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ORIGINAL ARTICLE

Medicine Science International Medical Journal

Medicine Science 2018;7(2):355-9

Analysis in terms of gender of morphometric characteristics of typical cervical vertebrae: A radiological study

Furkan Cevirgen[1], Leyla Karaca[2], Deniz Senol[1], Aymelek Cetin[1], Davut Ozbag[1]

[1] Inonu University Faculty of Medicine Department of Anatomy, Malatya, Turkey
[2] Inönü University, Faculty of Medicine, Department of Radiology, Malatya, Turkey

Received 17 December 2017; Accepted 04 January 2018
Available online 19.02.2018.with doi: 10.5455/medscience.2018.07.8753

Abstract
The objective of this study is to examine the morphometric characteristics of C3-C6 vertebrae in the cervical region through radiological images and to find out how they differ in terms of gender. CT images of 27 men and 27 women between the ages of 18 and 40 who did not have any symptoms were included in the study. In the study, area of vertebra (AV), vertebral foramen (VF), right and left transvers foramen (RTF-LTF) areas, lateral diameter of vertebral foramen (VF-L) and anterior-posterior diameter of vertebral foramen (VF-AP) of 216 cervical typical vertebrae (C3-C6) were measured through radiological images. No statistically significant results were found between AV, VF, VF-L, VF-AP, RTF and LTF radiological measurements taken from the C3, C4, C5 and C6 vertebrae of men and women for the same vertebral levels and between the rates of VF, RTF and LTF areas covered in AV ($p>0.05$). Paired comparisons of vertebrae were conducted with independent samples t test. Statistically significant difference was found in VF-L in men between C3 and C5, in VF-L and LTF between C3 and C6 and in AV, RTF and LTF between C4 and C6; while AV and LTF were found to be statistically significant in women between C4 and C6 ($p<0.05$). We believe that knowing the radiological measurement values of AV, VF, RTF-LTF, VF-L and VF-AP in typical cervical vertebrae will be very important and instructive for clinicians who have a role in conducting surgical interventions to this area.

Keywords: Morphometry, CT, vertebral foramen, transvers foramen

Introduction

The cervical column continues from the base of the skull above to the articulations with the first thoracic vertebra below at the root of the neck, as the most mobile region of the column and the host of the spinal cord [1]. As a result, widespread neurological disruption and even death can be the result of damage to the cord in this region. The cervical vertebrae are described with the presence of TF. There are a total of seven cervical vertebrae, the first, second and seventh of which are atypical, while the others are typical [1-3].

Between the arch and body of vertebrae, there is an opening called VF. These openings come on top of one another and form the spinal canal. Because of the ageing process or pathological processes like tumors or calcification of posterior longitudinal ligament, the cervical spinal canal would be stenotic, which would in turn cause chronic fatigue and fibromyalgia syndromes. In addition, as a result of subsequent neck pain radiculopathy and myelopathy, it is a common site of spondylosis. Thus, in order to be able to differentiate between normal and stenotic cervical spinal canal, it is important to know the measures of the spinal canal [4].

***Coresponding Author:** Deniz Senol, Inonu University Faculty of Medicine Department of Anatomy, Malatya, Turkey
E-mail: deniz.senol@inonu.edu.tr

Neural foraminal narrowing caused by degenerative osteophytes, facet hypertrophy, or laterally herniated discs is called cervical neural foraminal stenosis (NFS) [5-7]. A crucial tripod absorbing load and stress and enabling motion is formed by the intervertebral disc and facet joints. This complex can be affected by the normal aging process and it can be characterized by disc narrowing, facet joint subluxation, and osteophyte formation [8-11].

Thickened fibroligamentous structures, osteophyte formation, thyroid cartilage compression, and congenital absence of the TF have been reported to cause vertebrobasilar insufficiency as a result of the rotation of the head [16-19].

Except for the seventh, the vertebral vein, sympathetic nerves from inferior cervical ganglion and the vertebral artery (VA) pass though these foramen. At the level of TF of sixth cervical vertebra, the VA enters its vertebral course [20]. In the formation of cranial bony structures, cranial vasculature has a very important role [21,22]. A TF which is unilaterally small is associated with hypoplasia or aplasia of the VA and adjacent bony carotid canal narrowing usually accompanies internal carotid artery (ICA) hypoplasia [23].

