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Original Article

Anatomy Section

Anthropometry of Bodies of C3-C6 Cervical Vertebrae in Northwest Indian Population: A Cross-sectional Study

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ABSTRACT

Introduction: Knowledge of morphometric dimensions of cervical vertebrae is of immense help in choosing and designing implants for the cervical spine. Previous studies on this subject have emphasized that these dimensions have significant variations among different populations.

Aim: To determine and analyse morphometric parameters of the body of typical cervical vertebrae (C3-C6) in the Northwest Indian population.

Materials and Methods: This cross-sectional study was carried out on 164 typical cervical vertebrae (C3 to C6) retrieved from the skeleton collection in the Department of Anatomy at Pandit Bhagwat Dayal Sharma Postgraduate Institute of Medical Sciences, Rohtak, Haryana, India from February 2020 to April 2022. Morphometric parameters measured in the study were anteroposterior diameters and transverse diameter of both surfaces of the body, and height of anterior surface of the body using a digital vernier calipers. Descriptive statistical analysis was done with the help of Microsoft Excel version 2021.

Results: Of the total 164 sample, on the superior surface of the body anteroposterior diameter increased from C3 vertebrae (Mean±Standard Deviation {SD}= 14.67±1.42 mm) to C6 vertebrae (Mean±SD=15.73 mm). The anteroposterior diameter of the inferior surfaces of the body increased from C3 vertebrae (Mean±SD=15.71 mm) to C6 vertebrae (Mean±SD=16.26 mm). Similarly, the transverse diameter of the superior surface also increased from C3 vertebrae (Mean value of 20.24 mm) to C6 vertebrae (Mean value of 23.82 mm). Furthermore, the transverse diameter of the inferior surface increased from C3 vertebrae (Mean±SD=19.35 mm) to C6 vertebrae (Mean±SD=22.99 mm). However, the height of vertebral bodies was found minimum in C5 vertebrae (Mean±SD=10.69 mm) and maximum in C3 vertebrae (Mean±SD=12.04 mm).

Conclusion: The dimensions of morphometric parameters observed in the present study were differing from those reported by studies carried out in south Indian population and in the Western world. However, the study did not find any significant side differences in morphometric parameters of bodies of typical cervical vertebrae. Population-specific normal data are reported in this study for the first time.

Keywords: Implants, Morphometric, Spine, Typical

INTRODUCTION

The integrity of the spine or vertebral column is vital for the well-being of humans. When the cervical spine is affected by trauma, its successful management makes a difference between life and death. Out of seven vertebrae of the neck, the third to sixth vertebrae (C3-C6) are termed as typical. Important features of these include a small vertebral body that is convex anteriorly and flat or minimally concave posteriorly. The superior surface of the vertebral body can be distinguished by its saddle shape whereas the inferior surface is somewhat concave [1]. The dimensions of vertebral bodies help in the diagnosis as well as management of conditions like stenosis of the vertebral canal and stenosis of the intervertebral foramen, degenerative disorders of the spine, and other nervous system lesions of the vertebral canal [2].

Knowledge of morphometric dimensions of cervical vertebrae is of immense help in choosing and designing implants for the cervical spine. Furthermore, population-specific data can help in reducing complications of operations [3]. The morphometric parameters of the body are important while performing anterior fixation of bicortical screws [4].

In a Computed Tomography (CT) scan study on the height of subaxial vertebral bodies, it was concluded that the operating surgeon should carefully scrutinize the preoperative radiographic images for assessment of cervical vertebral height and intraoperatively crosscheck with c-arm images [5]. In the present study, authors measured the height of the body of cervical vertebrae as it is of paramount importance in choosing the correct size of the cervical plate in anterior cervical plating indicated in various conditions. Dimensions of the body of typical cervical vertebrae were also studied in the South Indian population with a sample size of 70 vertebrae [3]. In a cadaveric study in Nigeria, subaxial cervical vertebrae were studied with a sample size of 80 vertebrae [6].

Although ossification of the ligament in the cervical region has been reported as a possible cause of a difficult airway, sparing of ligaments related to cervical vertebrae was reported though it involved other parts of the spine [7]. The body along with intervertebral discs forms the anterior column. This column is one of the important transmitters of weight in these vertebrae [8]. The importance of using population-specific data for the sizing of implants, for the cervical spine was emphasized in a study on the Chinese population, as there are significant differences in these dimensions in different ethnic populations [9]. In 60% of spines, double foramina transversaria are seen atleast on one side [10]. Variations in morphometric parameters of the body may also affect normal anatomical dimensions of foramina transversaria.

