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Original Research Article

Morphometric Study of First Cervical Vertebrae (Atlas) in North East Bihar Region

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Abstract

This study aimed to evaluate the morphometric characteristics and anatomical variations of the atlas (first cervical vertebra) in the North-East Bihar population to support safer surgical interventions at the craniovertebral junction. A descriptive cross-sectional osteological study was conducted on 70 dried, intact adult atlas vertebrae using a Vernier caliper for precise measurements. Parameters assessed included vertebral canal dimensions, superior and inferior articular facets, and anterior and posterior arch heights. The results demonstrated a mean atlas width of 69.03 mm, with consistent vertebral canal dimensions indicating adequate space for neurovascular structures. Most parameters showed bilateral symmetry, except for the transverse diameter of the superior articular facet, which was statistically significant ($p < 0.05$). Overall, the findings revealed low variability and a homogeneous pattern, suggesting structural stability with minor functional adaptations. These morphometric insights are clinically relevant for surgical planning and instrumentation at the craniovertebral junction.

Keywords: Atlas vertebra, Morphometry, Craniovertebral junction, Articular facets, Vertebral canal, Cervical spine, Osteological study, Surgical anatomy.

INTRODUCTION

The first vertebra of the cervix (atlas) is the vertebra covering the upper end of the spine.

Anatomy of 1st cervical vertebra (Atlas)

Atlas (C1) is the first cervical vertebra or vertebra in the vertebral column which is very different in structure and functioning compared to the rest. It gets its name after the mythical character of Atlas who was thought to carry the burden of the heavens hence its bearing of the skull. The atlas does not have a vertebral body and spinous process as is the case of ordinary vertebrae, but it appears as a ring that is composed of anterior and posterior arches joined together by two masses located laterally[1]. Such a peculiar structure enables it to receive the occipital condyles of the skull and to be moved around in a large variety of directions whilst being stable.

The anterior arch is shorter with an anterior tubercle on its exterior surface with a facet on its posterior surface where it articulates with the dens of the axis (C2). The posterior arch is longer and has a posterior tubercle which is primitive spinous process. The vertebral artery runs on the upper surface of the posterior arch that runs to the back and then enters the extracranial cavity through the foramen magnum [2]. This anatomical connection causes the posterior arch of the atlas to become quite relevant during the process of surgery because any difference or abnormality can predispose a patient to vascular trauma.

The superior and inferior articular facet is found in the lateral masses of the atlas which are the strongest parts. The superior articular facets are huge, concave and kidney like and can articulate with the occipital condyles to create the atlanto-occipital joint. This joint also allows flexion and extension motion, which is normally known as the yes movement of the head [3]. Inferior articular facets on the other hand are comparatively flatter and they move with the superior facets of the axis making atlanto-axial joint, which permits head rotational movements[4].

The transverse process is another valuable characteristic of the atlas which is quite long and has the foramen transversarium through which vertebral artery and veins pass. The proximity of the atlas with the vertebral artery shows the clinical significance of the vertebra, particularly in surgeries that involve the fixing of supporting screws at the back[5]. Also, the atlas transverse ligament is important in the stabilization of dens of the axis, avoiding anterior movement and safeguarding the spinal cord[6].

Recent morphometric research studies have proved that the sizes of the atlas vary significantly across various populations due to various factors, which include ethnicity, age, and sex[7]. Such differences are of special significance in clinical practice, which can lead to the selection of surgical methods and the structure of implants. Knowledge of these anatomical facts is important not only to anatomists but also to clinicians who deal with the management of the craniovertebral junction pathologies.

Figure 1: First Cervical vertebra

Anatomy of the 2nd Cervical Vertebra (Axis)

The axis (C2) is the second cervical vertebra and it is a pivotal part of the cervical biomechanics. It is characterized by the availability of the odontoid process, or dens, which is tooth-like protuberance that projects superiorly above the vertebral body[1]. This is where the body of the atlas is left and it is a pivot on which the atlas and the skull swivel. The median atlanto-axial joint is a joint that consists of the articulation between the dens and the anterior arch of the atlas and can perform about half of rotational movement (cervical spine)[2].

