Int. J. Morphol.,
36(4):1439-1446, 2018.

The Foramen Transversarium of Typical and Atypical Cervical Vertebrae: Morphology and Morphometry

El Foramen Transverso de Vértebras Cervicales Típicas y Atípicas: Morfología y Morfometría

R. Sheik Abdul; L. Lazarus; C. Rennie & K. S. Satyapal

SHEIK ABDUL, R.; LAZARUS, L.; RENNIE, C. & SATYAPAL, K. S. The foramen transversarium of typical and atypical cervical vertebrae: morphology and morphometry. *Int. J. Morphol., 36(4)*:1439-1446, 2018.

SUMMARY: The seven cervical vertebrae found in the human body are classified into typical and atypical vertebrae. Their transverse processes contain foramen transversarium (FT) and traditionally there is one foramen present on each side, of similar size. However, variations of this foramen regarding its shape, size, number, laterality, location and osteometric characteristics have been documented in the literature. This morphological and morphometric study was conducted on 126 cervical vertebrae (82 typical and 44 atypical) obtained from the osteological bank at the University of Kwa-Zulu Natal to produce a database which may serve as a useful guideline to medical personnel. There were variations observed regarding shape, number of FT, laterality and position, which have not previously been reported. The most types of variations were evident in the typical cervical vertebrae, then secondly, the seventh cervical vertebrae. The axis vertebrae did not display any accessory FT or variations.

KEY WORDS: Cervical vertebrae; Typical cervical vertebrae; Atypical cervical vertebrae; Foramen transversarium; Vertebral artery.

INTRODUCTION

Foramen transversarium (FT) are bony canals found only in the transverse processes of cervical vertebrae (Dofe *et al*., 2015; Mulla & Pundge, 2015). There is normally one FT on each side of the vertebrae and are usually of a similar shape and size to each other (Moore *et al*., 2010). Kaya *et al*. (2011) reported that the shape and size of the FT varies for different vertebrae and individuals.

The transverse process is comprised of an anterior part known as the costal process and a posterior part, termed the true transverse process (Baylan, 2016). The FT exists by the formation of the transverse process whereby the costal element fuses to the body and the true transverse process (Patra *et al*., 2015). These foramen transmit the vertebral artery (VA), vertebral vein (VV) and vertebral nerve (Dofe *et al*.; Sabnis, 2015). However, the FT of C7 only transmits the VV and may sometimes be small or absent because the VA enters its vertebral course almost always through the FT of C6 (Dofe *et al*.; Sabnis).

The FT have been reported to have varying shapes based on its main (largest) diameter or direction of axis (Karau & Odula, 2013; Ramachandran *et al*., 2014). Type A is described as round, whilst Types B, C, D and E are elliptical with main diameters in an anteroposterior, transverse, oblique right to left and oblique left to right directions, respectively (Karau & Odula; Ramachandran *et al*.).

Different terminologies were used by many authors that reported varying number, shape and laterality of FT (Akhtar *et al*., 2015; Dofe *et al*.; Gujar *et al*., 2015; Sabnis; Sangari *et al*., 2015; Esakkiammal & Chauhan, 2016; Molinet *et al*., 2017). Studies have displayed three complete FT present on a vertebra, with one on one side and two on the other- these have been termed unilateral complete double (accessory) FT (Murlimanju *et al*., 2011; Karau & Odula; Ramachandran *et al*.; Yadav *et al*., 2014; Akhtar *et al*.; Sangari *et al*.; Esakkiammal & Chauhan; Molinet *et al*.). Murlimanju *et al*. and Rathnakar *et al*. (2013) also found triple FT unilaterally on a typical cervical vertebra. Some studies also observed the presence of double FT on both sides of the cervical vertebrae – these are referred to as bilateral complete double (accessory) FT (Sangari *et al*.; Esakkiammal & Chauhan).

Discipline of Clinical Anatomy, School of Laboratory Medicine and Medical Science, College of Health Sciences, University of KwaZulu-Natal, Westville Campus, Private Bag X54001, Durban, 4000, South Africa.

