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Original Research Article

Morphometric Study of Atlas Vertebra in relation to Sulcus Arteriae Vertebralis

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ABSTRACT

Background: Atlas(C1) is an atypical cervical vertebra shaped like a ring. Important structures like the vertebral artery, suboccipital plexus of veins and first cervical nerve pass through it. Knowledge of the variability of C1 is important for neurosurgeons, orthopaedicians, otorhynologists and other physicians who in everyday practice are in contact with disorders of the spine and their consequences. So, this study was undertaken to assess the various dimensions of the C1 in relation to the vertebral artery groove.

Methods and materials: Fifty dried human atlas vertebrae were studied. Various measurements were done and statistically analysed.

Results: Antero-posterior diameter (APD) of Foramen transversarium(FT) was measured as 7.73 ± 1.04mm on the right and 7.62 ± 0.90mm on left side. Transverse Diameter(TD) of FT was observed as 6.12 ± 0.97mm on the right side and 6.02 ± 0.97mm on the left side. Outer Distance of Vertebral Artery Groove(VAG) was measured as 26.22 ± 2.32mm and 25.84 ± 1.85mm on the right and left sides, respectively. Inner Distance of VAG was observed as 13.10 ± 1.66mm on right and 13.17 ± 1.57mm on the left side. APD of Superior Articular Facet(SAF) was 21.52 ± 2.36mm on right and 21.51 ± 2.07mm on left side.TD of SAF was 11.21 ± 1.47mm on right and 11.32 ± 1.53mm on left side. APD of Inferior Articular Facet(IAF) was observed as 17.54 ± 1.50mm on right and 17.70±1.60mm on left side. TD of IAF was observed as 14.99 ± 1.65mm on the right side and 14.94 ± 1.51mm on left side. Distance between lateral-most edge of both Foramen Transversaria was measured as 56.37 ± 4.11mm and distance between medial-most edge of both Foramen Transversaria was 44.78 ± 3.67mm. MaximumTD of Atlas was measured as 72.09± 5.59mm.

Conclusion: The study will generate information that would be useful for geometric modelling of vertebrae and give necessary morphometric data on human atlas vertebra in Indian population.

KEYWORDS: Atlas vertebra, Foramen transversarium, Vertebral Artery.

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INTRODUCTION

The atlas is the first cervical vertebra which supports the globe of the head [1].

It is remarkable in that it lacks a body, and is shaped like an irregular ring. Because it's a ring fracture results in disruption of this ring and more than one location is affected. Fractures of atlas account for approximately 5% of the

cervical spine injuries [2]. While the Jefferson fracture (a four part ring fracture) is the most frequent fracture pattern, there are many other variants like posterior arch, lateral mass, transverse process fractures [3].

Rheumatoid arthritis, destruction of bony elements by neoplasm and basilar invagination of odontoid into foramen magnum due to congenital anomaly are some of the non-traumatic causes that can cause damage to the atlas vertebra [4,5].

Atlantoaxial and craniovertebral instability present unique challenges in spinal surgeries [6]. Instability at the atlas and axis requires internal fixation not only for immediate stability, but also to provide long-term immobility so as to attain a solid fusion [7]. There are a wide variety of surgical techniques to achieve this, including anterior odontoid screw fixation or posterior fusion methods such as Gallie-type fusion, Brooke-Jenkins technique, interlaminar clamps or Sonntag's modified Gallie fusion [8]. Previously wiring methods like sublaminar, spinous process, tension band, facet and triple wiring were done [9].

Recently, transarticular and transpedicular screw fixation have been widely used [10]. As these surgical techniques and instruments continue to evolve, a detailed and precise knowledge about the atlas and its surrounding anatomy is required.

Atlas consists of two symmetrical lateral masses that are united by the anterior and posterior arches. These lateral masses are thick, supportive elements composed of both a superior and inferior articular surfaces [11].

This large size of lateral masses enables screw placement feasibility in almost all patients [12]. The sulcus arteriae vertebralis (groove for the vertebral artery) is situated on the cranial surface of the posterior arch at its junction with the lateral mass [11].

This smooth groove is for the lodgement of the vertebral artery with the venous plexus around it and the suboccipital nerve. There can be compression of these structures while passing through the vertebral ring and can lead to pain in temporal region, occipital headache, periodic photophobia, paraesthaesia of hands, leading to psychogenic tension, functional headache, cervical pain and stress [1].

The superior oval articular surface articulates with the occipital condyles. The inferior circular articular facet articulates with the superior articular surface of axis, both these surfaces differ from other cervical articular surfaces by being situated ventral to the exit sites of the spinal nerves. The transverse process, which extends more laterally than the other cervical processes serves as a good surgical landmark [11].

