



Research Article

Morphometric Study of the Atlas Vertebra in Western India Region

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ABSTRACT

Background: The first cervical vertebra (atlas) plays a crucial role in supporting the skull and facilitating head movements. Its unique anatomical configuration and proximity to vital neurovascular structures necessitate precise morphometric understanding for clinical applications.

Objective: To measure and analyze specific morphometric parameters of the atlas vertebra and assess their clinical significance in surgical planning and radiological interpretation.

Materials and Methods: The study was conducted on 60 dry adult human atlas vertebrae. Standard osteometric parameters were measured using a digital Vernier caliper with accuracy of ± 0.01 mm. Parameters included vertebral canal dimensions, articular facet measurements, and foramen transversarium distances. Data were statistically analyzed using mean $\pm$ standard deviation.

Results: Key measurements included anteroposterior vertebral canal diameter (28.83 ± 3.24 mm), transverse vertebral canal diameter (24.17 ± 3.43 mm), and outer distance of foramen transversarium (57.58 ± 3.80 mm). The study revealed consistent patterns with minor regional variations compared to other Indian populations.

Conclusion: Understanding these morphometric features is vital for safe surgical interventions in the craniovertebral region. The data provide valuable reference values for implant design and surgical planning in the Indian population.

Keywords: Atlas vertebra, morphometry, cervical spine, vertebral canal, articular facets, foramen transversarium.

INTRODUCTION

The atlas vertebra is positioned in a critical region adjacent to the vital centers of the medulla oblongata, which may become compressed in cases of dislocation involving the atlantoaxial and atlanto-occipital joints. Therefore, maintaining the stability of this complex is of utmost importance. Unlike typical vertebrae, the atlas lacks a centrum (body). Its vertebral arch is modified into a thick lateral mass on each side, united anteriorly by a short anterior arch and posteriorly by a longer posterior arch. The superior articular surface is kidney-shaped and concave, while the inferior surface is rounded or oval and nearly flat. The anterior arch, posterior arch, lateral masses, and superior surface together form the atlantal ring, of which the posterior arch constitutes about three-fifths of the circumference. On the superior surface of the posterior arch lies a broad groove that lodges the vertebral artery along with a venous plexus. The superior border provides attachment to the posterior atlanto-occipital membrane, whereas the inferior border gives attachment to the ligamentum flavum. The posterior tubercle represents a rudimentary spinous process and serves as the attachment site for the ligamentum nuchae. [1-3]

Surgical procedures in this region, including atlantoaxial fixation, transarticular screw placement, and foramen magnum decompression, rely heavily on accurate anatomical measurements to prevent neurovascular complications. The dimensions of the vertebral canal, articular facets, and foramen transversarium are particularly critical for surgical planning and implant selection.

MATERIALS AND METHODS

A total of 60 dry adult human atlas vertebrae were included in the study. The inclusion criteria comprised intact and well-preserved specimens, while damaged, deformed, or pathological bones were excluded. All measurements were taken using a digital vernier caliper with an accuracy of ± 0.01 mm.

Parameters Measured

1. Anteroposterior diameter of vertebral canal
2. Transverse diameter of vertebral canal
3. Length of superior articular facet (right and left)
4. Width of superior articular facet (right and left)
5. Length of inferior articular facet (right and left)
6. Width of inferior articular facet (right and left)
7. Outer distance of foramen transversarium
8. Inner distance of foramen transversarium

All measurements were recorded three times for accuracy, and mean values were used for statistical analysis.

RESULTS

Table: 1. Morphometric Parameters of Atlas Vertebra

Parameter	Mean $\pm$ SD (mm)
Vertebral Canal AP diameter	28.83 $\pm$ 3.24
Vertebral Canal Transverse diameter	24.17 $\pm$ 3.43
Superior Articular Facet Length (Right)	18.50 $\pm$ 2.30
Superior Articular Facet Length (Left)	18.54 $\pm$ 2.40
Superior Articular Facet Width (Right)	11.07 $\pm$ 2.31
Superior Articular Facet Width (Left)	11.90 $\pm$ 2.66
Inferior Articular Facet Length (Right)	16.60 $\pm$ 1.40
Inferior Articular Facet Length (Left)	16.24 $\pm$ 1.36
Inferior Articular Facet Width (Right)	15.33 $\pm$ 2.59
Inferior Articular Facet Width (Left)	15.27 $\pm$ 2.29
Foramen Transversarium Outer distance	57.58 $\pm$ 3.80
Foramen Transversarium Inner distance	44.12 $\pm$ 2.75

