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Reference Values of Transverse Foramina: A Quantitative Cadaveric Study of the Cervical Segment of the Nigerian Spine

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Authors' contributions

This work was carried out in collaboration among all authors. Author OMO designed the study and wrote the protocol of the manuscript. Authors OMO and OUL performed the statistical analysis. Author OUL wrote the first draft of the study. All authors managed the analyses of the study.

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Original Research Article

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ABSTRACT

Aim: To evaluate dimensions and provide reference values of transverse foramina of Nigerian Spines.
Study Design: Cross-sectional study
Place and Duration of Study: Department of Anatomy, Faculty of Basic Medical Sciences, University of Port Harcourt, Nigeria between April 2021 and August 2021.
Methodology: Measurements were taken on 57 cervical vertebrae ranging from C2 to C7. The bones were prepared by soil and water maceration. Only fully ossified bones of Nigerian origin were selected and were all free from deformities, evidence of trauma, fractures, osteoporosis.
Results: Mean values of the transverse diameter were as follow; C2=4.76±0.50mm for left and 5.50±0.44mm for right, C3=4.20±0.58mm for left and 5.10±0.69mm for right, C4=5.28±1.07mm for left and 5.38±0.67mm for right, C5= 5.29±0.81mm for left and 5.77±0.76mm for right, C6= are 6.02±0.87mm for left and 6.12±1.36mm for right, C7=14.09±1.73mm for male and 13.81±1.93mm for females
Conclusion: The result of the present work will further the understanding of morphological parameters of cervical spine region of Nigerian population. It will further be important in designing country specific anatomical screw plates, spinal implants.

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Keywords: Cervical vertebrae; Nigerian; transverse foramen; morphometric.

ABBREVIATIONS

FT : Transverse foramen
APD : Anteroposterior distance
TD : Transverse distance
FCSA : Foramen cross sectional area

1. INTRODUCTION

The Foramen transversarium (FT) is said to be one of the shared distinctive feature of all cervical vertebrae [1]. They are bony canals found only in the transverse processes of cervical vertebrae [2,3]. There is normally one FT on each side of the vertebrae and are usually of a similar shape and size [4].

The transverse process of the cervical vertebra when present consists of an anterior part known as the costal process and a posterior part; the true transverse process [5]. The anatomical location of the FT is at the formation of the transverse process where the costal element merges with the body and the true transverse process [6]. These foramina transmit the vertebral artery, vertebral vein, roots of spinal nerves, fibers of the sympathetic and occasionally a vertebral nerve between the C6 and C7 transverse foramen [2,7]. These are vessels which carry blood to and from the brain, and nerves which supply the upper limbs and in the case of vertebral nerve connect the stellate ganglia to the Cervical plexus. Also, the vertebral arteries which thread the FT usually from C6 and ascends into the cranium bilaterally, dense venous plexus surrounding the vertebral artery and sympathetic nerve fiber plexus to the posterior cranial fossa all passes through the incomplete osseous passage formed by the FT [8,9].

Typical cervical vertebrae bear transverse foramina for the passage of the vertebral artery, the C7 vertebra being an infrequent exception. Where significant variations in the size of the foramen exist, there are implications for the structural integrity of the vertebral artery and the capacity to adequately furnish oxygen rich blood to the brain.

The spine or vertebral column with regards to its vast array of connections to many tissues and major organs of the body is poorly understood. As a consequence of low awareness, coupled with misinformation, traditional scepticism about non-traditional methods of bone treatment and uncontrolled advertisement from alternative health practitioners' majority of trauma patients are reluctant to seek specialist care.

In addition, and even among health care providers, not much is available in the literature about this part of the cervical vertebrae and the relationship of its component parts to vital neurovascular structures.

This study focused on quantitative linear dimensions transverse foramen.

Data obtainable from it will find direct applications in the design of biomaterials such as anatomical plates, rods, screws, corsets, braces, and other synthetic surgical materials.

2. MATERIALS AND METHODS

This study was a cross sectional survey in which cadavers obtained from the Mortuary unit, Department of anatomy, University of Port Harcourt were used.