Previous studies on this subject have emphasized that these dimensions have significant variations among different populations. Authors did not find any published research paper in Northwest Indian population after an extensive review of the literature [2,10,11]. Hence, the present study was aimed to determine and analyse morphometric parameters of the body of typical cervical vertebrae (C3 to C6) in the Northwest Indian population.

MATERIALS AND METHODS

This cross-sectional study was carried out in the Department of Anatomy at Pandit Bhagwat Dayal Sharma Postgraduate Institute of Medical Sciences, Rohtak Haryana, India from February 2020 to April 2022. The Biomedical Research Ethics Committee of the institute approved the study vide letter No. BREC/19/147 dated 26.12.19 and guidelines laid down in the Declaration of Helsinki were complied with.

Inclusion criteria: Typical cervical vertebrae (C3 to C6) retrieved from the skeleton collection of a postgraduate medical institute were included in the study.

Exclusion criteria: Bones with deformity, distortion and breaks were excluded from the study.

This study was performed on typical cervical vertebrae, all of which have common anatomical features. C7 cervical vertebrae were excluded as it was atypical. A total of 41 vertebrae of each type making a total of 164, were used in the study. For skeleton collection, vertebrae were retrieved by the maceration method [12]. A separate maceration tank was used for retrieving each skeleton. Skeletons were numbered and preserved in separate skeletal bags and these vertebrae belonged to 41 cadavers.

Parameters were defined as per the study published by Rao EV et al., as described in [Table/Fig-1] [3]. Measurements were performed with the help of digital vernier calipers with the least count of 0.01 mm. Measurements were taken three times for every parameter.

Parameters	Description of method
Anteroposterior Diameter-Superior (APD-S)	This was measured on the superior surface of the body in the midline as shown in [Table/Fig-2].
Anteroposterior Diameter-Inferior (APD-I)	This was measured on the inferior surface of the body in the midline as shown in [Table/Fig-3].
Transverse Diameter-Superior (TD-S)	On the superior surface of the body, it was measured as maximum transverse distance as shown in [Table/Fig-4].
Transverse Diameter-Inferior (TD-I)	On the inferior surface of the body, it was measured as maximum transverse distance as shown in Figure [Table/Fig-5].
Height Anterior (HA)	On the anterior surface of the body, this was measured as the vertical distance in the midline as shown in Figure [Table/Fig-6].

[Table/Fig-1]: Morphometric parameters of bodies of C3-C6 vertebrae.

Vertebrae	APD-S Mean±SD (mm)	APD-I Mean±SD (mm)	TD-S Mean±SD (mm)	TD-I Mean±SD (mm)	HA Mean±SD (mm)
C3	14.67±1.42	15.71±1.11	20.24±1.54	19.35±1.35	12.04±1.38
C4	15.24±1.33	15.86±1.22	21.65±1.43	19.58±1.26	11.49±1.33
C5	15.26±1.27	16.25±1.43	22.09±1.71	20.28±1.62	10.69±1.19
C6	15.73±1.24	16.26±1.18	23.82±1.36	22.99±1.69	10.88±1.24

[Table/Fig-7]: Morphometric parameters of vertebral bodies C3-C6.
APD-S: Anteroposterior diameter-superior; APD-I: Anteroposterior diameter inferior; TD-S: Transverse diameter-superior; TD-I: Transverse diameter-inferior; HA: Height anterior; SD: Standard deviation

Vertebrae	p-value between APD-S and APD-I	p-value between TD-S and TD-I
C3	<0.001	<0.001
C4	0.007	<0.001
C5	<0.001	<0.001
C6	0.016	0.0111

[Table/Fig-8]: Difference between superior and inferior morphometric parameters of vertebral bodies C3-C6.
APD-S: Anteroposterior diameter-superior; APD-I: Anteroposterior-inferior; TD-S: Transverse diameter-superior; TD-I: Transverse diameter-inferior

DISCUSSION

The anteroposterior diameter of vertebral bodies have been studied by many authors in different populations as summarsed in [Table/Fig-9]. In a study by Prabavathy G et al., anteroposterior diameter reported was lower at C3 and C4 levels while it was higher at C5 and C6 levels than what was found in the present study [2]. In all the studies, mean anteroposterior diameter increased from C3 to C6. The mean anteroposterior diameter obtained in the present study (15.22 mm) is slightly lesser than the value reported by Rao EV et al., (15.69 mm) but higher than the anteroposterior diameter reported by Saluja S et al., (14.84 mm) [3,13]. The anteroposterior diameter of vertebral bodies reported by Bezaldua CJJ et al., in the Mexican population was slightly higher than what the authors found in the present study at all levels of the cervical spine [4]. The anteroposterior diameter obtained in the present study were similar to results reported by Khemnar G et al., [14]. This parameter was higher than that reported by Mahto AK and Omar S at all levels of the cervical spine except at the C6 level [11].