The objective of this study is to determine the dimensions of the cervical spinal canal and area of vertebrae radiograph to present clear anatomical guide lines for both anatomists and clinicians. In the diagnosis, prognosis and treatment of diseases associated with cervical spine and spinal cord, for example, spinal stenosis and intraspinal tumors, exact dimensions of cervical vertebral area and spinal canal are of great importance [24].

Material and methods

CT images of 27 men and 27 women between the ages of 18 and 40 who had tomography of the neck at İnönü University, Faculty of Medicine, Department of Radiology were included in the study. The measurements of 216 cervical vertebrae were assessed. The data of the patients who were thought not to have cervical pathology were studied and the patients were selected randomly. This is a retrospective study and patients included in the study were selected randomly for patients admitted to my hospital for any reason. Vertebral colon measurements were made by scanning volumetric thin section through images obtained by using Toshiba 64 slice tomography. The patient position was determined as neutral while having the scan. The images taken were assessed based on axial sections passing over the corpus upper section of each vertebra at Philips make Spectra Workstation.

Defining the Measurement Points

Area of vertebra (AV): The total area within the most exterior points of a cervical vertebra.

Vertebral foramen (VF): The area between the points which externally border the VF of a cervical vertebra.

Lateral diameter of vertebral foramen (VF-L): The lateral widest length of VF.

Anterior-posterior diameter of vertebral foramen (VF-AP): The anterior posterior widest length of VF.

Right transvers foramen (RTF): Area of right TF.

Left transvers foramen (LTF): Area of left TF. (Figure 1).

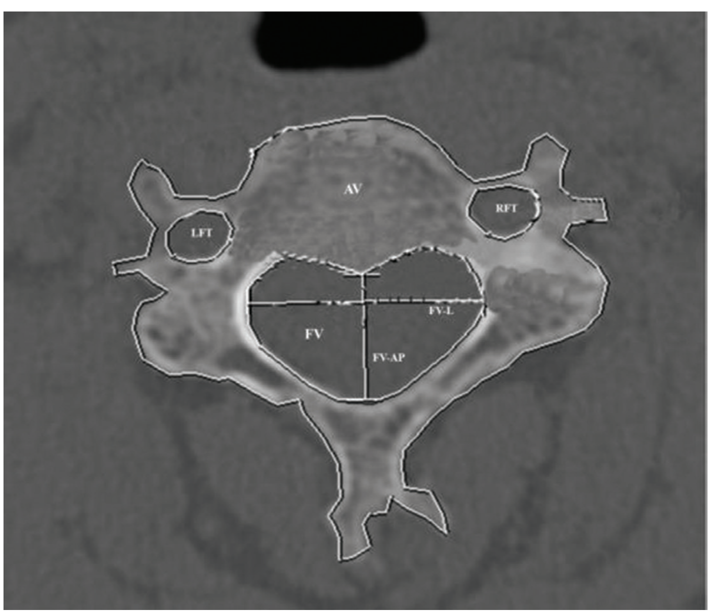

Figure 1. Measurements taken from vertebrae.

AV, VF, RTF and LTF of C3, C4, C5 and C6 vertebrae were calculated in mm^2, while VF-L and VF-AP were calculated in mm. While calculating the area, the cortexes of bone surfaces were drawn manually for each vertebra.

Statistical analysis

Statistical analysis was performed using the IBM SPSS version 22.0 software (IBM Corp., Armonk, NY, USA). The normality of the data was analyzed using the Shapiro-Wilk test. The Independent-Samples T-Test was used to analyze data. The descriptive data were expressed in mean (X) and range (min-max). A p value of <0.05 was considered statistically significant.