Using outlines from Cunningham's manual of practical anatomy [10] 57 cervical vertebral bones from cadavers with age ranging from 25 – 50 years were dissected, and the bones prepared by soil and water maceration. Use of chemicals, bleaching and polishing was not done. This is to preserve tissue and cellular architecture of end plates and discs.

After thorough defleshing and cleaning, investigations were carried out for general observations for; normal vertebral formula, fusion abnormalities, synostosis,cervical ribs, abnormal ribs, bifidity. They were all free from deformities, evidence of trauma, fractures, osteoporosis.

All measurements were done with the vertebra placed in the supine position in the axial plane by three different members of the research team and in accordance with standard protocols as espoused by White and Panjabo [11] Lee et al. [12].

Measurements were taken directly on the bones using a digital Vernier calliper with precision 0.01mm. The following measurements were taken;

The anteroposterior distance (APD) is the distance from the anterior border of FT to the posterior border. (Fig. 1).

The transverse diameters (TD) is the distance from the medial border of FT to the lateral border of FT. (Fig. 1).

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Foramina cross sectional area (FCSA) = (APD/2*TD/2).

Data collected from this study was subjected to statistical analysis IBM SPSS statistics for windows, version 23.0 Armonk, NY:IBM corp. Results were analysed for Descriptive statistics, t-tests and Pearson Correlation.

Fig. 1. Illustration showing dimensions of the transverse foramen *ab-anteroposterior distance; cd-transverse distance*

3. RESULTS

Table 1. Transverse distance of transverse foramina (mm)

	RIGHT		LEFT	
VERTEBRA LEVEL	Mean	SD	Mean	SD
C2	5.50	0.44	4.76	0.50
C3	5.10	0.69	4.20	0.58
C4	5.38	0.67	5.28	1.07
C5	5.77	0.76	5.29	0.81
C6	6.12	1.36	6.02	0.87
C7	3.11	0.49	2.54	0.61

Table 2. Antero-posterior distance of transverse foramina (mm)

	RIGHT		LEFT	
VERTEBRA LEVEL	Mean	SD	Mean	SD
C2	5.74	1.01	5.63	0.92
C3	5.59	0.90	5.43	1.14
C4	5.14	1.04	5.42	0.69
C5	5.71	1.00	5.98	0.72
C6	6.06	0.99	6.63	0.92
C7	3.01	0.57	2.84	0.48

Table 3. foramina cross sectional area of the transverse foramina (mm)

	RIGHT		LEFT	
VERTEBRA LEVEL	Mean	SD	Mean	SD
C2	7.80	1.76	6.94	2.07
C3	7.18	1.62	7.03	1.87
C4	7.00	1.84	7.17	1.52
C5	7.87	2.01	8.34	2.23
C6	9.44	3.00	10.01	2.09
C7	4.33	0.53	4.87	0.48

Table 4. Descriptive statistics for atypical and typical transverse foramen variables

Class (mm)	Variables	N	Minimum	Maximum	Sum	Mean	Std. Deviation
Atypical	T.F-L	17	3.28	5.66	75.88	4.46	0.63
	T.F-R	17	2.40	6.16	78.11	4.59	1.29
	APD-L	17	2.17	6.95	81.99	4.82	1.33
	APD-R	17	2.13	7.01	80.71	4.75	1.48
	FCSA-L (mm^2)	17	2.37	9.83	94.85	5.58	2.10
	FCSA-R (mm^2)	17	1.49	10.08	97.30	5.72	2.80
Typical	T.F-L	40	3.27	7.17	212.03	5.30	1.04
	T.F-R	40	3.22	7.15	223.66	5.59	0.98
	APD-L	40	4.07	7.88	235.94	5.90	0.96
	APD-R	40	3.15	7.68	225.81	5.65	0.99
	FCSA-L(mm^2)	40	3.33	13.18	316.41	7.91	2.31
	FCSA-R(mm^2)	40	3.98	13.50	319.96	8.00	2.36

Table 5. Differences between atypical cervical vertebrae transverse foramen variable pairs

