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Morphometric study of cervical vertebrae C3-C7 in South Indian population –A clinico-anatomical approach

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Abstract

Knowledge about the dimensions of the vertebral elements is necessary for the development of instrumentation related to cervical spine. Ethnic variations have been reported in these dimensions. This study included 350 dry cervical vertebras (C3-C7) of unknown age and sex, collected from the department of Anatomy, Mahathma Gandhi Medical College and Research Institute, Puducherry and other medical colleges in and around Puducherry. The dimensions of vertebral bodies, pedicles, laminae, spinous process, superior and inferior articular processes were measured and compared. No significant difference was noted between the measurements taken on the right and left side. The dimensions of the vertebral bodies were seen to be larger at lower levels. The larger dimensions of the pedicle were seen in C3 and thereafter decreased at lower levels. Height and length of lamina progressively increased from C3 to C7. The spinous process length was greatest at C7. The height of pedicle, superior and inferior articular processes decreased towards the lower cervical level.

Key words

Morphometry, typical cervical vertebra, instrumentation, foramen transversarium.

Introduction

The cervical part of vertebral column presents a convex ventral curvature (secondary curve) from 3 to 4 months after birth, when the infant learns to erect its head. The skeleton of neck comprises seven cervical vertebrae and all have one characteristic feature: the presence of foramen transversarium in each transverse process. The third to sixth cervical vertebrae are typical because they bear common features. The first and second vertebrae are atypical, since each possesses specific features for self-identification. The seventh cervical vertebra is transitional because the foramen transversarium may be absent or duplicated on one or both sides. Each vertebra consists of an anterior vertebral body and a posterior neural arch. The vertebral body has a central part of cancellous bone and a peripheral cortex of compact bone. The neural arch is constituted by pedicles, laminae, spinous process, and articulating facets.

Curvature of the cervical spine plays an important role in proper functioning. Serious damage can occur to spinal cord and cauda equina due to fracture and dislo-

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cation of vertebrae. Morphometry of cervical spine is important when used in orthopedic management for the treatment of cervical instability and decompression of neural structures. It is also important in case of vertebral column instrumentation (Pal and Routal, 1986) and placement of transpedicular screws, which is a complicated surgical procedure which is widely used for the treatment of unstable cervical spine after traumatic lesions of the middle and lower cervical spine (Abuzayed et al., 2010). Size of the vertebral bodies and size of the articular facets are different among various regions of vertebral column. Morphometric studies of cervical, thoracic and lumbar vertebrae have been done by many authors (Kayalioglu et al., 2007; Abuzayed et al., 2010)

Spinal instability caused by fracture, deformity or degenerative disease is corrected by spinal fixation. Vertebral column measurements had been done by different authors using different techniques: cadaveric study (Abuzayed et al., 2010), radiography (Sieradzki et al., 2008) and fluoroscopy (Urrutia-Vega et al., 2009). Some studies had been done to describe the morphology of typical cervical vertebra and their pedicles (Winkelstein et al., 2001; Bazaldua Cruz et al., 2011). Ethnic differences in dimensions of cervical spine have been reported across various populations.

The cervical spinal pedicles are very strong structural elements of the vertebra and offer the strongest point of attachment to the spine. Transpedicular screw fixation is especially useful if the posterior spinal elements (spinous processes, lamina) are unsuitable for fixation by hook or wire constructs (Coe et al., 1989). Cadaver based morphometric measurements used to guide surgeons in the placement of the pedical screw (Kayalioglu et al., 2007). Thorough understanding of pedicle anatomy is very important to minimize the rate of neurovascular complications in transpedicular stabilization of cervical spine (Gupta et al., 2013).

Adequate knowledge of spinal column morphology is necessary for the spinal surgeons to avoid damage to vertebral artery, spinal cord, or nerve roots during fixation interventions involving posterior cervical spine (Karaikovic et al., 2000). Thus, the present anatomic study was undertaken to obtain detailed anatomical data on various parameters of the cervical vertebrae to reduce the severity of complications caused by transpedicular screw placement.

Materials and methods

Three-hundred-fifty dry human cervical vertebras (C3-C7) of unknown age and sex from the Department of Anatomy, Mahathma Gandhi Medical College and Research Institute, Puducherry, and other medical colleges in and around Puducherry were studied. Only intact vertebrae were taken into consideration for the study. Damaged, malformed, and vertebra with signs of previous fractures were excluded from the study. The dimensions of vertebral bodies, pedicles, laminae, spinous process, superior and inferior articular processes of the typical cervical vertebrae were measured using a Vernier caliper with 0.1mm accuracy (Fig 1-5).