Table: 2. Comparative Analysis with Previous Studies

Parameter	Present Study Western India	Chetna et al. North India [4]	Lalitha B et al. South India [5]	Ansari MS et al. India [6]	Sengul G et al. Turki [7]	Gupta C et al. India [8]	Patel NP et al. South Gujarat [9]
Vertebral Canal AP diameter	28.83 $\pm$ 3.24	28.85 $\pm$ 3.14	28.71 $\pm$ 2.43	29.44 $\pm$ 2.54	46.2 $\pm$ 6.0	30.4	28.16 $\pm$ 2.05
Vertebral Canal Transverse diameter	24.17 $\pm$ 3.43	24.14 $\pm$ 3.41	25.51 $\pm$ 2.93	27.31 $\pm$ 2.74	28.7 $\pm$ 1.8	27.7	26.63 $\pm$ 2.05
Superior Articular Facet Length (Right)	18.50 $\pm$ 2.30	19.52 $\pm$ 2.38	22.47 $\pm$ 2.4	22.13 $\pm$ 2.26	19.9 $\pm$ 3.4	21.5	20.73 $\pm$ 1.68
Superior Articular Facet Length (Left)	18.54 $\pm$ 2.40	19.55 $\pm$ 2.43	22.81 $\pm$ 2.44	21.84 $\pm$ 2.11	18.6 $\pm$ 3.2	21.8	20.86 $\pm$ 1.97
Superior Articular Facet Width (Right)	11.07 $\pm$ 2.31	11.37 $\pm$ 3.41	10.10 $\pm$ 1.7	11.82 $\pm$ 1.79	9.6 $\pm$ 1.9	11.8	11.34 $\pm$ 1.82
Superior Articular Facet Width (Left)	11.90 $\pm$ 2.66	10.96 $\pm$ 2.86	9.95 $\pm$ 3.17	12.19 $\pm$ 1.58	9.8 $\pm$ 1.5	11.5	11.39 $\pm$ 1.50
Inferior Articular Facet Length (Right)	16.60 $\pm$ 1.40	16.64 $\pm$ 2.42	17.99 $\pm$ 1.55	16.24 $\pm$ 1.44	17.1 $\pm$ 2.6	18.0	17.89 $\pm$ 1.63
Inferior Articular Facet Length (Left)	16.24 $\pm$ 1.36	16.04 $\pm$ 2.56	17.75 $\pm$ 2.07	16.39 $\pm$ 1.93	17.5 $\pm$ 2.4	17.9	17.77 $\pm$ 1.53

Inferior Articular Facet Width (Right)	15.33 ± 2.59	14.36±1.59	15.15±1.48	15.84±1.83	8.8±1.5	14.6	14.97 ± 1.89
Inferior Articular Facet Width (Left)	15.27 ± 2.29	14.17±1.39	15.01±1.43	16.39±1.93	8.5±1.5	15.2	15.00 ± 2.03
FT Outer distance	57.58 ± 3.80	56.58±4.89	54.39±4.73	58.18±4.26	59.5±3.7	57.6	55.48 ± 3.83
FT Inner distance	44.12 ± 2.75	44.02±3.74	44.5±4.57	45.38±3.25	48.6±2.4	45.2	44.77± 4.34

DISCUSSION

The present study provides a detailed morphometric analysis of the first cervical vertebra, the Atlas (C1), a unique structure critical for cranio-cervical stability and mobility. When compared to previous studies from various geographical regions of India and Turkey, our findings reveal a compelling pattern of morphological consistency within the Indian population, punctuated by significant ethnic variations in key parameters, particularly those related to the articular facets and the vertebral canal.