Knowledge of the variability of atlas is important for neurosurgeons, orthopaedicians, otorhynologists and other physicians who in everyday practice are in contact with disorders of the spine and their consequences [13]. This will help in avoiding vascular complications as a result of vertibrobasilar insufficiency which may manifest as a variety of symptoms from dizziness to unconsciousness and death [1]. Keeping this in mind, the present study was taken on the Morphometry of atlas vertebra in relation to sulcus arteriae vertebralis in Indian population.

MATERIALS AND METHODS

Fifty atlas vertebrae, available in the Department of Anatomy, Dayanand Medical College and Hospital, Ludhiana were studied. The specimens selected were dry, complete, of human cadaveric vertebrae of Indian origin. Vertebrae with gross vertebral pathology were excluded.

Various dimensions were taken with the help of Vernier Calipers, metric scale and graph paper. All the measurements were recorded in millimetres(mm) and bilaterally wherever applicable. The measured data was statistically analysed including test of significance (paired t-test). Comparison was done with existing studies. The p value < 0.05 was considered to be significant and > 0.05 was considered to be insignificant.

ANATOMICAL MEASUREMENTS ON ALTAS

Antero-Posterior Diameter(APD) of Foramen Transversarium(FT) – the maximum distance between two points, one on the anterior and another on the posterior margin of FT along

its principal axis. (A-B Fig. 1)

Transverse Diameter(TD) of FT – it is the maximum distance between two points on the lateral and medial margin of FT perpendicular to the principal axis. (C-D, Fig. 1)

APD of Superior Articular Facet (SAF)– maximum antero-posterior dimension of superior articular surface along its principal axis directed anteromedially. (N-O,Fig. 1)

TD of SAF– the maximum transverse dimension of superior articular surface perpendicular to the antero-posterior dimension. (P-Q,Fig. 1)

APD of Inferior Articular Facet (IAF)– the maximum antero-posterior dimension of inferior articular surface along its principal axis directed anteromedially. (R-S,Fig. 2)

TD of IAF – maximum transverse dimension of inferior articular surface perpendicular to the antero-posterior dimension. (T-U, Fig. 2)

Outer Distance of Vertebral Artery Groove(VAG) – the distance from posterior midline to the lateral most edge of vertebral artery groove on the outer cortex. (E-F, Fig.1)

Inner Distance of VAG – distance from posterior midline to the medial most edge of vertebral artery groove on the inner cortex. (G-F, Fig. 1)

Maximum Transverse Diameter of Atlas (MTD) – distance between both the tips of transverse processes. (H-I,Fig. 1)

Distance between Lateral Most Edge of both Foramen Transversaria (distance between both lateral-most edge of FT) – it was measured as the distance between lateral borders of upper rims of two transverse foramina. (J-K,Fig. 1)

Distance between Medial Most Edge of both Foramen Transversaria (distance between both medial-most edge of FT) – it was measured as the distance between medial borders of upper rims of two transverse foramina. (L-M,Fig. 1)

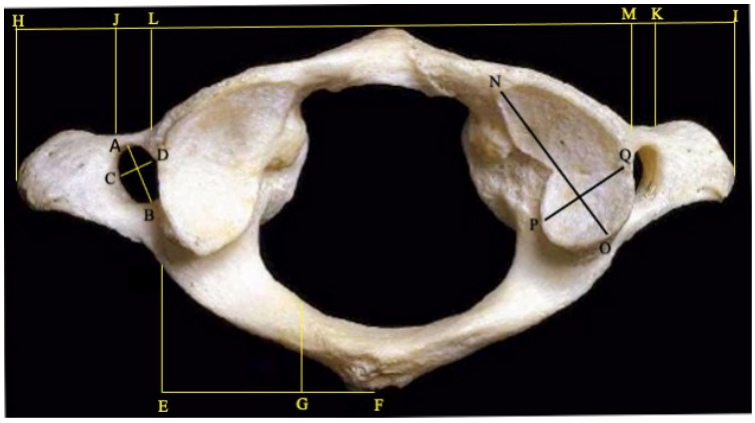

Fig. 1: Superior View of Atlas.