Incomplete FT occur when the bone does not completely enclose the FT. These can be present as single or double incomplete FT (Sabnis; Esakkiammal & Chauhan). The latter has a double bubble appearance (Sabnis).

Murlimanju *et al*. observed that accessory FT were only present in the lower cervical vertebrae (C6 and C7). Ramachandran *et al*. reported no accessory FT occurring in C1 and C2 vertebrae, whilst Akhtar *et al*. recorded absent accessory FT in only C2 vertebrae. Esakkiammal & Chauhan documented only their typical cervical vertebrae as having accessory FT.

The morphometric size of the FT was established by studies that displayed measurements of its anteroposterior and transverse diameters (Karau & Odula; Sangari *et al*.). Karau & Odula found the difference between the transverse and anteroposterior diameters to be statistically significant.

Deformities and variations in FT may result in vertebral vessels being compressed by movements (Mulla & Pundge). This may cause vascular insufficiency which leads to common symptoms like migraines, shoulder pain, neck pain or severity of cerebrovascular incidents (Sultana *et al*., 2015). The blood flow can therefore be modified due to a strong link existing between the diameter of the FT and the blood flow of the VA (Kotil & Kilincer, 2014).

This study aimed to investigate the morphology and morphometry of the FT in typical and atypical cervical vertebrae and to report on any variations thereof.

MATERIAL AND METHOD

Osteometric investigations were performed on 126 (82 typical and 44 atypical) dried human cervical vertebrae which were obtained from the existing osteological bank at the Department of Clinical Anatomy, University of KwaZulu-Natal. Metric as well as non-metric parameters were analyzed and a database was created. Vertebrae with damaged or broken FT were excluded, whilst vertebrae with the bilateral presence of FT were included. Age and sex were not documented. Morphology was established by macroscopically analysing the FT superiorly, and recording the shape present on each side in accordance with the criteria employed by previous authors (Karau & Odula; Ramachandran *et al*.; Molinet *et al*.). For those that did not fit into the criteria, they were classified as type F-M for ease of reference and then checked by a second observer for confirmation. Variations, regarding laterality in number and shape of FT, were documented. The larger FT were taken as the main, while the smaller were accepted as the accessory FT (Dofe *et al*.). The position of the accessory FT on each side in relation to the main FT were recorded. Unusual sizes in appearance of the FT were also documented.

Morphometry was established by using a digital caliper (Whitworth - 0.01mm precision). Measurements were collected superiorly of the anteroposterior and transverse diameters of the main FT. Each diameter was measured three times to reduce intra-observer error. The average was then calculated. The data collected was analysed using STATA (Version 13). The Pearson Chi-Square and the One-Way ANOVA tests were implemented. All p values that were less than 0.05 were deemed statistically significant. Ethical clearance was obtained for this study from the Biomedical Research Ethics Committee (BREC) of the University of KwaZulu-Natal (BE288/17).

RESULTS

Incidence. There were 82 (65.08 %) typical and 44 (34.92 %) atypical cervical vertebrae in the sample analysed. Of the atypical cervical vertebrae, 9 (7.14 %) were identified as C1 vertebrae, 15 (11.90 %) were C2 and 20 (15.87 %) were C7 vertebrae. The incidence of the parameters investigated were calculated out of the total number of typical (n=82) and atypical (n=44) cervical vertebrae, bilaterally.

Morphology

(i) Shape of Main FT. The various shapes of the FT were classified into groups viz. Types A-M. Type A was described as being round; Type B was elliptical with the largest anteroposterior diameter; Type C was elliptical with the largest transverse diameter; Type D was elliptical with a large oblique diameter from right to left; Type E was elliptical with a large oblique diameter from left to right; Type F was triangular; Type G was square; Type H was rectangular; Type I was kite-shaped; Type J was leaf shaped; Type K was a semicircle; Type L was irregularly shaped and Type M was termed double bubble (incomplete double). Figure 1 displays Types F-M which are unique to this study. The incidences of the shapes of the FT is recorded in Table I and II for right and left sides, respectively. By comparing the type of cervical vertebrae (typical and atypical) with the shape of the right FT, a p value of <0.001 had resulted (Table I). When compared with the left FT, the same p value was obtained (Table II).

