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Anatomical dimensions of the typical cervical vertebrae and their clinical implications

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SUMMARY

The aim of the present study was to study the dimensions of various parts of the typical cervical vertebrae in anatomical samples. This study included 100 cadaveric dried typical cervical vertebrae, which were obtained at the osteology section. This study lacks the information on sex and chronological number of cervical vertebrae being studied. The dimensions of different parts of vertebrae like the body, pedicle, spinous process, laminae and articular facets were measured. The data of the right and left sides were statistically analysed by using the software 'EZR' (version 1.38, 2019). The shapes of the superior and inferior articular facets were macroscopically observed. The mean height of the typical cervical vertebra was 10.92 ± 1.35 mm; the vertebral body anteroposterior length was 14.79 ± 1.96 mm and 15.56 ± 1.95 mm at the superior and inferior borders; the vertebral body transverse length was 23.22 ± 2.16 mm and 19.88 ± 2.38 mm at the superior and inferior borders respectively; the spinous process length was 15.25 ± 4.25 mm; the vertebral foramen anteroposterior and transverse length were 12.33 ± 1.68 mm and 21.98 ± 1.82 mm respectively. The pedicle length was more ($p>0.05$) at the right side than the left. In the remaining parameters of the paired structures, there was no statistically significant difference observed ($p<0.05$). The morphometric data of the present study will enlighten the operating spine surgeon during procedures like internal fixation and decompression procedures of fracture spine. We believe that the surgical implants should be devised as per the morphometric data of the particular population.

Key words: Cervical Vertebra – Decompression – Internal fixation – Morphometry – Spine

INTRODUCTION

The cervical spine instrumentation procedures require prior knowledge about the vertebral morphology (Prabavathy et al., 2017). The morphometry of the vertebral body is helpful in diagnosing conditions like cervical canal stenosis and spinal cord tumours. The dimensions are also required for the anterior neurosurgical approach for the cervical reconstructions (Abuzayed et al., 2010). The pedicle dimensions are essential for the surgical screw size selection (Prabavathy et al., 2017). Dimensions of the lamina are helpful in the laminoplasty procedure (Hosono et al., 2006) and for studying the ossification of the posterior longitudinal ligament (Wang et al., 1998). The mor-

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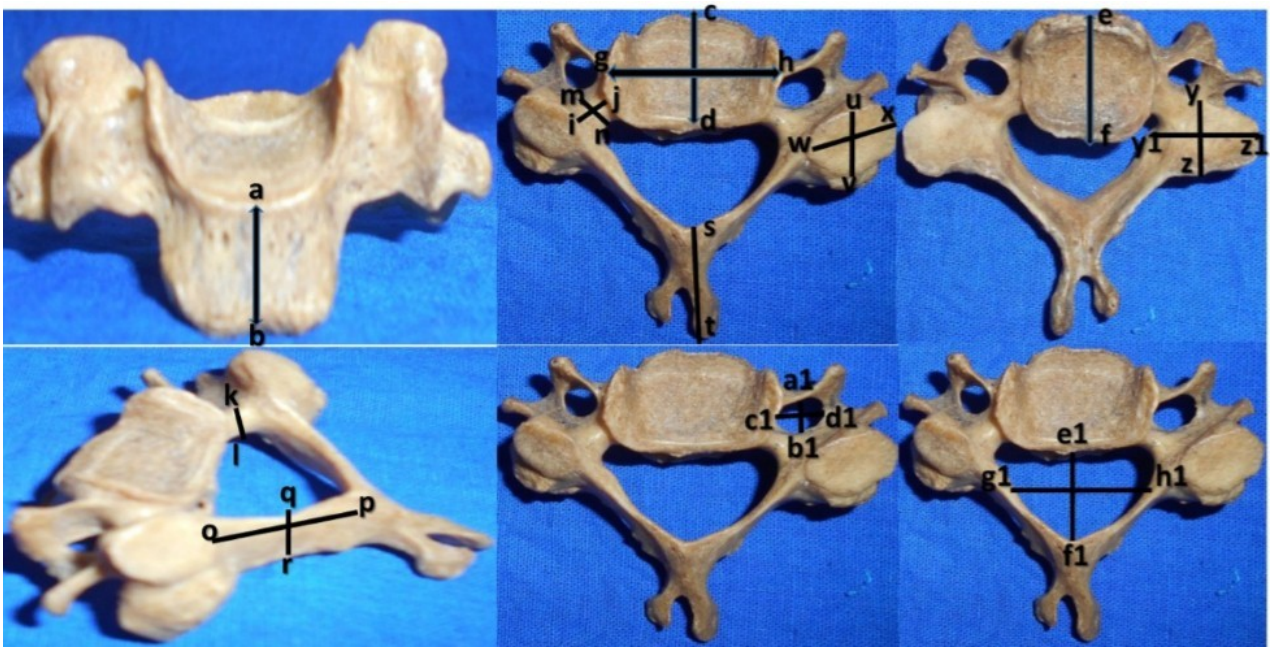