The transverse diameter of bodies increased from C3 to C6 as observed in this study. A similar pattern was noted in the case of

[Table/Fig-2]: Measurement of Anteroposterior Diameter-Superior (APD-S). **[Table/Fig-3]:** Measurement of Anteroposterior Diameter-Inferior (APD-I). **[Table/Fig-4]:** Measurement of Transverse Diameter-Superior (TD-S). **[Table/Fig-5]:** Measurement of Transverse Diameter-Inferior (TD-I). **[Table/Fig-6]:** Measurement of Height Anterior (HA). (Images from left to right)

STATISTICAL ANALYSIS

Descriptive statistical analysis was done with the help of Microsoft Excel version 2021. The mean and standard deviation for each parameter was measured. The p-value between the superior and inferior surface parameters was calculated using Student's t-test. The p-value <0.05 was considered statistically significant.

RESULTS

The APD-S and APD-I, both showed a increase from C3 to C6, and the maximum diameter was found at C6 vertebra [Table/Fig-7]. Increasing dimensions are in concurrence with the general trend of the increasing size of vertebral bodies, down the length of spine.

There was a significant difference between the parameters of the superior and inferior surface of the body [Table/Fig-8].

the studies done by Bezaldua CJJ et al., and Khemnar G et al., [4,14]. But, studies by Prabavathy G et al., and Mahto AK and Omar S, reported an increase in mean transverse diameter from C3 to C5 and, then it decreased from C5 to C6 [2,11]. While a study by Abuzayed B et al., reported a minimum mean transverse diameter at the C4 vertebra and then it increased from C4 to C6 [15].The mean transverse diameter obtained in the present study was 21.95 mm which was slightly more than the value reported by Rao EV et al., (21.49 mm) but lesser than the values reported by Saluja S et al., (22.18 mm) and, Balamurugan S and Ahmad TPW, (22.15 mm) [3,13,16]. Balamurugan S and Ahmad TPW and Abuzayed B et al., conducted computerised tomography based morphometry of typical cervical vertebrae [Table/Fig-10].

The height of vertebral bodies reported by Prabavathy G et al., [2] and Mahto AK et al., [11] was lower at C3, C4, and C5 levels and

Vertebrae	Prabavathy G et al., [2]	Bezaldua CJJ et al., [4]	Mahto AK and Omar S [11]	Abuzayed B et al., [15]	Khemnar G and Garud R [14]		Present study	
	APD (mm)	APD (mm)	APD (mm)	APD (mm)	APD-S (mm)	APD-I (mm)	APD-S (mm)	APD-I (mm)
C3	13.18±0.33	14.68±2.63	13.6±0.18	15.6±2.52	14.57±1.50	15.56±1.75	14.67±1.42	15.71±1.11
C4	14.40±0.29	16.36±0.99	14.4±0.15	16.2±2.18	14.91±1.86	15.73±1.89	15.24±1.33	15.86±1.22
C5	15.40±0.29	17.45±1.29	15.2±0.21	15.6±2.02	15.14±1.75	16.31±1.98	15.26±1.27	16.25±1.43
C6	16.34±0.53	17.47±1.48	15.8±0.19	16.8±2.15	15.57±1.67	15.87±1.93	15.73±1.24	16.26±1.18
Population	South Indian	Northeastern mexico	Bihar	Anatolia	Maharashtra		Northwest Indian	
Sample size n=	350 dry vertebrae (no. of sets not mentioned)	30 sets (120 vertebrae)	240 dry vertebrae	CT scan study on 48 individuals (192 vertebrae)	57 sets (228 vertebrae)		41 sets (164 vertebrae)	
Year of study	2017	2011	2015	2009	2019		2022	

[Table/Fig-9]: Comparison of anteroposterior diameter of bodies with other studies.
APD: Anteroposterior diameter; APD-S: Anteroposterior diameter-superior; APD-I: Anteroposterior diameter-inferior; CT: Computed tomography