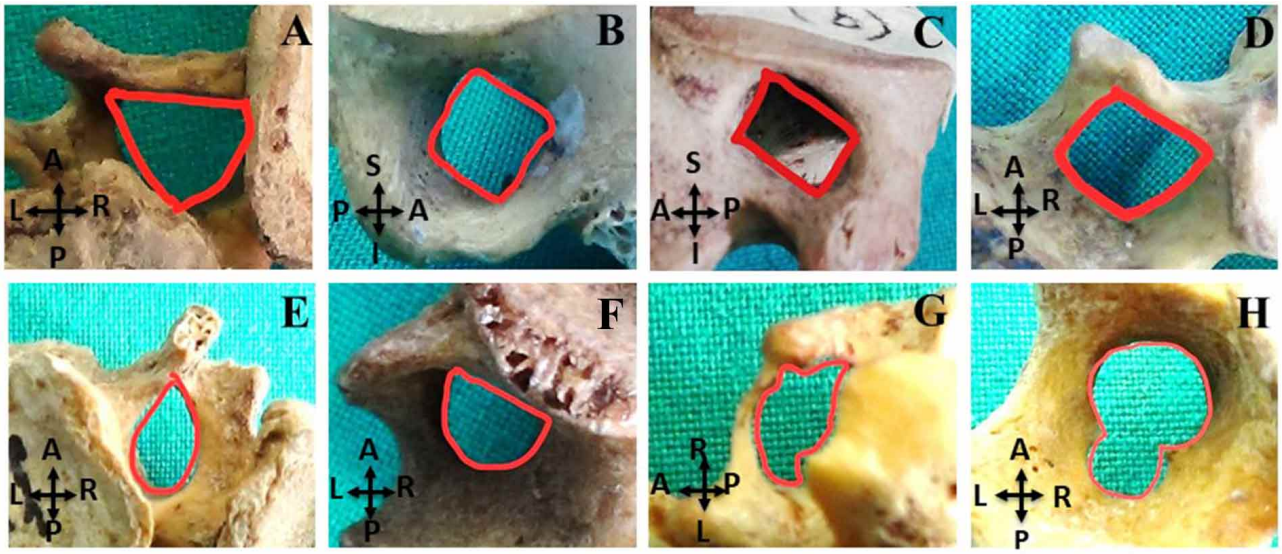

Fig. 1. Variant shapes observed in the current study. A: Type F; B: Type G; C: Type H; D: Type I; E: Type J; F: Type K; G: Type L; H: Type M.

Table I. Incidence of cervical vertebrae vs. shape of main FT on the right side.

Shape of Right FT	Vertebra (%)				Total (%) (n=126)
	Typical (n=82)	Atypical (n=44) C1	C2	C7	
Type A: Round	34.15	2.27	6.82	2.27	26.19
Type B: Elliptical (anteroposterior)	0	9.09	2.27	0	3.97
Type C: Elliptical (transverse)	14.63	0	0	0	9.52
Type D: Elliptical (oblique: right to left)	18.29	2.27	9.09	0	15.87
Type E: Elliptical (oblique: left to right)	6.10	2.27	0	11.36	8.73
Variations					
Type F: Triangular	13.41	0	2.27	0	9.52
Type G: Square	0	0	4.55	0	1.59
Type H: Rectangular	0	0	2.27	0	0.79
Type I: Kite	1.22	0	2.27	0	1.59
Type J: Leaf	0	0	2.27	6.82	3.17
Type K: Semicircle	2.44	0	0	2.27	2.38
Type L: Irregular -	1.22	0	2.27	9.09	4.76
Type M: Double Bubble (incomplete double)	8.54	2.27	0	13.64	11.11
				P value = < 0.001	

Table II. Incidence of cervical vertebrae vs. shape of main FT on the left side.