(mm)	Variables	Mean	Std. Deviation	Std. Error Mean	T	df	p-value	Inference
Pair 1	T.F-L - T.F-R	-0.34400	1.08290	.27960	-1.230	14	0.239	Not sig
Pair 2	APD-L - APD-R	.19400	1.43920	.37160	.522	14	0.610	Not sig
Pair 3	FCSA-L - FCSA-R (mm^2)	-.22600	2.00265	.51708	-.437	14	0.669	Not sig

Note: T.F-L= left transverse foramen diameter, T'F-R= right transverse foramen diameter, APD-L= left anteroposterior diameter, APD-R=right anteroposterior diameter, FCSA-L= left foramen cross sectional area and APD-R= right foramen cross sectional area

Table 6. Differences between typical cervical vertebrae transverse foramen variable pairs

(mm)	Variables	Mean (mm)	Std. Deviation	Std. Error Mean	T	df	*P*-value	Inference
Pair 1	T.F-L - T.F-R	-.29075	1.19446	.18886	-1.539	39	0.13	Not sig
Pair 2	APD-L - APD-R	.25325	1.24748	.19724	1.284	39	0.20	Not sig
Pair 3	FCSA-L - FCSA-R (mm^2)	-.08875	2.73559	.43254	-.205	39	0.84	Not sig

Note: T.F-L= left transverse foramen diameter, T'F-R= right transverse foramen diameter, APD-L= left anteroposterior diameter, APD-R=right anteroposterior diameter, FCSA-L= left foramen cross sectional area and APD-R= right foramen cross sectional area

Descriptive statistics for atypical and typical transverse foramen variables: TD measurements were given as C2=4.76±0.50mm for left and 5.50±0.44mm for right, C3=4.20±0.58mm for left and 5.10±0.69mm for right, C4=5.28±1.07mm for left and 5.38±0.67mm for right, C5= 5.29±0.81mm for left and 5.77±0.76mm for right, C6= are 6.02±0.87mm for left and 6.12±1.36mm for right, C7=2.54±0.61mm for left and 3.11±0.49mm for right sides (Table 1).

APD measurements were given as C2=5.63±0.92mm for left and 5.74±1.01mm for right, C3=5.43±1.14mm for left and 5.59±0.90mm for right, C4= 5.42±0.69mm for left

and 5.14±1.04mm for right, C5= 5.89±0.72mm for left and 5.71±1.00mm for right, C6=6.63±0.92mm for left and 6.06±0.99mm for right, C7=2.84±0.48mm for left and 3.01±0.57mm for right sides. (Table 2).

FCSA" measurements were given as C2=6.94±1.44mm for left and 7.80±1.32mm for right, C3=7.03±1.87mm for left and 7.18±162mm for right, C4=7.17±1.52mm for left and 7.00±1.84mm for right, C5= 7.87±2.01mm for left and 8.34±2.23mm for right, C6=10.01±2.09mm for left and 9.44±3.00mm for right, C7=4.87±0.48mm for left and 4.33±0.53mm for right (Table 3).

Table 7. Differences between atypical and typical cervical vertebrae transverse foramen variables

Variables (mm)	T	Df	Sig. (2-tailed)	Inference
T.F-L	-3.088	55	0.003	Sig
T.F-R	-3.201	55	0.002	Sig
APD-L	-3.448	55	0.001	Sig
APD-R	-2.684	55	0.010	Sig
FCSA-L (mm^2)	-3.581	55	0.001	Sig
FCSA-R (mm^2)	-3.148	55	0.003	Sig

Note: T.F-L= left transverse foramen diameter, T'F-R= right transverse foramen diameter, APD-L= left anteroposterior diameter, APD-R=right anteroposterior diameter, FCSA-L= left foramen cross sectional area and APD-R= right foramen cross sectional area

Table 8. Correlation between atypical cervical vertebra transverse foramen variables

		T.F-R	APD-R	FCSA-R
T.F-R	r	1	0.708**	0.893**
	p-value		0.001	0.000
	N	17	17	17
APD-R	r	0.708**	1	0.944**
	p-value	0.001		0.000
	N	17	17	17
FCSA-R	r	0.893**	0.944**	1
	p-value	0.000	0.000	
	N	17	17	17