Results

In measurements of the radiological images of men included in the study, C3 vertebrae's average AV was measured as 1257.6±181.9 mm^2, average VF area as 297±42.3 mm^2, average VF-L area diameter as 25.4±1.6 mm, average VF-AP diameter as 15.9±1.7 mm, average RTF area as 30.9±9.8 mm^2, and average LTF area was measured as 31±9 mm^2. C4 vertebrae's average AV was measured as 1212.1±174.6 mm^2, average VF area as 284.4±39.2 mm^2, average VF-L area diameter as 26.1±2.1 mm, average VF-AP diameter as 15.5±1.8 mm, average RTF area as 26.6±5.3 mm^2, and average LTF area was measured as 31.5±6.5 mm^2. C5 vertebrae's average AV was measured as 1282.9±116 mm^2, average VF area as 297.7±42.9 mm^2, average VF-L area diameter as 26±4.5 mm, average VF-AP diameter as 16±2.1 mm, average RTF area as 32.4±9.2 mm^2, and average LTF area was measured as 32±7.2 mm^2. C6 vertebrae's average AV was measured as 1361.8±162.2 mm^2, average VF area as 308.4±51.7 mm^2, average VF-L area diameter as 27.2±1.9 mm, average VF-AP diameter as 16.5±2.3 mm, average RTF area as 32.8±8.5 mm^2, and average LTF area was measured as 36.1±6.9 mm^2 (Table 1).

In measurements of the radiological images of women included in the study, C3 vertebrae's average AV was measured as 1259.4±151.8 mm^2, average VF area as 309.3±5 mm^2, average VF-L area diameter as 26±2.4 mm, average VF-AP diameter as 16.3±1.5 mm, average RTF area as 32.6±12 mm^2, and average LTF area was measured as 33.6±11.4 mm^2. C4 vertebrae's average AV was measured as 1211.1±150.7 mm^2, average VF area as 318.4±47.8 mm^2, average VF-L area diameter as 26.4±2 mm, average VF-AP diameter as 16±1 mm, average RTF area as 27.1±5.2 mm^2, and average LTF area was measured as 28.9±7.4 mm^2. C5 vertebrae's average AV was measured as 1270.6±176.7 mm^2, average VF area as 307.8±37.7 mm^2, average VF-L area diameter as 26.5±1.2 mm, average VF-AP diameter as 16.3±1.3 mm, average RTF area as 31.3±8 mm^2, and average LTF area was measured as 33.9±9.8 mm^2. C6 vertebrae's average AV was measured as 1373.1±184.5 mm^2, average VF area as 320.4±47.4 mm^2, average VF-L area diameter as 27.2±1.9 mm, average VF-AP diameter as 16.7±1.5 mm, average RTF area as 34.3±13.3 mm^2, and average LTF area was measured as 38.3±13.5 mm^2 (Table 2).

Independent-Samples T-Test was conducted on the data to find out whether there were differences between the AV, VF, VF-L, VF-AP, RTF and LTF radiological measurement of men and women taken from C3, C4, C5 and C6 vertebrae. According to the results of the analysis, in the AV, VF, VF-L, VF-AP, RTF and LTF radiological measurement of men and women taken from C3, C4, C5 and C6 vertebrae, no statistically significant difference was found between the same vertebral levels ($p>0.05$), (Table 3).

Table 1. AV, VF, VF-L, VF-AP, RTF and LTF measurement results of men

Vertebrae	Test	AV	VF	VF-L	VF-AP	RTF	LTF
C3	X±sd	1257.6±181.9	297±42.3	25.4±1.6	15.9±1.7	30.9±9.8	31±9
	Min-Max	996.1-1687.7	244.8-365.7	22.2-28.3	13.2-19.5	19.7-57	19.3-53.2
C4	X±sd	1212.1±174.6	284.4±39.2	26.1±2.1	15.5±1.8	26.6±5.3	31.5±6.5
	Min-Max	934.6-1642.6	219.3-337	23-29.8	11.6-19.8	13.7-37.3	22.5-47.5
C5	X±sd	1282.9±116	297.7±42.9	26±4.5	16±2.1	32.4±9.2	32±7.2
	Min-Max	1038.4-1492.2	220.6-379.7	9.5-29.4	12.6-21.9	20.3-58.8	20.7-45.8
C6	X±sd	1361.8±162.2	308.4±51.7	27.2±1.9	16.5±2.3	32.8±8.5	36.1±6.9
	Min-Max	1137-1704.8	212.4-410.9	23.7-31.7	12.9-20.8	22.6-57	23.2-53.2