Fig 1. Measurements performed in the present study. Vertebral body-height (ab), anteroposterior length at superior border (cd), anteroposterior length at inferior border (ef), transverse length (gh); Pedicle-length (ij), height (kl), width (mn); Lamina-length (op), height (qr); Spinous process length (st); Superior articular facet-height (uv), width (wx); Inferior articular facet-height (yz), width (y1z1); Foramen transversarium-antero-posterior length (a1b1), transverse length (c1d1);Vertebral foramen-antero-posterior length (e1f1), transverse length (g1h1).

phology of the superior and inferior articular facets is enlightening because these facets transmit the forces exerted on the cervical spine (Pal and Routal, 1996). Transfacet fixation is being routinely performed for the cervical stabilization (Bozbuga et al., 2004; Liu et al., 2006). Unfortunately, the implants are used globally, and it was observed that population variations exist in the measurements of the vertebrae (Karaikovic et al., 2000). Measuring the anatomical dimensions of cervical vertebrae may help in designing the implants. Because of the clinical and surgical implications of this context, the present investigation was undertaken. The objective of the present research was to study the dimensions of the different parts of the typical cervical vertebrae in a sample Indian population. The aim is also to determine the morphological types of the superior and inferior articular facets. Regrettably, it was not possible to determine the sex of the vertebra in this study and the sequential number of the vertebra were unknown.

MATERIALS AND METHODS

One hundred cadaveric dried typical cervical adult vertebrae were included in this investigation. These vertebrae were available at the osteology section. Apart from the fact that they are adult, the specific age and sex of the vertebrae were unknown. We could not segregate the dried cervical vertebrae into third (C3), fourth (C4), fifth (C5) or sixth (C6). The vertebrae which had pathological changes like inflammative, neoplastic, traumatic or degenerative changes and fractures were excluded from the present study. There were no congenital and developmental malformations of the vertebrae being studied. The dimensions of the different parts of the vertebrae like the body, pedicle, spinous process, laminae and articular facets were measured by using the digital Vernier calliper. The present study has been approved by our institutional ethics committee.

The following measurements (Fig. 1) are performed in the present study:

1. Vertebral body height (ab)
2. Vertebral body antero-posterior length at superior border (cd)
3. Vertebral body antero-posterior length at inferior border (ef)
4. Vertebral body transverse length (gh)
5. Pedicle length right side & left side (ij)
6. Pedicle height right side & left side (kl)
7. Pedicle width right side & left side (mn)
8. Lamina length right side & left side (op)
9. Lamina height right side & left side (qr)
10. Spinous process length (st)
11. Superior articular facet height right side & left side (uv)
12. Superior articular facet width right side & left side (wx)
13. Inferior articular facet height right side & left side (yz)
14. Inferior articular facet width right side & left side (y1z1)
15. Foramen transversarium antero-posterior length right side & left side (a1b1)
16. Foramen transversarium transverse length right side & left side (c1d1)

Table 1. Dimensions of unpaired parts of the typical cervical vertebra (n=100)

parameter measured	mean ± SD (measurements in mm)
vertebral body height	10.92 ± 1.35
vertebral body antero-posterior length at superior border	14.79 ± 1.96
vertebral body antero-posterior length at inferior border	15.56 ± 1.95
vertebral body transverse length at superior border	23.22 ± 2.16
vertebral body transverse length at inferior border	19.88 ± 2.38
spinous process length	15.25 ± 4.25
vertebral foramen antero-posterior length	12.33 ± 1.68
vertebral foramen transverse length	21.98 ± 1.82