**. Correlation is significant at the 0.01 level (2-tailed).

Note: r= Pearson correlation coefficient, N= amount, T'F-R= right transverse foramen diameter, APD-R=right anteroposterior diameter, and APD-R= right foramen cross sectional area

Table 9. Correlation between typical cervical vertebra transverse foramen variables

Variables		T.F-R	APD-R	FCSA-R
T.F-R	*r*	1	0.437**	0.827**
	p-value		0.005	0.000
	N	40	40	40
APD-R	*r*	0.437**	1	0.860**
	p-value	0.005		0.000
	N	40	40	40
FCSA-R	*r*	0.827**	0.860**	1
	p-value	0.000	0.000	
	N	40	40	40

**. Correlation is significant at the 0.01 level (2-tailed).

Note: r= Pearson correlation coefficient, N= amount, T'F-R= right transverse foramen diameter, APD-R=right anteroposterior diameter, and APD-R= right foramen cross sectional area

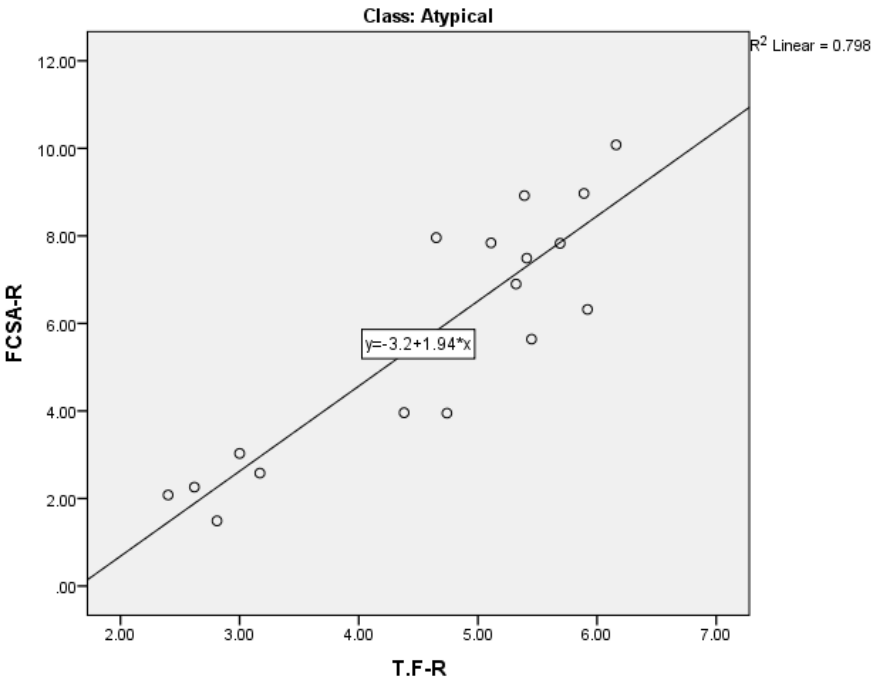

Fig. 2. Scatterplot of atypical cervical transverse foramen cross sectional area and transverse foramen diameter

*The cross sectional area of the foramen can be estimated using the linear equation y=3.2+1.94*x where y= cross sectional area and x= the diameter of the transverse foramen*