Table 2. AV, VF, VF-L, VF-AP, RTF and LTF measurement results of women

Vertebrae	Test	AV	VF	VF-L	VF-AP	RTF	LTF
C3	X±sd	1259.4±151.8	309.3±5	26±2.4	16.3±1.5	32.6±12	33.6±11.4
	Min-Max	1009.9-1571.9	231.4-413.9	23.3-31.4	13.6-18.6	16-71.4	18.4-69.3
C4	X±sd	1211.1±150.7	318.4±47.8	26.4±2	16±1	27.1±5.2	28.9±7.4
	Min-Max	1007.7-1554.6	263.7-441.8	23.1-31.6	14.2-17.7	18.1-33.9	16-48.1
C5	X±sd	1270.6±176.7	307.8±37.7	26.5±1.2	16.3±1.3	31.3±8	33.9±9.8
	Min-Max	983.8-1640.8	242.8-381	24.4-28.4	14.8-19.3	17.9-47.2	21.3-53.7
C6	X±sd	1373.1±184.5	320.4±47.4	27.2±1.9	16.7±1.5	34.3±13.3	38.3±13.5
	Min-Max	1020.3-1912.8	231.4-413.9	23.8-31.4	13.6-19	19.5-71.4	21.7-69.3

Table 3. Independent-Samples T-Test results of AV, VF, VF-L, VF-AP, RTF and LTF measurements of men and women taken from C3, C4, C5 and C6 vertebrae

Vertebrae	AV	VF	VF-L	VF-AP	RTF	LTF
C3	.744	.617	.986	.389	.524	.310
C4	.904	.065	.756	.208	.718	.389
C5	.692	.459	.438	.617	.904	.630
C6	.524	.524	.986	.796	.959	.904

Paired Independent-Samples T-Test was conducted on the data to find out between which levels of C3, C4, C5 and C6 vertebrae there were differences in AV, VF, VF-L, VF-AP, RTF and LTF measurements of men. According to the results of the analysis, VF-L was found to be statistically significantly different between C3 and C5, VF-L and LTF were found to be statistically significantly different between C3 and C6 and AV, RTF and LTF were found to be statistically significantly different between C4 and C6 ($p<0.05$), (Table 4). Paired Independent-Samples T-Test was conducted on the data to find out between which levels of C3, C4, C5 and C6 vertebrae there were differences in AV, VF, VF-L, VF-AP, RTF and LTF measurements of men. According to the results of the analysis, AV and LTF were found to be statistically significantly different between C4 and C6 ($p<0.05$), (Table 4).

The rate of VF to AV was found as 0.233±0.025 in men, while the rate of RTF to AV was found as 0.024±0.005 and the rate of LTF to AV was found as 0.025±0.005. The rate of VF to AV was found as 0.248±0.043 in women, while the rate of RTF to AV was found as 0.024±0.006 and the rate of LTF to AV was found as 0.026±0.006. According to the Independent-Samples T-Test results conducted, no statistically significant difference was found between the rates of place VF, RTF and LTF covered in AV in different cervical vertebra levels of men and women ($p>0.05$), (Table 5).

Table 4. Paired Independent-Samples T-Test results of C3, C4, C5 and C6 vertebrae of men and women

	Vertebrae	AV	VF	VF-L	VF-AP	RTF	LTF
Men	C3-C4	.593	.399	.309	.480	.278	.570
	C3-C5	.310	.907	.025	.809	.344	.593
	C3-C6	.056	.524	.005	.480	.361	.022
	C4-C5	.102	.667	.352	.301	.051	.890
	C4-C6	.013	.209	.173	.185	.015	.031
	C5-C6	.249	.730	.836	.438	.770	.082
Women	C3-C4	.326	.796	.335	.389	.153	.134
	C3-C5	.904	.823	.163	.863	.931	.959
	C3-C6	.076	.438	.076	.469	.770	.309
	C4-C5	.361	.945	.605	.605	.117	.202
	C4-C6	.009	.877	.248	.153	.076	.014
	C5-C6	.082	.459	.309	.438	.667	.344

Table 5. Independent-Samples T-Test results of rates of place VF, RTF and LTF covered in AV in C3-C6 vertebrae of men and women