Body. Height: Distance between superior and inferior borders of the vertebral body at the midline. Antero-posterior length: Distance between the anterior surface and posterior surface of the body at the midline. Transverse length: Distance between two lateral surfaces of the vertebral body.

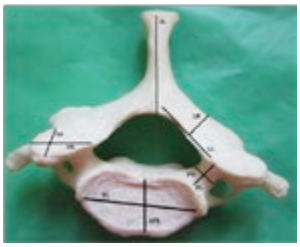

Figure 1 – Cervical vertebra, superior view. APL: body antero: posterior length. TL: body Transverse length. PW: pedicle width. PL: pedicle length. LH: lamina height. LL: lamina length. SL: spinous process length. SH: superior articular process height. SW: superior articular process width.

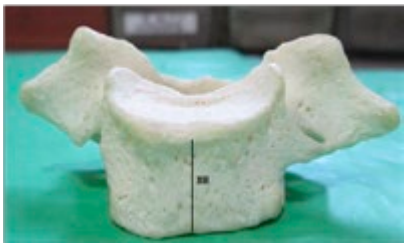

Figure 2 – Cervical vertebra, anterior view. BH: body height.

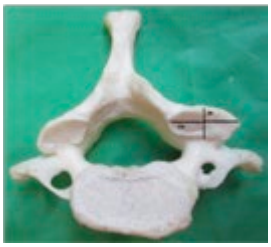

Figure 3 – Cervical vertebra, inferior view. IH: inferior articular process height. IW: inferior articular process width.

Figure 4 – Measurement of length of spinous process using a Vernier caliper.

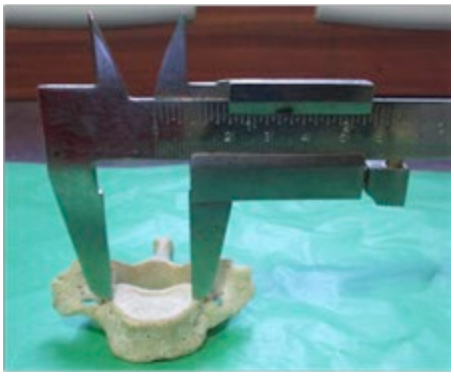

Figure 5 – Measurement of transverse length of vertebral body using a Vernier caliper.

Pedicle. Length: Distance between the anterior limit of superior articular facet and posterior limit of the vertebral body. Height: Distance between superior and inferior border of pedicle. Width: distance between the medial and lateral borders

Lamina. Height: Distance between the superior and inferior borders of lamina. Length: Distance between the spinous process and lateral border of superior articular process

Spinous process. Length: Distance from the superior border to tip of the spinous process.

Superior articular process. Height: Distance from the inferior border to superior vertex of the process. Width: Transverse diameter of the process.

Inferior articular process. Height: Distance from the superior border to inferior vertex of the process. Width: Transverse diameter of the process.

Quantitative data are given as mean and standard deviation. Student's *t* test was used to compare the means of parameters.

Results

A total of 350 dry cervical vertebras were studied. The differences for all the evaluated parameters between the right and left side were found insignificant.

Bodies. The maximum and minimum antero-posterior Length was recorded at C6 and C3 respectively. Transverse diameter was maximum at C5 and minimum at C3. The maximum height was observed at C7 and lowest at C4. There was increase in the size of the vertebral bodies at the lowest levels (Table 1).

Pedicles. The maximum length of the pedicle was noted at C3 and the minimum at C5 and C6. The largest height was noted at C3 and smallest at C7. The greatest width was recorded at C3 and the smallest at C4. The results showed that the larger dimensions of the pedicle were seen in C3 and thereafter decreased at lower levels (Table 2).

Laminae. The greatest height of laminae was observed at C7 and the smallest at C3. The length was maximum at C7 and minimum at C3 (Table 3)

Spinous process, superior and inferior articular process. The spinous process length was greatest at C7 and smallest at C4. The height of superior articular process

Table 1 – Dimensions (mm) of vertebral bodies C3-C7.

Vertebra	Anteroposterior length		Transverse length		Height	
	Mean	SD	Mean	SD	Mean	SD
C3	13.18	0.33	22.80	0.10	8.72	0.19
C4	14.40	0.29	23.54	0.26	8.40	0.18
C5	15.40	0.29	26.46	0.51	10.42	0.11
C6	16.34	0.53	25.42	0.38	11.44	0.25
C7	16.12	0.57	26.12	3.76	11.62	0.37

Table 2 – Pedicle dimensions (mm) of C3-C7 vertebrae.