Shape of Left FT		**Vertebra**				**Total (n=126)**
		Typical (n=82)	**Atypical (n=44)**			
			C1	**C2**	**C7**	
Type A: Round		32.93	2.27	20.45	0	**29.37**
Type B: Elliptical (anteroposterior)		0	4.55	0	0	**1.59**
Type C: Elliptical (transverse)		18.29	0	0	2.27	**12.70**
Type D: Elliptical (oblique: right to left)		2.44	2.27	0	18.18	**8.73**
Type E: Elliptical (oblique: left to right)		18.29	4.55	2.27	0	**14.29**
	Variations					
Type F: Triangular		10.98	2.27	4.55	2.27	**10.32**
Type G: Square		0	0	4.55	0	**1.59**
Type H: Rectangular		0	0	0	0	**0**
Type I: Kite		0	0	0	0	**0**
Type J: Leaf		2.44	0	2.27	4.55	**3.97**
Type K: Semicircle		2.44	2.27	0	2.27	**3.17**
Type L: Irregular	-	1.22	0	0	2.27	**1.59**
Type M: Double Bubble (incomplete double)		10.98	0	0	11.36	**11.11**
					P value = < 0.001	

(ii) Variations in Number, Shape and Laterality of FT. Accessory FT were present in 23.2 % of typical cervical vertebrae, bilaterally. Table III displays unilateral variations in number, shape and laterality of the FT in typical and atypical cervical vertebrae. Bilaterally, 7.32 % of the typical vertebrae had complete double FT and 2.44 % had incomplete double FT. Accessory FT were present in atypical cervical vertebrae in 27.27% and 22.73 % in right and left sides, respectively. Incomplete single FT was found bilaterally in 2.27 % of the atypical cervical vertebra (C1) and incomplete double was observed in 9.09 % (C7). This study found a unique variation on the right side which was a combination of incomplete double FT and single complete FT (2.27 %) (Fig. 2). The p value of the vertebrae type vs. right side variation (shape, number and laterality) was <0.001. This value was also the same for the left side variation.

Table III. Incidence of cervical vertebrae type vs. variations (based on number, shape and laterality) unilaterally.

Variation	Right (%)				Left (%)			
	Typical (n=82)	Atypical (n=44)			Typical (n=82)	Atypical (n=44)		
		C1	C2	C7		C1	C2	C7
Complete double	6.10	0	0	2.27	3.66	2.27	0	4.55
Complete triple	0	0	0	0	1.22	0	0	0
Incomplete single	0	0	0	0	0	0	0	2.27
Incomplete double or double bubble	7.32	0	0	11.36	8.54	0	0	2.27
Incomplete double or double bubble + single complete	0	2.27	0	0	0	0	0	0

Table IV. Incidence of vertebra type vs. unilateral position of accessory FT in relation to the main FT for the right and left sides

Position	Right (%)				Left (%)			
	Typical (n=82)	Atypical (n=44)			Typical (n=82)	Atypical (n=44)		
		C1	C2	C7		C1	C2	C7
Not applicable (no accessory FT)	76.81	15.91	34.10	22.73	76.81	15.91	34.10	27.27
Unknown	0	0	0	2.27	0	0	0	0
Anterior	0	0	0	2.27	0	0	0	0
Anterolateral	0	0	0	0	0	0	0	2.27
Anteromedial	0	0	0	4.55	0	0	0	0
Posterior	4.88	0	0	0	2.44	0	0	2.27
Posterolateral	4.88	0	0	0	4.88	0	0	0
Posteromedial	0	0	0	2.27	2.44	0	0	0

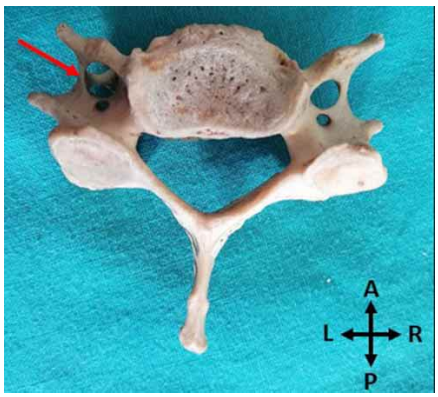

Fig. 2. Superior view of typical cervical vertebra with a variation, not previously reported, of double FT superiorly and triple FT inferiorly on the left side (red arrow).