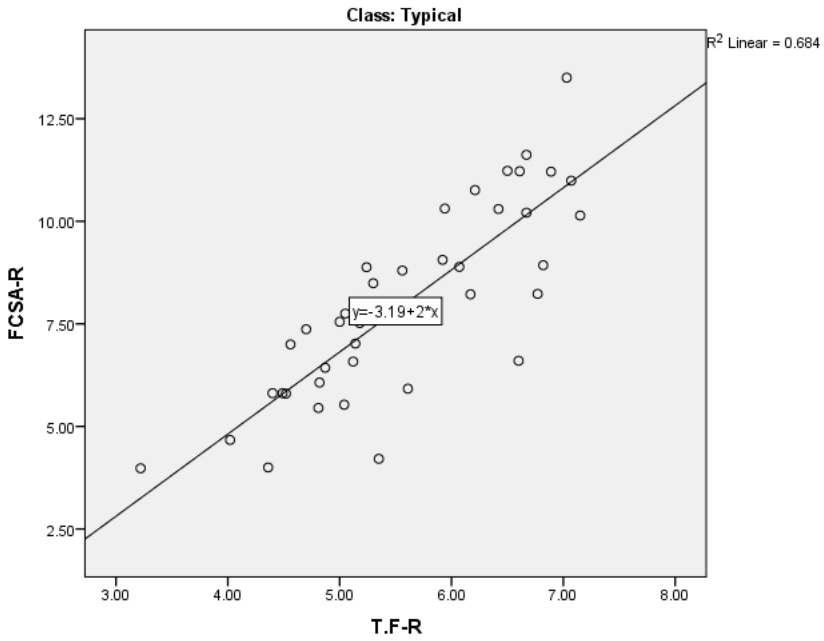

Fig. 3. Scatterplot of transverse foramen diameter and foramen cross sectional area of typical cervical vertebrae

*The cross sectional area of the foramen can be estimated using the linear equation y=3.19+2*x where y= cross sectional area and x= the diameter of the transverse foramen*

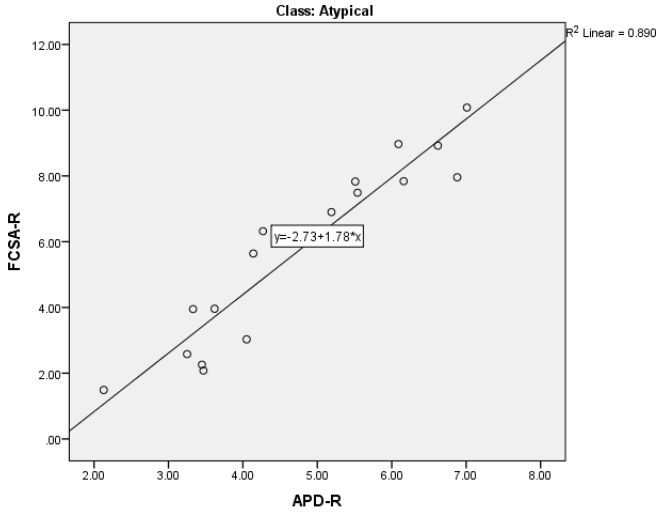

Fig. 4. Scatterplot of atypical cervical transverse foramen cross sectional area and anteroposterior diameter

*The cross sectional area of the foramen can be estimated using the linear equation y=2.73+1.78*x where y= cross sectional area and x= anteroposterior diameter*

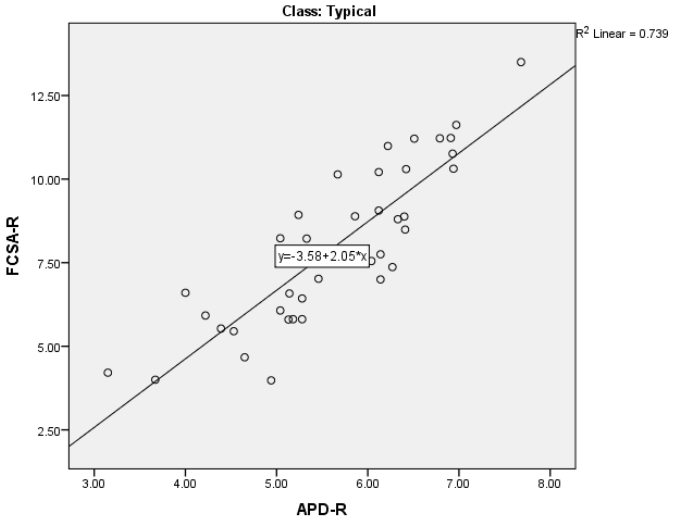

Fig. 5. Scatterplot of typical cervical transverse foramen cross sectional area and anteroposterior diameter

*The cross sectional area of the foramen can be estimated using the linear equation y=3.58+2.05*x where y= cross sectional area and x= anteroposterior diameter*

Mean values for the atypical cervical vertebrae were 4.46±0.63mm and 4.59±1.29mm for left and right transverse diameter respectively, 4.82±1.33mm and 4.75±1.48mm for left and right anteroposterior diameters respectively, 5.58±2.10mm^2 and 5.72±2.80mm^2 for left and right foramina cross sectional area respectively (Table 4).