Vertebra	Length		Height		Width	
	Mean	SD	Mean	SD	Mean	SD
C3	6.96	0.28	7.50	2.01	5.80	1.66
C4	6.14	1.21	7.10	0.92	4.40	1.42
C5	4.46	0.70	7.06	1.87	4.80	0.96
C6	5.36	0.49	6.80	0.77	4.70	0.74
C7	5.44	0.58	6.64	0.68	4.96	0.39

Table 3 – Dimensions (mm) of spinous process, superior and inferior articular processes of C3-C7 vertebrae.

Vertebra	Spinous process		Superior articular process				Inferior articular process			
	Length		Height		Width		Height		Width	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
C3	10.46	1.54	10.88	2.22	10.64	1.97	11.48	0.39	11.48	0.37
C4	10.14	1.75	11.56	2.04	11.40	0.61	11.74	0.47	11.28	0.49
C5	12.04	1.44	10.1	2.14	11.56	1.33	10.46	0.38	10.72	0.24
C6	13.78	2.04	10.84	1.26	11.06	0.57	9.30	0.42	11.36	0.41
C7	22.78	2.03	10.68	1.10	10.52	2.54	10.92	1.29	11.46	0.68

Table 4 – Lamina dimensions (mm) of C3-C7 vertebrae.

Vertebra	Height		Length	
	Mean	SD	Mean	SD
C3	8.20	1.16	21.58	1.64
C4	9.34	1.61	22.72	0.86
C5	11.56	1.09	23.20	0.74
C6	12.56	1.34	23.74	1.03
C7	13.52	0.49	24.08	0.80

was greatest at C4 and least at C5 and width was greatest at C5 and smallest at C7. The height of the inferior articular process was greatest at C4 and smallest at C6. The width of the latter process was maximum at C7 and minimum at C5. The height of superior and inferior articular processes decreased towards lower cervical level (Table 4).

Discussion

Thorough anatomical knowledge is required for accurate cervical spine instrumentation. Several authors have described about the various parameters of the vertebral columns. Ethnic variations have been reported for these dimensions (Karaikovic et al., 2000); the present study was done in south Indian region.

Body. Knowledge of normal dimensions of vertebral bodies is important in diagnosing various clinical conditions such as stenosis, degenerative disorders and other space-occupying lesions. It is also useful for anterior cervical reconstructions using plate fixation (Abuzayed et al., 2010). Growth of the vertebral body may be related to genetic, racial, postural and occupational disorders. The present results for vertebral body correlate with those of Mahto and Omar (2015). Bazaldua Cruz et al. (2011) observed that the transverse diameter was greatest at C7 and smallest at C3 and the maximum height was found at C7 and minimum at C5 in the Mexican population, at variance with present results. A study by Abuzayed et al. (2010) conducted in a

Table 5 – Comparison of vertebral body diameter (mm) from present and previous studies.

Vertebra	Mahto and Omar (2015)		Bazaldua Cruz et al. (2011)		Present study	
	APL	TL	APL	TL	APL	TL
C3	13.6±0.18	22.8±0.21	14.68±2.63	19.17±3.04	13.18±0.33	22.8±0.10
C4	14.4±0.15	23.6±0.28	16.36±0.99	20.75±1.86	14.4±0.29	23.54±0.26
C5	15.2±0.21	26.4±0.30	17.45±1.29	20.88±3.73	15.4±0.29	26.46±0.51
C6	15.8±0.19	25.2±0.23	17.47±1.48	22.17±2.17	16.34±0.53	25.42±0.38
C7	-	-	17.42±1.33	23.44±3.48	16.12±0.57	26.12±3.76

APL: antero-posterior length. TL: transverse length.

Table 6 – Comparison of pedicle diameter (mm) from present and previous studies.