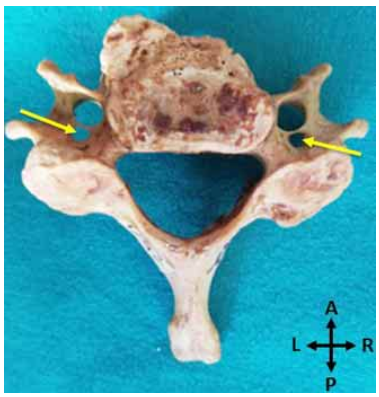

Fig. 3. Superior view of typical cervical vertebra, displaying posterolateral accessory FT (not previously reported) (yellow arrows).

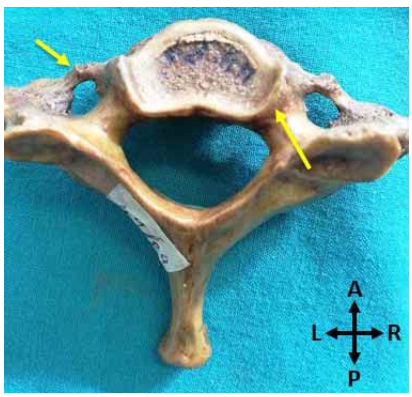

Fig. 4. Superior view of atypical cervical vertebra (C7), displaying anterolateral accessory FT on the left side and posteromedial on the right (not previously reported) (yellow arrows).

(iii) Position of accessory FT. The incidence of the position of the accessory FT in relation to the main FT, unilaterally, are depicted in Table IV. Bilaterally, the accessory FT was seen posterior to the main FT in 4.88 % and posterolateral in 7.32 % of typical cervical vertebrae. The bilateral posterolateral position can be viewed in figure 3. In atypical cervical vertebrae, 2.27 % of C1 vertebrae had their accessory FT positioned anterior to the main FT (bilaterally). Bilaterally, in 2.27 % of C7 vertebrae, the accessory FT was positioned anterolateral to the main FT. The p value of the vertebra type vs. position of right accessory FT was <0.001, while it was 0.004 for the left side.

(iv) Size Appearance. Regarding asymmetry of the FT, the typical cervical vertebrae exhibited smaller FT on the right side in 2.44 % of cases. Asymmetrical FT was smaller on the atypical cervical vertebrae in 6.92 % (C7) on the right side and in 2.27 % (C7) on the left side. In 2.27 % of cases, the main FT and accessory FT appeared to be of the same size, so the main FT could not be distinguished from the accessory. It was a Type M variation.

Morphometry. The mean anteroposterior and transverse diameters of the right and left main FT of typical and atypical cervical vertebrae are found in Table V with their standard deviations. The vertebra type vs. anteroposterior diameter of the right main FT had a p value of 0.917. The p value for the left side was 0.987. When a comparison was made between vertebra type and transverse diameter of the right main FT, a p value of 0.804 had resulted. For the left side, the p value was found to be 0.941 (Table V).

Comparisons made regarding morphology and morphometry resulted in p values of <0.001. These comparisons were shape vs. anteroposterior diameter on the right side as well as for the left side, and shape vs. transverse diameter of the right and left sides.

Table V. Vertebra type vs. anteroposterior and transverse diameters of the main FT (mm) for the right and left sides (with standard deviations).