Several significant ligaments help to fix the dens in place, one of which is the transverse ligament of the atlas, which attaches the dens to the anterior arch, and the alar ligaments, which run out of the dens to the occipital condyles. These ligaments are important to ensure stability of craniovertebral junction and to avoid too much movement that may endanger the spinal cord[3]. This is because any rupture of these ligaments or fracture of dens can lead to instability and can have severe neurological outcomes.

The axis is stronger in structure than the atlas, the vertebral body is well-developed, pedicles are thick, and the laminae are strong. The spinous process is normally large and bifid, and serves the purpose of attaching the muscle and ligaments of the neck movement [4]. The better articular facets occur on either side of the dens, and are joined to the inferior ones of the atlas. These aspects are directed to allow a proper rotational flow but with stability [5].

The foramen transversarium which pass through the vertebral arteries are also contained in the transverse processes of the axis. The vertebral artery running through the area is usually complicated and can change; therefore, it is a decisive factor to consider whenever performing surgery[6]. Recent research also indicates morphometric differences in the axis, especially in the size of the dens and articular facets and is valuable in preoperative planning and safe positioning of instrumentation[7].

The axis is, on the whole, a pivot point of the head movement and is an important factor in the stability and functionality of the cervical spine. It is a major subject of anatomical and clinical studies due to its distinctive structure and rapport to the neighboring organs.

Figure 2: Second cervical vertebra

Background of the Study

The cervical spine is a very special and functionally complicated area of the vertebral column that is very vital in holding up the head, protecting the spinal cord, and permitting an enormous variety of movements. The atlas (C1) along with the other cervical vertebrae is in a special position on the craniovertebral junction and forms the junction between the skull and the spine[1]. Its unique morphology that includes the lack of a vertebral body and the appearance of a ring structure permits the reception of the occipital condyles and makes it possible to flex, extend, and rotate the head [2].

The significance of the atlas is not just limited to the structural aspect of the body because it is directly linked to important neurovascular components, such as the spinal cord, vertebral arteries, and medulla oblongata [3]. Any change or deviation in its morphology has immense clinical outcomes especially with regard to trauma, congenital defects and degenerative pathology [4]. Consequently, morphometric work of atlas vertebra has been a subject of significant concern in the recent times.

Rationale of the Study

One of the most important structures of the body that contributes to stability and mobility of the craniovertebral junction is the atlas vertebra. Its morphmetric features however, can differ among various groups of people because of genetic and environmental variations. There are few data on these variations in the North East Bihar region. This is thus done to present an in-depth morphometric data on this population. The results will be applicable in the enrichment of anatomy, surgical procedures, and clinical outcomes.

Research Question –What are the morphometric dimension and anatomical variation in atlas (first cervical vertebra) in population of north east Bihar region? And how this data can contribute to safer surgical planning at craniovetebral junction.

Aim - To analyse the morphometric characteristics and anatomical variations of the first cervical vertebra (atlas) in the North-East Bihar population

OBJECTIVES

To measure the morphometric parameters of the atlas vertebra which include

1. Diameter of vertebral canal
2. Diameter of superior articular facets and inferior articular facet of left and right side
3. Anterior and posterior height of arch.

Hypothesis

- **Null Hypothesis-** There is no significant difference in the morphometric parameters of the atlas vertebra in the North-East Bihar population compared with previously reported population
- **Alternate Hypothesis-** There is significant variation in the morphometric parameters of the atlas vertebra in the North-East Bihar population compared with previously reported population

MATERIAL AND METHODS

This is a Descriptive cross-sectional morphometric study. The study was conducted in the Department of anatomy JLNMCH Bhagalpur. Dried adult human atlas vertebrae where in included in the study which were taken from osteology collection of the Anatomy department. Intact and well-preserved adult atlas vertebrae without structural damage and deformity were included. We excluded vertebra poorly preserved and broken atlas and vertebra with pathological deformities and congenital anomalies