Mean values for the typical cervical vertebrae were 5.30±1.04mm and 5.59±0.98mm for left and right transverse diameter respectively, 5.90±0.96mm and 5.65±1.00mm for left and right anteroposterior diameters respectively, 7.91±2.30mm^2 and 8.00±2.36mm^2 for left and right foramina cross sectional area respectively (Table 4).

From paired t test analysis, atypical cervical transverse foramen cervical vertebrae pairs were not significantly different (Table 5).

From paired t test analysis, typical cervical transverse foramen cervical vertebrae pairs were not significantly different (Table 6).

Independent t-test shows that there are significant differences between atypical and typical cervical vertebrae transverse foramen variables (Table 7).

Pearson correlation test statistics revealed positive and strong correlations between T.F and FCSA (r=0.893, p<0.00); APD and FCSA (r=0.944, p<0.000). (Table 8).

Pearson correlation test statistics revealed positive and strong correlations between T.F-R and FCSA-R (r=0.827, p<0.00), APD and FCSA (r=0.860, p<0.00) (Table 9).

4. DISCUSSION

Comparison between the mean values for typical and atypical transverse foramen parameters showed that typical transverse foramen values are greater than that of the atypical in all the measured parameters. Furthermore, the measurements showed for the right side, the transverse distance of the of the transverse foramen to be greater and also for the anteroposterior distance of the transverse foramen, the left side showed greater values, as this suggests a larger left-sided vertebral artery and a possible asymmetric blood supply of these arteries [13]. This hypothesis has been proposed by Duan et al. [15] on their work on vertebral artery course and function at the craniocervical junction {number}.

Santosh et al. [15] carried out a study to evaluate dimensions and anatomical variants of the foramen transversarium of typical Cervical Vertebrae. Using vernier calipers following results were presented; Mean diameter of the right and left transverse foramen 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. This was slightly in range with this study with mean varying from 3.22mm to 7.15mm (mean =5.60± 0.98mm) and 3.27mm to 7.17mm (mean =5.30±1.04mm). Gupta and Agarwal [16] recorded that the transverse diameters of the right transverse foramina varied from 2.44mm to 8.76mm with a mean diameter of 5.78±1.10mm.

The transverse diameters of the left transverse foramina showed wide variation from 2.53mm to 8.56mm with a mean diameter of 5.84 ± 1.03mm. Sheik et al. [17] studied 126 cervical vertebrae (82 typical and 44 atypical). The morphometric analysis revealed that in typical cervical vertebra, the mean anteroposterior diameter on the left side (4.34 ± 1.63 mm) was slightly smaller than on the right side (4.60 ± 1.67mm) but in this study the means values were given off as 5.90±0.96mm and 5.65±1.00mm for left and right anteroposterior diameters respectively.

T-test analysis conducted further showed that there is significant difference between the parameters measured in the typical and atypical transverse foramina but a strong correlation between the parameters in typical and those of the atypical transverse foramina

5. CONCLUSION

In the Nigerian population, there were no significant differences in foramen dimensions with respect to sides (right or left), this is particularly important for spine surgeons and in forensic investigations. We have been able to derive an equation to predict cross sectional area using the aforementioned parameters. Anatomical knowledge on the dimension of transverse foramen and their variations are important for the clinicians and various medical or health care practitioners. also result of the present work will further the understanding of morphological parameters of cervical spine region of Nigerian population. It will further be important in designing spinal implants which would be biomechanically compatible to the anatomy of Nigerians.

DISCLAIMER

The products used for this research are commonly and predominantly use products in our area of research and country. There is absolutely no conflict of interest between the authors and producers of the products because we do not intend to use these products as an avenue for any litigation but for the advancement of knowledge. Also, the research was not funded by the producing company rather it was funded by personal efforts of the authors.

CONSENT

It is not applicable.

ETHICAL APPROVAL

The Research Ethics Committee of the University of Port Harcourt approved this study with

reference number; UPH/CEREMAD/ REC/MM84/ 045

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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