Vertebra	Diameters of right side				Diameters of left side			
	Anteroposterior		Transverse		Anteroposterior		Transverse	
	Mean (mm)	Standard deviation (mm)	Mean (mm)	Standard deviation (mm)	Mean (mm)	Standard deviation (mm)	Mean (mm)	Standard deviation (mm)
Typical (n=82)	4.34	1.63	5.03	1.97	4.60	1.67	5.43	2.00
Atypical (n=44)								
C1	5.09	2.97	4.52	2.66	5.85	2.31	5.14	2.13
C2	5.24	0.84	5.48	0.72	5.30	0.98	5.36	0.72
C7	1.96	1.87	2.12	1.98	2.51	2.06	2.87	2.47
Total (n=126)	4.12	1.97	4.58	2.30	4.44	1.94	5.00	2.18
P values	0.917		0.804		0.987		0.941	

DISCUSSION

The morphological analysis revealed that in the typical cervical vertebrae, the most common shape in the right and left FT was Type A, as it was found in 34.15 % and 32.93 %, respectively (Table I). This concurs with the results reported by Ramachandran *et al*. and Molinet *et al*. On the right side of atypical cervical vertebrae, the most common shape in C1 was Type B (9.09 %), in C2 it was Type D (9.09 %) and in C7 it was Type M (13.64 %) (Table I). On the left side of the atypical cervical vertebrae, the most common shape in C1 was Type B and Type E which were equally found in 4.55 % of cases, Type A was most commonly found in C2 (20.45 %) and Type D was most commonly found in C7 (18.18 %) (Table II). The shapes of the FT were analysed in relation to the type of cervical vertebrae (typical and atypical) and the p value of <0.001 was obtained for both the right (Table I) and left (Table II) sides. This means that there was a strong significance between the type of cervical vertebra and the shapes of the main FT found on their right and left sides. This type of comparison was not considered by previous authors.

In typical cervical vertebrae, the most common variation (number, shape and laterality) on the right side was the complete double FT (bilateral) and double bubble FT (unilateral) (Table III) which both occurred in 7.32 % of cases. Yadav *et al*. also observed this variation as most common in their study. On the left side, incomplete double FT (unilateral) (8.54 %) was the most common variation and this was in accordance with the literature of Sabnis. The current study found a variation in number, shape and laterality of the FT, which has not previously been reported. It was a typical cervical vertebra (1.22 %) that was found to display complete double FT superiorly and complete triple FT inferiorly, on the left side (Fig. 2). On the right side of atypical cervical vertebrae, the most common variations in C1 were incomplete double + single complete FT, as well as incomplete single (bilateral) FT, which both occurred in 2.27 %. In C7, incomplete double (unilateral) (11.36 %) was most prevalent. On the left side, incomplete single (bilateral) and complete double (unilateral) FT was most common in C1 (2.27 % each) (Table III). In C7 vertebrae, the most common variation on the left side was incomplete double (bilateral) (9.09 %).

In typical cervical vertebrae, the position of accessory FT, on the right and left sides were most commonly found posterolateral (bilateral) to the main FT (7.32 % each). In atypical cervical vertebrae, on the right side, the accessory FT was most commonly found in C7 and the most common position of it was anteromedial (unilateral) to the main FT, as well as posteromedial (bilateral) (4.55 % each). On the left side, the accessory FT was also predominantly found in C7 and it was posteromedial to the main FT (4.55 %). Previous authors have not reported on anterolateral (Fig. 4), anteromedial, posterolateral (Fig. 3) and posteromedial positions (Fig. 4). The vertebrae type was analysed regarding the position of the accessory FT and a p value of <0.001 was obtained for the right side and 0.004 for the left side.

The present study found the presence of asymmetrical FT, with one foramen being smaller on one side and larger on the other. In typical vertebrae, the smaller FT was found on the right side in only 2.44 % of cases. This implies that in typical cervical vertebrae, the larger FT is usually found on the left side. This was also found by Yadav *et al*. In atypical cervical vertebrae, asymmetry was only observed in C7 vertebrae, which displayed the smaller FT on the right in 6.92 % and on the left side in

2.27 % of cases. It is notable that the C7 vertebrae had the smallest asymmetrical FT than all the other cervical vertebrae. This was also present in the study by Sabnis. The C7 was also observed to have smaller FT present bilaterally than all the other cervical vertebrae, which was also evident from the study conducted by Yadav *et al*.