Vertebral Canal Dimensions

The Anteroposterior (AP) and Transverse diameters of the vertebral foramen of the Atlas are of paramount importance, as this space accommodates the spinal cord, dentate ligaments, and the spinal accessory nerves. Our measured AP diameter (28.83 ± 3.24 mm) aligns remarkably well with all cited studies from India, which show a variation of less than 1.5 mm. This high degree of homogeneity across diverse Indian regions suggests a standardized bony enclosure for the neuraxial structures at this level in the Indian populace.

In stark contrast, the data from Sengul G et al. in Turkey [7] reports a substantially larger AP diameter (46.2 ± 6.0 mm). This profound discrepancy, far beyond standard statistical variation, underscores a significant ethnic divergence in the anatomy of the posterior arch and the positioning of the lateral masses. This has direct implications for the space available for the cord (SAC), a critical measurement in conditions like atlanto-axial instability and Chiari malformation. It strongly advocates for the use of population-specific reference ranges in diagnostic imaging.

Articular Facet Morphology

The superior and inferior articular facets of the Atlas are integral to the atlanto-occipital and atlanto-axial joints, respectively, governing the nodding and rotational movements of the head.

- **Superior Articular Facets:** Our values for facet length and width are consistent with those reported by Chetna et al. and Patel NP et al. [9]. However, the studies by Ansari MS et al. [6] and Lalitha B et al. [5] report consistently larger facet lengths. Given that the superior facets articulate with the occipital condyles, this variation could influence the contact area and load distribution at the cranio-cervical junction, potentially affecting joint biomechanics and the risk of degenerative changes.
- **Inferior Articular Facets:** A similar pattern is observed with the inferior facets, which articulate with the Axis (C2). The most striking finding is the width of the inferior articular facets. Our measurements (Right: 15.33 ± 2.59 mm; Left: 15.27 ± 2.29 mm) are in close agreement with most Indian studies but are nearly double those reported in the Turkish cohort [7] (Right: 8.8 ± 1.5 mm; Left: 8.5 ± 1.5 mm). This is a critical anatomical difference, as the geometry of the inferior facets directly governs the range and quality of axial rotation. Such a marked variation suggests potential differences in the rotational kinematics and stability of the atlanto-axial joint between these populations, which could influence surgical approaches like C1-C2 transarticular screw fixation or the design of atlanto-axial spacers.

Interpedicular and Transverse Process Dimensions

The "FT Outer distance" and "FT Inner distance" in the context of the Atlas refer to the outer and inner spans between the transverse foramina, which house the vertebral arteries. The consistency of these measurements across all studies, including the Turkish data [7], is a noteworthy finding. Our values (FT Outer: 57.58 ± 3.80 mm; FT Inner: 44.12 ± 2.75 mm) show minimal deviation from other reports. This indicates that the spatial relationship of the transverse processes and the course of the vertebral arteries through the Atlas are a conserved anatomical feature across these ethnic groups. This is surgically reassuring, as these landmarks are crucial for procedures involving the lateral masses and for avoiding vertebral artery injury during C1 screw placement.

The present study holds considerable clinical relevance. It provides precise morphometric measurements essential for surgical planning, particularly in procedures such as C1 lateral mass screw fixation and transarticular stabilization, where accurate anatomical knowledge is crucial to avoid neurovascular injury. The findings also contribute valuable data for implant design, offering population-specific measurements that can aid in the development of customized cervical spine

implants suited to regional anatomical variations. In the field of radiology, this study assists in distinguishing normal anatomical variations of the atlas from pathological alterations, thereby improving diagnostic accuracy.

CONCLUSION

In conclusion, the morphometric data from our study on the Atlas vertebra demonstrates a strong concordance with other Indian studies, establishing a reliable baseline for the population. However, the significant disparities observed in critical parameters like the vertebral canal AP diameter and inferior articular facet width, particularly when compared to the Turkish data, highlight profound ethnic variations in the anatomy of the cranio-vertebral junction. These findings have direct clinical relevance for the diagnosis of cranio-cervical pathologies, the preoperative planning of instrumentation, and the potential development of population-specific implant designs. Further research with standardized methodologies across diverse ethnic cohorts is essential to fully map the anatomical landscape of the Atlas and optimize surgical safety and efficacy.

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