Vertebrae	Prabavathy G et al., [2]	Bezaldua CJJ et al., [4]	Mahto AK and Omar S [11]	Abuzayed B et al., [15]	Khemnar G and Garud R [14]		Present study	
	TD (mm)	TD (mm)	TD (mm)	TD (mm)	TD-S (mm)	TD-I (mm)	TD-S (mm)	TD-I (mm)
C3	22.80±0.10	19.17±3.04	22.8±0.21	22.3±1.8	20.99±2.10	19.13±2.48	20.24±1.54	19.35±1.35
C4	23.54±0.26	20.75±1.86	23.6±0.28	22±2.5	21.91±2.67	18.97±2.96	21.65±1.43	19.58±1.26
C5	26.46±0.51	20.88±3.73	26.4±0.30	23.5±2.72	22.81±2.31	21.46±3.33	22.09±1.71	20.28±1.62
C6	25.42±0.38	22.17±2.17	25.2±0.23	24.5±3.07	24.74±2.47	23±2.91	23.82±1.36	22.99±1.69
Population	South Indian	Northeastern Mexico	Bihar	Anatolia	Maharashtra		Northwest Indian	
Sample size	350 dry vertebrae (no. of sets not mentioned)	30 sets (120 vertebrae)	240 dry vertebrae	CT scan study on 48 individuals (192 vertebrae)	57 sets (228 vertebrae)		41 sets (164 vertebrae)	
Year of study	2017	2011	2015	2009	2019		2022	

[Table/Fig-10]: Comparison of transverse diameter of bodies.
TD: Transverse diameter; TD-S: Transverse diameter-superior; TD-I: Transverse diameter-inferior; CT: Computed tomography

higher at the C6 level. Studies by Abuzayed B et al., and Khemnar G and Garud R, reported higher values of height of bodies than the present study at all levels [14,15]. In the present study, the mean height of the body decreases from C3 to C6. But studies by Abuzayed B et al., and, Khemnar G and Garud R reported a decrease in mean height from C3 to C5 and then it increased from C5 to C6 [14,15] [Table/Fig-11].

Vertebrae	Prabavathy G et al., [2]	Mahto AK and Omar S [11] (2015)	Abuzayed B et al., [15] (2009)	Khemnar G and Garud R [14] (2019)	Present study (2022)
	HA (mm)	HA (mm)	HA (mm)	HA (mm)	HA (mm)
C3	8.72±0.19	8.9±0.11	13.8±1.93	12.10±1.35	12.04±1.38
C4	8.40±0.18	8.1±0.10	12.95±1.74	11.79±1.68	11.49±1.33
C5	10.42±0.11	10.1±0.17	12.82±1.96	10.79±1.31	10.69±1.19
C6	11.44±0.25	11.3±0.16	13.89±2.37	11.42±1.18	10.88±1.24
Population	South Indian	Bihar	Anatolia	Maharashtra	Northwest Indian
Sample size	350 dry vertebrae	240 dry vertebrae	CT scan study on 48 individuals (192 vertebrae)	57 sets (228 vertebrae)	41 sets (164 vertebrae)
Year of study	2017	2015	2009	2019	2022

[Table/Fig-11]: Comparison of Height of vertebral bodies.
HA: Height anterior; CT: Computed tomography

Bodies of neck vertebrae are involved in various types of pathological and traumatic processes. Interventions required for successful management of these processes necessitate that surgeon must be aware of morphometric parameters. This study has provided the required data for the northwest Indian population. Furthermore, the outcome of this research provides population-specific data to local and international manufacturers of implants, plates, and screws, needed for interventions on C3-C4. Authors believe that this will lead to improved outcomes and a decrease in complications of operation on these bones, especially in anterior spine surgeries [10]. Cervical spine arthrodesis is another important surgical procedure that involves the fusion of bodies of cervical vertebrae. This population-specific data will help the surgeons operating in this region in performing fusion surgeries more confidently. Morphometric data of bodies of cervical vertebrae is essential for the population-specific designing of disc prostheses [17]. Authors propose that various populations have been conjugally isolated for centuries. This implies the accumulation of some unique set of genes in different ethnological populations, which can explain the differences in the results of published studies and the current study. The study sensitises all stakeholders like surgeons and vertebral body prosthesis manufacturers, about the need of designing and using orthopaedic hardware specific to a particular population.

Limitation(s)

Sexual dimorphism of a morphometric parameter included in this study could not be studied, due to the insufficient number of female skeletons. The sample size of this study could also have been increased if it was feasible to involve other medical colleges in the study.

CONCLUSION(S)

The dimensions of morphometric parameters observed in this study were differing from those reported by studies carried out in south India and in the western world. However, the study did not find any significant side differences in morphometric parameters of bodies of typical cervical vertebrae. Population-specific data reported in this study will be useful for better designing of prostheses. This is further expected to enhance innovations in surgical procedures performed in this population thereby enhancing outcomes of surgeries especially involving bodies of C3-C6 vertebrae.

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