On the right side of a C7 vertebra (2.27 %), the main and accessory FT appeared to be of the same size, and therefore could not be distinguished from each other. It was an incomplete double FT. Dofe *et al*. also found this on the right side of a cervical vertebra, but it was a complete double FT.

The morphometric analysis revealed that in typical cervical vertebra, the mean anteroposterior diameter on the left side (4.34 mm) was slightly smaller than on the right side (4.60 mm) (Table V). This was also present in the study conducted by Sangari *et al*. In the atypical cervical vertebrae, the mean right anteroposterior diameter for C1, C2 and C7 were 5.09 mm, 5.24 mm and 1.96 mm, respectively. Whereas the mean left anteroposterior diameters in C1, C2 and C7 were 5.85 mm, 5.30 mm and 2.51 mm, respectively. This indicates that the right FT are smaller than the left FT, anteroposteriorly. When the right and left anteroposterior diameters were each compared to the type of cervical vertebrae (typical and atypical), there were no significances (Table V). This indicates that the right or left anteroposterior diameters were not influenced by the type of cervical vertebra. These parameters were not statistically compared by previous authors.

In typical cervical vertebrae, the left mean transverse diameter (5.43 mm) was larger than the right (5.03 mm) (Table V). This concurred with the findings by Sangari *et al*. In atypical cervical vertebrae, the right transverse diameter for C1, C2 and C7 were 4.52 mm, 5.48 mm and 2.12 mm, respectively. The left transverse diameter C1, C2 and C7 were 5.14 mm, 5.36 mm and 2.87 mm, respectively. Therefore, the transverse diameter for C1 and C2 were smaller on the right vertebrae whereas C2 had a greater transverse diameter on the left vertebrae. When the right and left transverse diameters were independently compared to the type of cervical vertebrae (typical and atypical), there were no statistically significant values (Table V). This reveals that the cervical vertebrae types did not influence the transverse diameter on the left or right sides. These comparisons were not made in previous studies.

There were strong significances observed between shape of main FT and the anteroposterior and transverse diameters ($p = 0.001$ for each comparison). This means that the shape of the main FT on each side of the vertebrae and their respective anteroposterior or transverse diameters, were dependent on each other. These parameters were not statistically analysed by previous authors.

CONCLUSION

The present study highlights many different parameters and variations of typical and atypical cervical vertebrae, some of which have not been previously reported in literature. It is important to understand the FT and the relationship it has with vessels so that there is a greater chance of preventing poor cervical surgery.

SHEIK ABDUL, R.; LAZARUS, L.; RENNIE, C. & SATYAPAL, K. S. El foramen transverso de vértebras cervicales típicas y atípicas: Morfología y morfometría. *Int. J. Morphol., 36(4)* :1439-1446, 2018.

RESUMEN: Las siete vértebras cervicales que se encuentran en el cuerpo humano se clasifican como vértebras típicas y atípicas. Sus procesos transversos presentan un foramen transverso (FT) y normalmente este foramen es de tamaño similar en cada lado. Sin embargo, se han reportado en la literatura variaciones de este foramen, con respecto a su forma, tamaño, número, lateralidad, ubicación y características osteométricas. Este estudio morfológico y morfométrico se realizó en 126 vértebras cervicales (82 típicas y 44 atípicas) obtenidas del banco de Osteología de la Universidad de Kwa-Zulu Natal, para producir una base de datos que pueda servir como una guía útil para el personal médico. Se observaron variaciones con respecto a la forma, el número de FT, la lateralidad y la posición, que no se habían reportado anteriormente. La mayoría de los tipos de variaciones eran evidentes en las vértebras cervicales típicas y en segundo lugar en las séptimas vértebras cervicales. Los axis no mostraron ningún FT accesorio o variaciones.

PALABRAS CLAVE: Vértebras cervicales; Vértebras cervicales típicas; Vértebras cervicales atípicas; Foramen transversarium; Arteria vertebral.

