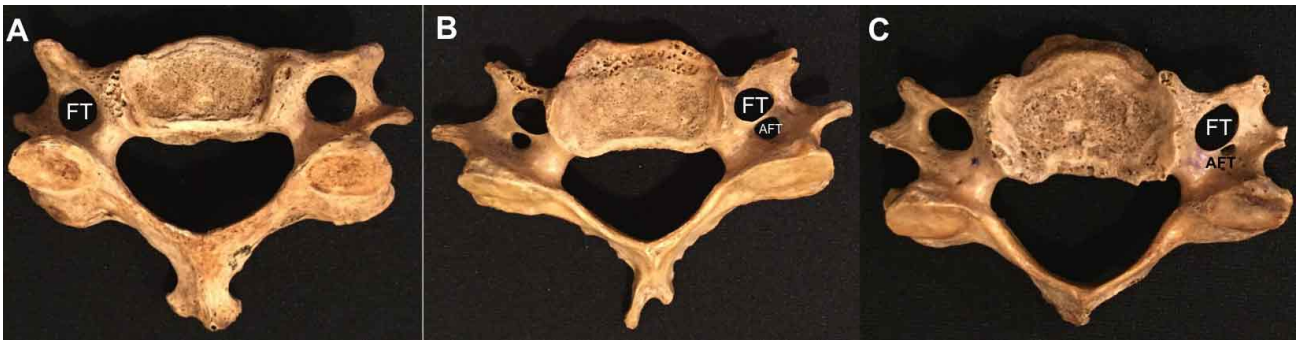

Fig. 2. Cervical vertebrae. A. Foramen transversarium (FT). B. Bilateral accessory foramen transversarium (AFT). C. Unilateral accessory foramen transversarium.

Table I. Cervical vertebrae characteristics. Maximum left (Max. left); Minimum left (Min. left) diameters; Maximum right (Max. right) and minimum right (Min. right) of the vertebrae. Shape as described by Taitz *et al*. (1978). The mixed (mix) classification corresponds to the vertebrae presented differently to the right and left. The presence of osteophytes (OST) and accessory foramen transversarium (AFT).

Cervical vertebrae	n	Diameter (mm)				Shape (%)						OST (%)	AFT (%)
		Max. Left	Min. Left	Max. Right	Min. Righ	1	2	3	4	5	Mix		
C1	25	7.01	5.51	6.63	4.98	20	20	0	24	24	12	1 (4)	4 (16)
C2	22	8.82	4.53	6.11	4.78	68	0	4.5	0	22	0	0 (0)	0 (0)
C3-C6	64	5.29	4.43	6.11	5.15	43.7	0	32	15.6	3.1	7.8	5 (7.8)	15 (23.4)
C7	9	5.42	4.72	5.3	4.47	33.3	0	0	11.1	11.1	4.8	1 (11.1)	2 (22.2)
Total	121					41.3	4.1	18.8	14	12.3		5.7	17.35

Using the shape classification by Taitz *et al*., 90.08 % presented the same shape bilaterally, and in a 9.91 % in differents shapes. The presentation of distinct shapes is as it follows: shape 1 41.32 %; shape 2 4.13 %; shape 3 18.8 %; shape 4 14.04 %; shape 5 12.39 % (Fig. 1).

With regard to the presence of AFT, 17.35% of the vertebrae presented it, being a 66.6 % unilaterally, 57.14 % on the right side and 42.85 % on the left (Fig. 2).

DISCUSSION

In the past, various authors have conducted many studies regarding the variations in number, size and shape of the FT. The AFT is a low-frecuency anatomical variation, and it may therefore be possible to predict the modification in the course and in the pattern of the vertebral artery, vertebral vein and sympathetic nerves inside the FT (Aydinogly *et al*., 2001), and it is also possible to find a duplicated vertebral artery (Taitz *et al*.).

With respect to the shape and diameter of the FT, Sangari *et al*. (2015), found the mean diameter of the right and left FT varied from 2.54 mm to 7,79 mm (mean: 5.55 ± 0.87 mm) and from 2.65 mm to 7.35 mm (mean: 5.48 ± 0.77 mm) respectively. These values are different from our results. In our study, we categorized the shape of the FT according to the criteria by Taitz *et al*. We found that most of the foramina on the right and left sides had shape 1. This contrasts with the work done by other authors that shape 4 was predominant (40.2 %), on the right side, while shapes 2 and 5 were predominant (39.2 % each) on the left (Karau & Odula, 2012).