Method of Data Collection

This was a descriptive, cross sectional, osteological study, carried out on dried human atlas vertebrae to get detailed morphometric data relevant to surgical approaches to craniovertebral junction in North East Bihar population. The work was done in the Department of anatomy J.L.N.M.C., Bhagalpur by using a manual measurement method using a Vernier calliper. A total of 70 dried, intact human atlas vertebrae (C1) of unknown sex were the subjects of the study. All of the bones used in the study were part of existing departmental osteology collections as well as Forensic Dept. that were used routinely for undergraduate and postgraduate teaching. No new cadaveric material was procured specifically for the project and no identifying information regarding donors was available so issues of patient confidentiality did not arise. The study followed institutional norms related to the use of unclaimed/ donated skeletal material for research and teaching purposes and the protocol was discussed with departmental authorities. As the study was purely an osteological and observational study with no intervention on human participants, but the principles of respectful handling of human remains were strictly followed.

TOOLS: - Vernier Calliper

All linear measurements were made with a Vernier calliper with a least count (resolution) of 0.01 mm, which allowed for high precision measurement of small osteometric distances. The instrument comprised a stainless-steel main scale and a digital sliding jaw mechanism which was able to display the measurement directly in millimetres, thereby reducing the error of parallax and subjective error in reading which are inherent in purely mechanical scales

Figure 3: Width of Atlas

Figure 4: Antero- Posterior diameter of canal

Figure 5: Transverse Diameter of canal

Figure 6: Transverse diameter of superior articular facet

Figure 7: Anteroposterior diameter of superior articular facet

Figure 8: Transverse diameter of Inferior articular facet

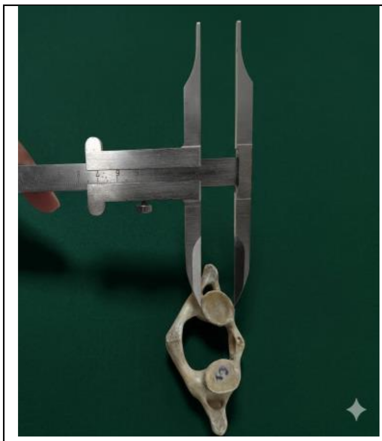

Figure 9: Transverse diameter of Inferior articular facet

Figure 10: Posterior arch height

Figure 11: Anterior arch height

Anatomical landmarks and special measurements

The following morphometric parameters were measured for each atlas vertebra with the help of a digital Vernier calliper.

- Width of Atlas (Transverse Diameter)
- Vertebral Foramen Dimensions
- Superior Articular Facet and Inferior Articular Facet Measurements
- Height of Anterior and Posterior Arches

Vernier Caliper:

Among the different instruments for the osteometric analysis, the Vernier caliper has been commonly used because of its precision, reliability and adaptability to measure small anatomical structures. In the studies involving the first cervical vertebra (atlas), the Vernier caliper is the main tool to obtain linear dimensions of bony landmarks that are fundamental in understanding anatomical variability and determining surgical procedures [8]

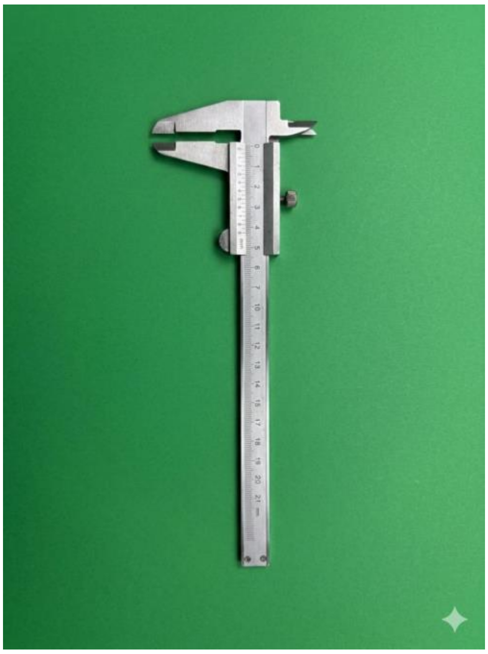

Figure 12: Vernier calliper

Statistical Analysis

Data was entered into Microsoft Excel and analysed using SPSS software.