Vertebra	Bozbuga et al. (2004)		Kayalioglu et al. (2006)		Bazaldua Cruz et al. (2011)		Present study	
	Length	Width	Length	Width	Length	Width	Length	Width
C3	5.3±0.6	4.5±0.5	6.15±1.38	4.16±0.76	6.96±0.28	22.8±0.10	5.27±1.39	5.14±2.22
C4	5.4±0.6	4.4±0.6	6.14±1.19	4.57±0.74	6.14±1.21		23.54±0.26	4.47±1.08
C5	5.4±0.7	4.7±0.6	5.51±1.21	5.03±0.72	4.46±0.70		26.46±0.51	4.55±0.98
C6	5.8±0.8	4.7±0.5	5.67±1.05	5.28±0.93	5.36±0.49		25.42±0.38	4.84±1.17
C7	-	-	-	-	5.44±0.58	4.96±0.39	4.20±0.54	4.78±1.01

Turkish population using computerized tomography scans reported the dimensions of the body as slightly greater than the values reported in the cadaveric studies done by Ebraheim et al. (2008) and the study done by Bazaldua Cruz et al. (2011). Table 5 shows the comparison of antero-posterior and transverse length of vertebral body with previous studies.

Pedicles. The length and width of the pedicles are very important for the selection of screw size for transpedicular fixation surgery. The morphometry of cervical vertebral pedicles was studied by Kayalioglu et al. (2007) who reported that the greatest pedicle length was at C3 and the greatest pedicle width was at C6 and that pedicle height increased from C3 to C5 and decreased slightly at C6, at variance with present data. Banerjee et al. (2012) observed the maximum value of pedicle length at C4 and the minimum at C7. Table 6 shows the comparison of pedicle length and width with previous studies.

Laminae. The dimensions of the lamina are useful in laminoplasty techniques. Cervical laminoplasty is a surgical procedure frequently used for the treatment of cervical spondylotic myelopathy (Hosono et al., 2006), for the resection of spinal medulla tumours and in case of ossification of the posterior longitudinal ligament (Wang et al., 1998) C7 laminae play an important role in the maintenance of cervical spine stability (Pal and Routal, 1986). In the present study, the greatest height of laminae was observed at C7 and smallest at C3. The length was maximum at C7 and minimum at

Table 7 – Comparison of lamina diameter (mm) from present and previous studies.

Vertebra	Bazaldua Cruz et al. (2011)		Present study	
	Height	Length	Height	Length
C3	12.27±3.30	15.67±1.82	8.20±1.16	21.58±1.64
C4	11.37±1.30	18.37±1.77	9.34±1.61	22.72±0.86
C5	11.27±1.12	19.32±2.01	11.56±1.09	23.2.±0.74
C6	12.24±1.78	18.69±2.03	12.56±1.34	23.74±1.03
C7	14.31±1.50	18.19±1.57	13.52±0.49	24.08±0.80

Table 8 – Comparison of spinous process (mm) from present and previous studies.

Vertebra	Bazaldua Cruz et al. (2011)	Rekha parashar et al. (2014)	Present study
	Length	Length	Length
C3	15.53±3.10	10.80±0.97	10.46±1.54
C4	15.38±2.61	10.20±1.34	10.14±1.75
C5	16.63±3.04	12.50±0.96	12.04±1.44
C6	21.81±5.00	14.64±1.45	13.78±2.04
C7	29.12±5.86	22.10±2.02	22.78±2.03

C3. The maximum height and length was noted at C7. According to Parashar et al. (2014) the lamina height increases progressively from C3 to C7, as found here. Bazaldua Cruz et al. (2011) observed that the height of lamina decreases from C3 to C5 and increases again from C6 to C7, at variance with present results. Table 7 shows the comparison of height and length of the laminae with previous studies.

Spinous process, superior and inferior articular processes. The articular processes make up the posterolateral columns that transmit compressive forces exerted on the cervical column (C3-C7) (Pal and Routal, 1986). Transfacet fixation has infrequently been used for cervical column stabilization, which is considered as an alternative to transpedicular fixation (Bozbuga et al., 2004; Liu et al., 2006). Bazaldua Cruz et al. (2011) and Parashar et al. (2014) also observed maximum value of cervical spinous process at C7.

Conclusion

The dimensions of the body, spinous process and laminae increase from C3 to C7. The height of pedicle, superior and inferior articular processes decrease descending the cervical column. These morphologic characteristics are associated with the change from the cervical lordosis curvature to the thoracic kyphosis curvature and with the increase in cervical column mobility. These results emphasize the impor-

tance of preoperative computed tomography and conventional radiography of each patient in planning a surgical procedure and selecting the appropriate size of the instruments, thus avoiding possible postoperative complication related to implants. The present results show high individual variations in many parameters that highlight the risk of damaging important neurovascular structures during transpedicular screw fixation. A detailed anatomical knowledge of the cervical spine is required for successful surgical management in the degenerative, traumatic and neoplastic diseases of cervical spine.

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