Table 2. Dimensions of paired parts of the typical cervical vertebra (n=200). Mean±SD, measurements in mm, statistical significance, p>0.05, 'paired t test'.

parameter measured	right side	left side	p value
pedicle length*	5.49 ± 1.04	5.33 ± 1.13	0.04
pedicle height	5.95 ± 0.91	6.01 ± 0.95	0.39
pedicle width	4.55 ± 0.8	4.49 ± 0.89	0.38
lamina length	26.81 ± 2.29	26.52 ± 2.62	0.05
lamina height	9.90 ± 1.44	10.01 ± 1.5	0.12
superior articular facet height	9.08 ± 1.41	9.02 ± 1.47	0.78
superior articular facet width	10.79 ± 1.56	10.72 ± 1.56	0.40
inferior articular facet height	8.35 ± 1.33	8.53 ± 1.42	0.19
inferior articular facet width	11.70 ± 1.53	11.87 ± 1.72	0.24
foramen transversarium antero-posterior length	4.93 ± 0.82	4.89 ± 0.89	0.59
foramen transversarium transverse length	5.67 ± 1.03	5.64 ± 0.89	0.59

17. Vertebral foramen antero-posterior length (e1f1)
18. Vertebral foramen transverse length (g1h1)

The different morphological shapes of superior and inferior articular facets of the typical cervical vertebrae were macroscopically observed over the right and left sides. The morphometric data obtained in this study are represented as mean± SD, and the dimensions are given in millimetre. When comparable, the right and left sided measurements differences were analyzed by using the 'paired t test'. The 'p' value less than 0.05 is considered as statistically significant. The 'EZR software, version 1.38, 2019' (Kanda, 2015) has been used for the statistical calculus.

RESULTS

The morphometric data of the present study are represented in Table 1 and Table 2. The measurements that are performed over the midline structures of the vertebra like the body, spinous process and vertebral foramen are given in Table 1. It was observed that vertebral body antero-posterior length was higher at the inferior border than its superior border, and vertebral body transverse length was more at its superior border than inferior. However most of the measurements of the typical cervical vertebrae were performed over the paired structures like pedicle, lamina, superior and inferior articular facets. These measurements were performed over the right and left sides, and the same along with the statistical comparison are represented in Table 2. There were no statistically significant differences observed over the measurements of right and left sides (p>0.05), expect the length of the pedicle, which was higher (p<0.05) for the right side.

The comparison of the parameters between male and female vertebrae was not possible, because we could not segregate them according to sex. Also the present study has the limitation of not segregating the typical cervical vertebrae into C3, C4, C5 or C6, and hence comparison between these was not possible.

It was observed that 46% of the superior articular facets were transversely oval in shape, 16% were kidney shaped, 12% were comma-shaped, 10% were triangular, 6% wedge-shaped, 4% circular, 4% pear-shaped and 2% had rhomboid morphology (Fig. 2). The inferior articular facets were