The following statistical tests were used:

- Mean and standard deviation for all morphometric parameters
- Independent or paired t-test to compare right and left side measurements
- Frequency and percentage for morphological variations

A p-value < 0.05 will be considered statistically significant

RESULTS

The study was done on dried and well-preserved atlas vertebra and table 1 shows the descriptive statistics of all the variables taken in study. We have identified mean, standard deviation and range of minimum and maximum measurement.

Table 1: Descriptive statistics of all variables

Parameter	N	Mean	SD	Range
Width of Atlas	70	69.0287	3.3987	74.75–60.6
Anteroposterior Canal Diameter	70	25.5231	1.8827	32.1–20.5
Transverse Canal Diameter	70	21.9852	1.8397	27.5–18.25
Anterior Arch Height	70	7.4207	1.1505	10.85–5.3
Posterior Arch Height	70	5.3452	0.8337	8.85–3.25
Anteroposterior Right Superior Facet	70	17.7999	2.0305	21.75–12.75
Anteroposterior left Superior Facet	70	18.2901	2.5067	25–11.75
Transverse Right Superior Facet	70	7.8075	1.2847	11.5–5.5
Transverse left Superior Facet	70	8.3284	1.5433	11.6–4.15
Anteroposterior Right Inferior Facet	70	14.2653	1.7738	20.85–11.75
Anteroposterior left Inferior Facet	70	14.8344	2.1671	20.2–10.5
Transverse Right Inferior Facet	70	10.416	1.4114	13.85–6.8
Transverse left Inferior Facet	70	10.6573	1.4799	13.95–7.85

In our study most of the atlas width was in between 68 to 70 range with frequency of 18.

Anteroposterior Diameter of vertebral Canal measurement most of the atlas was in range of 26 to 28 mm and maximum number of transverse diameter was in range of 21 to 22.5mm. The maximum anterior arch height was recorded in between 7 to 8 mm and maximum posterior arch height was measured in between 5 to 6 mm. Most of the atlas with Anteroposterior Diameter for right superior facet was in between 16 to 18 and for left superior facet it was in between 15 to 17mm. Transverse Diameter of Right Superior Facet maximum frequency was in between 7 to8 mm and for left superior facet it was also in between 7 to 8mm. For inferior facet right Anteroposterior diameter frequency was mostly in between 14 to 15mm and for left most of the frequency was in between 14 to 16mm. For the transverse diameter of right inferior facet most of the finding was in between 9 to 10mm and for the left side it was in between 10 to 11mm.

Table 2: Statistical analysis of morphometric parameters

Parameter	Rt Mean ± SD	Lt Mean ± SD	t-value	p-value	Significance
A-P Sup. Articular Facet	17.80 ± 2.03	18.29 ± 2.51	1.28	>0.05	Not Significant
Transverse Sup. Articular Facet	7.81 ± 1.28	8.33 ± 1.54	2.16	<0.05	Significant
A-P Inf. Articular Facet	14.27 ± 1.77	14.83 ± 2.17	1.65	>0.05	Not Significant
Transverse Inf. Articular Facet	10.42 ± 1.41	10.66 ± 1.48	0.98	>0.05	Not Significant

Table 2 shows Statistical analysis of morphometric parameters were transverse superior articulating facet data was found to be significant and other parameter were not significant compare to left and right data.

We have analysed the data by applying independent t test between left and right and t values were obtained. The p-value shows the significance in the given table. P-value lower than 0.05 were consider significant and higher than that were not significant.