REFERENCES

Akhtar, J.; Madhukar, P. K.; Rahman, S. & Kashyap, N. A morphometric study of foramen transversarium of dried cervical vertebrae. *Int. J. Res. Med. Sci., 3(4)*:912-6, 2015.

Baylan, H. The importance of the atlas vertebra and its variations. *J. Hum. Rhythm, 2(4)*:135-7, 2016.

Dofe, M. Y.; Kasote, A. P. & Meshram, M. M. The study of cervical vertebrae showing variational presentation of foramen transversarium. *Int. J. Anat. Res., 3(2)*:1128-32, 2015.

Esakkiammal, N. & Chauhan, R. Clinical significance of presence of accessory foramen transversarium in typical cervical vertebrae. *Int. J. Res. Med. Sci., 4(12)*:5231-6, 2016.

Gujar, S. M.; Oza, S. G. & Shekhawat, J. P. A study of accessory foramen transversarium in dry cervical vertebrae and its clinical implications. *Natl. J. Integr. Res. Med., 6(6)*:27-30, 2015.

Karau, P. B. & Odula, P. Some anatomical and morphometric observations in the transverse foramina of the atlas among Kenyans. *Anat. J. Afr., 2(1)*:61-6, 2013.

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.

Kotil, K. & Kilincer, C. Sizes of the transverse foramina correlate with blood flow and dominance of vertebral arteries. *Spine J, 14(6)*:933-7, 2014.

Molinet, G. M.; Robles, F. P. & Roa, I. Anatomical variations of the foramen transversarium in cervical vertebrae. *Int. J. Morphol., 35(2)*:719-22, 2017.

Moore, K. L.; Dalley, A. F. & Agur, A. M. R. *Clinically Oriented Anatomy.* 6th ed. Philadelphia, Wolters Kluwer Health/Lippincott Williams & Wilkins, 2010.

Mulla, N. G. & Pundge, S. J. Double foramen transversarium. A case report. *Int. J. Curr. Res. Rev., 7(16)*:6-8, 2015.

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

Patra, A.; Kaur, H.; Chhabra, U.; Kaushal, S. & Kumar, U. Double foramen transversarium in dried cervical vertebra: An osteological study with its clinical implications. *Indian J. Oral Sci., 6(1)*:7-9, 2015.

Ramachandran, K.; Ravikumar, P. C. & Manavalan, M. S. A study on the foramen transversarium in cervical vertebrae. *Int. J. Health Sci. Res., 4(12)*:178-83, 2014.

Rathnakar, P.; Remya, K. & Swathi. Study of accessory foramen transversaria in cervical vertebrae. *Nitte Univ. J. Health Sci., 3(4)*:97-9, 2013.

Sabnis, A. Anatomical variations in foramen transversarium. *Indian J. Appl. Res., 5(12)*:504-6, 2015.

Sangari, S. K.; Dossous, P. M.; Heineman, T. & Mtui, E. P. Dimensions and anatomical variants of the foramen transversarium of typical cervical vertebrae. *Anat. Res. Int., 2015*:391823, 2015.

Sultana, Q.; Avadhani, R.; Varalakshmi, K. L.; Shariff, M. H. & Blessina. Variations of foramen transversarium in atlas vertebrae: A morphological study with its clinical significance. *Nitte Univ. J. Health Sci., 5(2)*:80-3, 2015.

Yadav, Y.; Goswami, P. & Bharihoke, V. An osteological study of foramen transversarium: Variations and clinical aspects. *J. Evol. Med. Dent. Sci., 3(68)*:14562-6, 2014.

Corresponding author:
Dr. L. Lazarus
Department of Clinical Anatomy
School of Laboratory Medicine and Medical Science
College of Health Sciences
University of KwaZulu-Natal
Private Bag X54001
Durban
4000
SOUTH AFRICA

Email: ramsaroopl@ukzn.ac.za

Received: 22-11-2017
Accepted: 23-03-2018