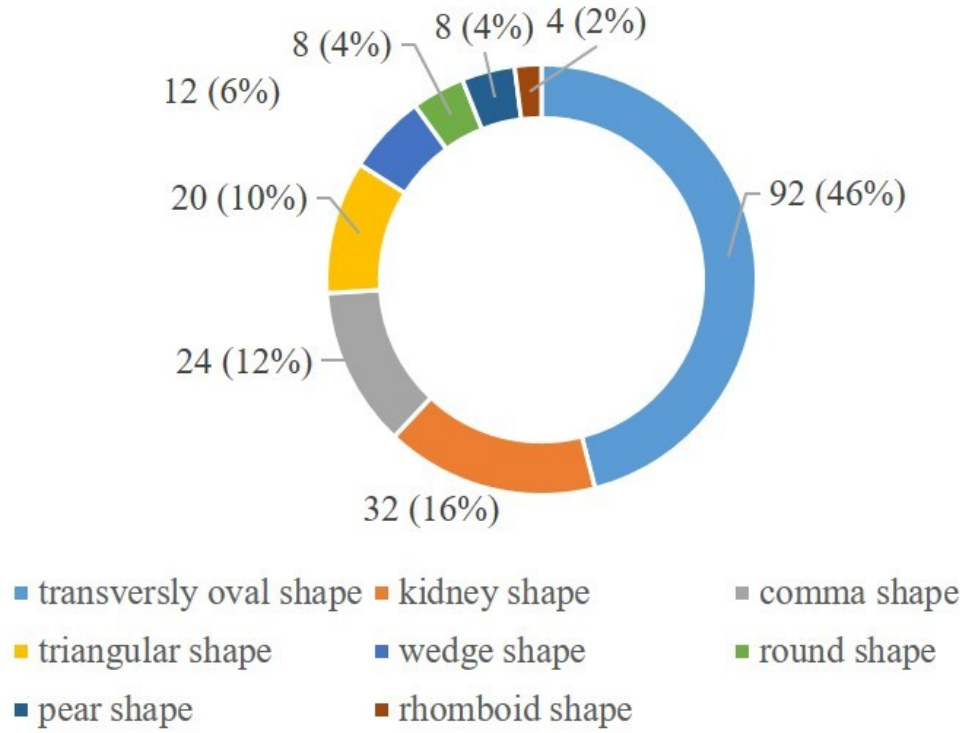

Fig 2. Frequency of various morphological shapes of superior articular facets of the typical cervical vertebrae (n=200).

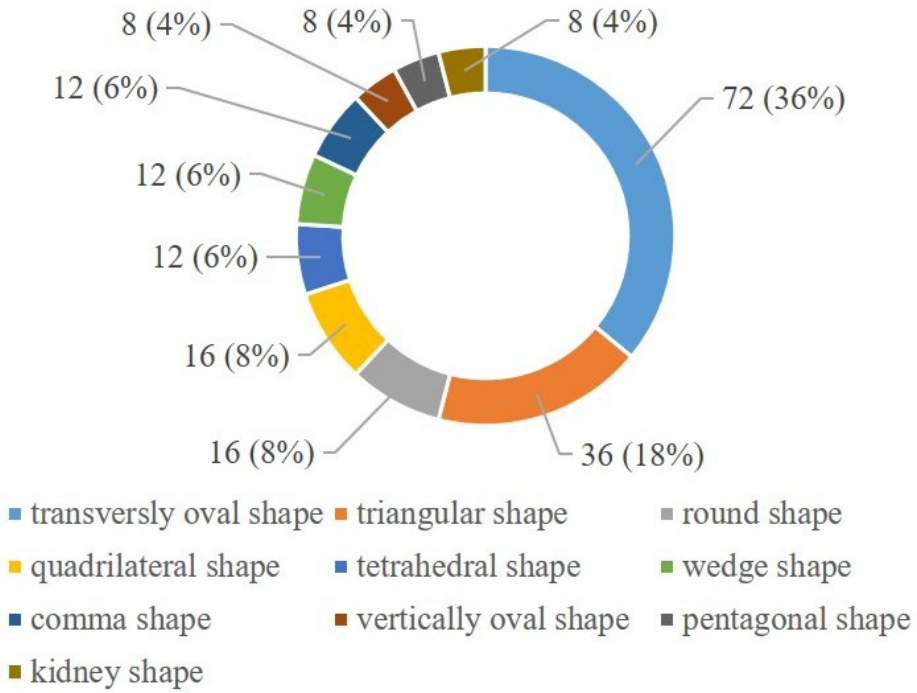

Fig 3. Frequency of various morphological shapes of inferior articular facets of the typical cervical vertebrae (n=200).

transversely oval in 36% cases, 18% were triangular, 8% were circular, 8% had quadrilateral shape, 6% tetrahedral shaped, 6% wedge shape, 6% comma shaped, 4% had vertical oval shape, 4% pentagonal shape, and 4% resembled kidney-shape morphology (Fig. 3). It was observed that the superior articular facets had similar shape over the right and left sides in only 40% cases. But in the remaining 60% cases, the shape was different over the right and left sides. The inferior articular facets had the same shape in 48% cases, and in 52% of cases the shape was different on both sides.