C3-C6	Test	VF/AV	RTF/AV	LTF/AV
Men	X±sd	0.233±0.025	0.024±0.005	0.025±0.005
	Min-Max	0.157-0.301	0.011-0.039	0.015-0.040
Women	X±sd	0.248±0.043	0.024±0.006	0.026±0.006
	Min-Max	0.163-0.414	0.010-0.045	0.011-0.044
p	T-Test	0.451	0.342	0.521

Discussion

With the stenosis of one or both of the sagittal and transverse widths in VF due to various reasons, medulla spinalis can be left under pressure. A similar situation is also true for TF and the VA passing through. "Vertebral canal stenosis syndrome", which is one of the subjects neurosurgeons and orthopedists are intensely interested in recently, is a clinical picture which occurs as a result of medulla spinalis getting pressure due to the stenosis of sagittal and/or transverse diameters of vertebral canal for various reasons and it includes neurological symptoms. This situation is also known as "spinal stenosis" and it can develop due to various reasons [25-31].

Francis (1955) found that cervical spinal canal was narrower in Sudan population when compared with American population [32]. Tossel (2005) proved that the cervical area measurements of adult Sudanese population were approximately similar to those of South African black population; however, he also stated that Sudanese were below the stated limit [33].

Mohamed (2015) found the mid-sagittal diameter (VF-AP) from C3 to C5 as 12.37±1.13 mm. The mid-sagittal spinal canal (VF-AP) of C5 was found to be larger when compared with C4 and C3. Average mid sagittal diameter (VF-AP) was calculated as 21.3±2.79 mm [34] in Sudan population. In our study, the narrowest VF-AP in men was found as 15.5±1.8 mm in C4, while the largest VF-AP was found as 16.5±2.3 mm in C6. In women, the narrowest VF-AP was found as 16±1 mm in C4, while the largest VF-AP was found as 16.7±1.5 mm in C6.

Mohamed (2015) calculated mid sagittal diameter (VF-AP) larger in men when compared with women in Sudan population [34]. However, no statistically significant difference was found between VF-AP of men and women.

In their studies, Taitz et al. (1978) in Israel population, Cagnie et al. (2005) in Belgium population, Zhao et al. (2008) in China population found that TF diameter increased from C3 to C6 [22,35,36]. The results of this study are in parallel with the aforementioned studies.

In their study, Gupta et al. found VF-L was 22.4±1.8 mm in men and 22.15±1.5 mm in women for C3 vertebra, while it was 22.3±0.56 mm in men and 21.5±2.4 mm in women for C4 vertebra, 22.3±1.05 in men and 21.58±2.0 mm in women for C5 vertebra and 23.39 ±2.27 mm in men and 22.2±1.3 mm in women for C6 vertebra [37] in India population. In this study, VF-L was 25.4±1.6 mm in men and 26±2.4 mm in women for C3 vertebra, while it was 26.1±2.1 mm in men and 26.4±2 mm in women for C4 vertebra, 26±4.5 in men and 26.5±1.2 mm in women for C5 vertebra and 27.2±1.9 mm in men and 27.2±1.9 mm in women for C6 vertebra.

In their study, Zhao et al. found RTF area in C3 vertebra as 21.98±4.71 mm^2 in men and as 20.79±3.71 mm^2 in women, as 23.49±8.34 mm^2 in men and as 22.35±8.25 mm^2 in women in C4 vertebra, as 27.30±4.90 mm^2 in men and as 25.60±5.05 mm^2 in women in C5 vertebra, as 29.02±8.79 mm^2 in men and as 28.21±8.49 mm^2 in women in C6 vertebra in China population [36]. In our study, RTF area was found as 32.4±9.2 mm^2 in men and 31.3±8 mm^2 in women.

Cervical spinal stenosis is a pathological condition in which the cervical spinal canal becomes narrow because of various predisposing factors. The clinical importance of identifying spinal stenosis is outlined by its occurrence amongst older individuals and the prevalence of painful symptoms associated with this condition. The results of TF measurements of men and women in this study are in parallel with the results of Zhao et al. [36]. We believe that this study will be extremely important and guiding for clinicians in the diagnosis of NFS, vertebral basilar insufficiency and pathologies such as cervical tumors as well as for anatomists in having an idea about morphometric measurements of Turkish population. We believe that this study will be a resource for future studies.

Competing interests
The authors declare that they have no competing interest.

Financial Disclosure
The authors declared that this study has received no financial support.

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