By contrast, the presence of the AFT, has been previously reported (Taitz *et al*.; Aydinoglu *et al*., 2001; Murlimanju *et al*.; Das *et al*.; Sharma *et al*., 2010; Chandravadiya *et al*., 2013; Rathnakar *et al*., 2013; Agrawal *et al*., 2012; Murugan & Verma, 2014), in different populations with distinct results. Aydinoglu *et al*. (2011) in his study, after observing 222 cervical vertebrae, reported a frequency of 6.7 % of the AFT on both sides; meanwhile, Das *et al*. and Kaya *et al*. reported values of 1.5 % and 22.7 % respectively. Agrawal *et al*. reported the presence of a bilateral ATF in 1.25%, and unilateral in 2.5 % from a total of 160 typical cervical vertebrae. Conversely, Katikieddi & Setty (2014) studied 100 cervical vertebrae, and reported the presence of AFT in 3%, with 2 % and 1% located unilaterally and bilaterally respectively. Other authors report double FT in 22.00 % vertebrae, among which double foramen were observed unilaterally in 10.67 % vertebrae and bilaterally in 11.33 % vertebrae (Patra *et al*., 2015).

Meanwhile, in the present study, we observed the AFT in 17.35% of the cases. These data are similar to the results reported by Murugan & Verma, who observed 150 cervical vertebrae, finding 12.6 % of the vertebrae with an AFT, and Mishra *et al*. (2014), who reported 14.09 % cases from a total of 220 dry typical (C3-C6) cervical vertebrae from both sexes. The C3-C6 segment had a higher frecuency of AFT, with a 23,4 %, similar to the results of El Shaarawy *et al*., who observed the incidence of AFT as being more common in the lower cervical spine (C5, C6 and C7). Regarding the locations of the AFT, in our study we observed a higher unilateral presentation, consistent with the findings of other authors (Agrawal *et al*.; Chandravadiya *et al*.; Chaudhari *et al*., 2013; Katikireddi & Setty).

Osteophytes were present in 5.7 % of the vertebrae, presenting mostly in the C7 segment, much lower than those reported by Sanchis-Gimeno *et al*. (2005), which indicate that the C6 segment is the most prevalent (39.28 %), at 15 % of the vertebrates analyzed (n=560).

The embryological development of the vertebral artery, the main content of the FT, may be closely related to the presence of these variations. The vertebral artery develops from the fusion of the longitudinal anastomosis that joins the cervical intersegmentary arteries, which branches from the primitive dorsal aorta (Ionete & Omojola, 2006). The duplication of the vertebral artery, is thought to represent the failure of the controlled regression of two intersegmentary arteries, and a segment of the primitive dorsal aorta. Further, developmental changes could account for the variations observed. Previous authors have cited stress and posture in the erect human as factors responsible for shaping the bony architecture of the neck region (Taitz & Nathan, 1986).

The morphological knowledge of this variation type is clinically important in many ways, due to the modifications 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 auditive disorders. Either way, it is crucial to knowing the alterations of the FT, particulary for the surgeons and neurosurgeons, prior to a posterior cervical surgery. Fort he 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 informs. Our study provides more information about the incidence and morphological characteristics of the FT.

In conclusion, despite of the difference in results in the studies corresponding to the FT, in terms of sample, sex and segments to be analyzed, this report provides additional information about the incidence and morphology of the FT

and it's variations. The presence of an AFT in all the vertebrae was of 17.35 %, with the C3-C6 segment having the highest incidence (23.4 %). The unilateral presentation is the most common. The morphological knowledge is clinically and surgically important, given that the course of the vertebral artery may be disturbed in such situations. Further studies about this topic can be correlated with the data found in medical images and clinical histories or patients symptoms.

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RESUMEN: Las vértebras cervicales son reconocidas principalmente por la presencia del foramen transverso (FT), por el cual transita la arteria y vena vertebral además de fibras simpáticas. Las variaciones en el FT pueden estar asociadas con una alteración en el calibre y el curso de la arteria vertebral. El objetivo del presente estudio fue observar y describir la anatomía así como las variaciones en el FT. Fueron analizadas 121 vértebras cervicales, en las cuales el FT fue observado macroscópicamente de manera bilateral así como el foramen transverso accesorio (FTA) en las que se encontrara presente. La forma y diámetros máximo y mínimo del FT fue medido de manera bilateral con ayuda de un cáliper digital. De 121 vértebras cervicales, la totalidad presentaron FT con diámetros máximo y mínimo derecho de 5,60 y 4,40 mm respectivamente y de 5,92 y 5,56 mm máximo y mínimo del lado izquierdo. Con respecto a la clasificación de forma de Taitz *et al*. (1978) el 90,08 % presentó la misma forma de manera bilateral y un 9,91% formas distintas. La forma 1 se presentó en un 41,32 %, la 2 en un 4,13 %, forma 3 18,8 %, 4 14,04 % y 5 en 12,39 %. Con respecto a la presencia de FTA, un 17,35 % lo presentó, siendo 66,6 % unilaterales, un 57,14 % derecho y 42,85 % izquierdo. La anatomía y variaciones en el FT y la arteria vertebral y los componentes nerviosos están interrelacionados. Su conocimiento morfológico es clínicamente importante, ya que el curso de la arteria vertebral puede distorsionarse en tales situaciones. Por lo que es importante a la hora de adoptar medidas cautelares para salvaguardar la arteria vertebral en las cirugías de columna cervical.

PALABRAS CLAVE: Vértebra cervical; Foramen transverso; Foramen accessorio; Arteria vertebral.

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