DISCUSSION

The morphometric data of the present study was compared with the previous studies from other

Table 3. Population-wise comparison of the data of the typical cervical vertebral body. Measurements in millimeters; VBHa-vertebral body height at anterior aspect; VBHp-vertebral body height at posterior aspect; VBAPs-vertebral body anteroposterior length at superior aspect; VBAPi-vertebral body anteroposterior length at inferior aspect; VBWs-vertebral body width at superior aspect; VBWi-vertebral body width at inferior aspect

population and authors	VBHa	VBHp	VBAPs	VBAPi	VBWs	VBWi
Turkish (Polat et al., 2019)	10.64	-	14.03	-	24.45	-
Indian (present study, 2019)	10.92 ± 1.35	-	14.79 ± 1.96	15.56 ± 1.95	23.22 ± 2.16	19.88 ± 2.38
Mexican (Bazaldua et al., 2011)	-	-	16.49 ± 1.59	-	20.74 ± 2.7	-
Singaporean (Tan et al., 2004)	10.02 ± 0.25	11.27 ± 0.15	14.12 ± 0.12	15.27 ± 0.3	14.8 ± 0.07	16.17 ± 0.12

Table 4. Population-wise comparison of the data of the typical cervical vertebral pedicle. Mean±SD, measurements in mm

population and authors	pedicle length	pedicle width	pedicle height
Turkish (Polat et al., 2019)	5.65 ± 1.83	3.66	-
Indian (present study, 2019)	5.41 ± 1.08	4.52 ± 0.84	5.98 ± 0.93
Egyptian (Mohi Eldin et al., 2014)	7.06	5.18	6.65
Mexican (Bazaldua et al., 2011)	4.75 ± 1.11	4.75 ± 1.33	6.95 ± 1.29
Singaporean (Tan et al., 2004)	-	4.76 ± 0.18	6.37 ± 0.21

Table 5. Population-wise comparison of the data of lamina, spinous process and articular facets of the typical cervical vertebrae. SP-spinous process; SAF-superior articular facet; IAF-inferior articular facet

dimensions	Indian (present study, 2019)	Turkish (Polat et al., 2019)	Mexican (Bazaldua et al., 2011)
SP length	15.25 ± 4.25	17.91	17.33 ± 3.43
lamina width	26.66 ± 2.45	13.45	14.82
lamina height	9.95 ± 1.47	9.87	11.78
SAF height	9.05 ± 1.44	16.24	10.55 ± 2.25
SAF width	10.75± 1.56	9.72	11.33 ± 1.86
IAF height	8.44 ± 1.37	12.69	10.58 ± 2.23
IAF width	11.78 ± 1.62	10.2	11.17 ± 1.81

population subgroups. The vertebral body dimensions were compared and represented in Table 3. The findings of our anatomical study are almost similar to the Singaporean and Mexican anatomical data, although the vertebral body anteroposterior length was higher for the Mexican population (Bazaldua et al., 2011). The vertebral body width was smaller at both superior and inferior aspects for the Singaporean population (Tan et al., 2004). Abuzayed et al. (2010) studied the dimensions of the vertebral body radiologically in Turkish population, and according to them the average width of the vertebral body was 23.8 mm. In their radiological study, the anteroposterior length ranged between 15.6 mm and 17.6 mm with an average of 16.4 mm. In the same study, the vertebral body height at the anterior aspect varied between 12.8 mm and 15.4 mm, with an average of 13.8 mm. The pedicle morphometry of the present study was also compared with other population groups, and this is represented in Table 4. The pedicle length and width were higher for the Egyptian population as reported by Mohi Eldin (2014). The lamina and spinous process dimensions were studied earlier in the Mexican and Turkish studies by Bazaldua et al. (2011) and Polat et al. (2019). The comparison (Table 5) showed that lamina width was higher in our study than their studies, although lamina height was higher in Bazaldua et al. (2011) study. Also the spinous process was longer in Mexican and Turkish populations as cited above (Table 5). Table 6 shows the population-wise comparison of the data of vertebral and transverse foramina of the present study with the others. It was observed that the dimensions were slightly higher for the Greek population and lesser in Turkish population. The studies were also performed radiologically by Sieradzki et al. (2008) and Urrutia-Vega et al. (2009), using a fluoroscope and it was opined that population differences exist among the dimensions of cervical vertebrae. Hence, it is understood that the surgical implants should be devised as per the dimensions of the sample population. Unfortunately, the implants are being used globally, and this may not give good postoperative results. The patients may suffer from some sort of discomfort due to the mismatching in the size of the implant. From