DISCUSSION

The purpose to the study was determine the morphometric and anatomical variation in atlas (first cervical vertebra) in population of north east Bihar Region. And also how this data can contribute to safer surgical planning at craniovetebral junction which would be helpful in for the surgeon. The main objective of study was to identify morphometric parameter of vertebral canal, articulating facet and height of arch of the first cervical vertebra. We aim to check the significance of data in the mentioned parameter of atlas.

Throughout the course of this study, atlas demonstrated consistent morphometric data with mean width of 69.03mm. The vertebral canal diameter demonstrated anteroposterior with 25.52mm and transverse diameters with 21.99mm. The arch height was recorded as 7.42mm from anterior and 5.35mm from posterior. The data indicates broad and spacious vertebral canal which is helpful in supporting neurovascular structures.

The articular facet dimensions of superior articular facets was recorded approximately 18mm in anteroposterior and approximately 8 mm in transverse diameter likewise dimensions of inferior articular facets was recorded approximately 14.5mm in anteroposterior and approximately 10.5 mm in transverse diameter. This shows that superior facets are larger in anteroposterior dimension compare to inferior facets which are relatively wider in transverse dimension. This suggests the functional load distribution differences in both the articular surface.

In side-to-side comparison left side values were consistently slightly higher than right and only transverse diameter of superior articular facet showed statistical significance ($p<0.05$) while all other parameters where not significant with p-value higher than 0.05. The most anatomical variation are not clinically significant with the data findings. The sample shows homogeneity in data due to low standard deviation and indicating high reliability and consistency of measurement. There is moderate variability observed in articular facets which suggest for the functional adaptation of head movement and load distribution. Also, there is low variability seen in the data of vertebral canal and arch height which suggest stable structural anatomy with adaptive joint surface for space for spinal cord.

The mean width of the atlas in our study (69.03 mm) is nearly similar to that of Unnati J Panchal *et al.,* (2025) who noted similar dimensions in a population in Western India suggesting a regional consistency in the morphology of the atlas [9]. Similarly, what we observed, of predominantly symmetrical dimension of right and left articular facet, is concordant with a study by N Bhat *et al.,* (2024) which highlighted minor bilateral variations but overall structural symmetry of the atlas[10]. However, a statistically significant asymmetry, which was observed in the transverse diameter of the superior articular facet in our study, is substantiated by that reported by Rahyussalim AJ *et al.,* (2025), who showed that significant morphometric variations are affected by biomechanical and demographic factors [11]. Furthermore, our results, demonstrating the normality distribution pattern and similar morphometric values are compatible with recent cadaveric analyses focusing on the reliability of atlas measurements for surgical applications [12]. Thus, our study supports the literature but strengthens the concept of subtle yet clinically relevant asymmetry in certain parameters.

The present study has a number of limitations that should be considered in interpreting the study findings. Firstly, the study was on a relatively small sample size (n=70), which may not necessarily reflect the general population and therefore limits the generalizability of the results. Secondly, no demographic information such as age, sex and ethnicity is provided and therefore no subgroup analysis can be made, which is important as morphometric variations can occur due to these factors. Thirdly, measurements were taken from dry vertebrae and therefore, the effect of soft tissues, cartilage, and in vivo biomechanical forces were not able to be determined which limits the direct clinical applicability.

CONCLUSION

The morphometric analysis of the atlas vertebra reveals a predominantly symmetrical anatomical pattern with minimal side-to-side variation. Although minor differences were observed between right and left sides, only the transverse diameter of the superior articular facet demonstrated statistically significant asymmetry. The overall normal distribution and low variability of measurements indicate a homogeneous sample population and reliable data. These findings highlight the structural stability of the atlas vertebra while suggesting localized functional adaptation at the superior articular facets, which may be relevant for biomechanical load transmission and clinical interventions involving the craniovertebral junction.

RECOMMENDATIONS

Future studies should include larger, diverse populations with age and sex stratification. Use imaging modalities like CT for greater accuracy and clinical correlation. Incorporate raw data analysis for advanced statistics. Comparative regional studies and biomechanical assessments are recommended to enhance surgical applicability and rehabilitation planning of atlas vertebra morphometry.

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