Table 6. Population-wise comparison of the data of vertebral foramen and transverse foramen of the typical cervical vertebrae. Mean±SD, measurements in mm; VFAPL-vertebral foramen anteroposterior length; VFTL-vertebral foramen transverse length; FTAPLr-foramen transversarium anteroposterior length on right side; FTAPLl-foramen transversarium anteroposterior length on left side; FTTLr-foramen transversarium transverse length on right side; FTTLl-foramen transversarium transverse length on left side

dimension measured	Indian (present	Turkish (Polat et al.,	American (Sangari et	Greece (Evangelopoulos et al.,
sample	cadaveric	cadaveric	cadaveric	radiological
VFAPL	12.33 ± 1.68	13.85	-	12.96 ± 1.63
VFTL	21.98 ± 1.82	20.88	-	-
FTAPLr	4.93 ± 0.82	4.23	5.17 ± 0.89	5.68 ± 1.68
FTAPLl	4.89 ± 0.89	4.28	5.13 ± 0.79	5.9 ± 0.9
FTTLr	5.67 ± 1.03	4.78	5.69 ± 1.04	6.57 ± 0.92
FTTLl	5.64 ± 0.89	4.95	5.87 ± 0.89	6.73 ± 1.06

this perspective, the anatomical dimensions will help in the correct sizing and manufacturing of the implants.

Among the various parts of the vertebra, the pedicles are considered as very strong elements that provide the strongest attachment to the vertebral column. If the internal fixation of posterior segments like the spinous process and lamina by using a wire or hook is not technically possible, the transpedicular screw fixation is the only option available (Coe et al., 1989). Kayalioglu et al. (2007) reported that the basic anatomical measurements of vertebrae have helped the surgeons during the transpedicular screw fixation. It was also described that the morphometric data of the pedicle is important to the surgeon during the transpedicular stabilization of the spine (Gupta et al., 2013). The correct size of the implant will prevent the postoperative complications like compression and pain.

The transpedicular screw fixation procedure for the cervical region is challenging, because this involves the potential risk of major neurovascular injury (Mohi Eldin, 2014). The preoperative radiological observation of the spine is essential to estimate the dimensions of the pedicle, because of the variability in the pedicle morphology. Mohi Eldin (2014) reported that, during the transpedicular internal fixation, if the pedicle diameter is smaller than 5 mm, then a smaller screw, like 2.7 mm size can be used. He also suggested that, if the pedicles are too small and there is no appropriate screw size available, the case should not be posted for the surgery. Jones et al. (1997) reported that an individualized approach should be observed for transpedicular screw fixation, because of the variability in pedicle measurements.

The detailed anatomical knowledge and morphometric data are essential for the surgical intervention of the diseases of the cervical spine. We believe that the present study has provided important morphometric data about the different parts of typical cervical vertebrae. The data can be used as a morphological database for the sample Indian population. However, the present study has few limitations, the age and sex of the vertebrae were not determined. It was also not possible to segregate the dried vertebrae into C3, C4, C5 and C6. Future implications of this study include studying the cervical spine by using CT scan images. This will provide the anatomical data of C3, C4, C5 and C6 separately.

In conclusion, the present study has provided the dimensions of different parts of typical cervical vertebrae in a sample Indian population. The morphological types of superior and inferior articular facets were also determined. The morphometric data of the present study are enlightening to the neurosurgical literature. The data may assist the operating spine surgeon during procedures like internal fixation of the fractured spine and decompression procedures, which are performed for the cervical spondylosis.

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