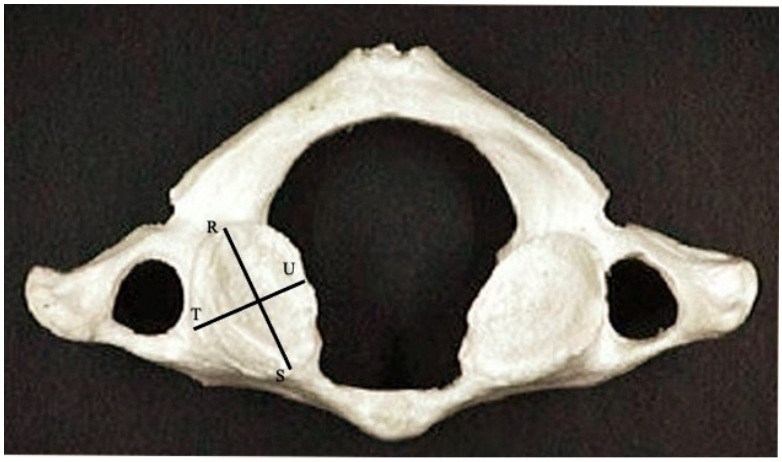

Fig. 2: Inferior View of Atlas

RESULTS

S.No.	Parameter	Range(mm)		Mean± S.D. (in mm)	
		Right	Left	Right	Left
1	TD of FT	4.76 – 9.46	4.14 – 8.14	6.12 ± 0.97	6.02 ± 0.97
2	APD of FT	5.38 – 9.94	5.80 – 9.76	7.73 ± 1.04	7.62 ± 0.90
3	Outer Distance of VAG	22.36 – 31.16	22.68 – 29.66	26.22 ± 2.32	25.84 ± 1.85
4	Inner Distance of VAG	8.78 – 18.12	9.78 – 17.10	13.10 ± 1.66	13.17 ± 1.57
5	APD of SAF	17.00 – 27.00	16.74 – 26.48	21.52 ± 2.36	21.51 ± 2.07
6	TD of SAF	8.42 – 15.10	9.22 – 16.42	11.21 ± 1.47	11.32 ± 1.53
7	APD of IAF	14.28 – 21.24	12.24 – 21.30	17.54 ± 1.50	17.70 ± 1.60
8	TD of IAF	12.70 – 19.84	12.80 – 19.98	14.99 ± 1.65	14.94 ± 1.51
9	MTD of Atlas	60.46 – 85.80		72.09 ± 5.59	
10	Distance between Lateral-Most Edge of both Foramen Transversaria	49.00 – 68.68		56.37 ± 4.11	
11	Distance between Medial-Most Edge of both Foramen Transversaria	37.84 – 53.10		44.78 ± 3.67	

Table 1 shows the recorded observations with range, mean and standard deviation(SD). Standard statistical analysis was done. Test of significance (paired t-test) was carried out for comparison of right and left sides. The p value < 0.05 was considered to be significant and > 0.05 was considered to be insignificant. For all parameters, this was insignificant showing bilateral symmetry.

DISCUSSION

FT is formed by a vestigial costal elements, the vertebral vessels and nervous plexus are caught between the bony parts. Since the vertebral vessels are a factor in the formation of the FT it can be assumed that variations in the presence, course and tortuosity of the vertebral vessels will be manifested in the changes of FT. Any deformation of the foramen can cause derangements of these structures in their course. Moreover the transverse and antero-posterior diameters of FT reflect the differences in size and anatomy of vertebral artery [14]. Table 2 shows mean TD of FT observed in the present study is higher than Taitz et al[15] and Mehta G et al [16] and lower than Karau Bundi et al[17] and Rocha et al[14]. The values of mean APD are higher in present study. Present study has been conducted in the North Indian population whereas Mehta G et al [16] has studied in Karnataka (South India). Both parameters show a wide variation which can be correlated with the development of foramen transversarium.

The location of vertebral artery on a groove on the superior surface of posterior arch of atlas is vulnerable to injury during surgical procedures in this region. In routine spinal surgeries where the posterior arch of atlas is exposed, relevant anatomy of vertebral artery plays a vital role. It is of prime importance to be aware of the distance of vertebral artery on either side of midline to avoid vascular injury. Table 3 shows that the values of Outer distance of vertebral artery groove and the inner distance of the VAG in the present study are comparable to the studies done by Lalitha B [18] and Gupta C et al [19] and Rocha et al[14], whereas Patel NP et al [20] and Sengul et al[21] have reported lower values. Patel NP et al[20] has studied in Gujarati population and Lalitha B[18] in south Indian population. This suggests that there is regional variation in the morphometry of atlas. In a study by Tan et al[22] on Asians this parameter was measured as 24.28 ± 2.27mm on right side and 24.61 ± 1.25 on left side, also by Jian et al[23] on Chinese as 27.0 ± 3.2mm on right and 26.0 ± 3.6mm on left. Our values are closer to these studies; hence there are some ethnic similarities.

The mean distance between lateral-most edge of both foramen transversaria and the mean distance between medial-most edge of both foramen transversaria, the values observed in the Indian studies are similar.

Transarticular screw fixation has become one of the primary treatment options for C1-C2

Table 2: Comparison of studies on the diameters of Foramen Transversarium.

Author	Population	TD of Foramen Transversarium		APD of Foramen Transversarium	
		Right	Left	Right	Left
Taitz et al	Israel	5.52 ± 0.93	5.76 ± 0.76	7.26 ± 0.87	7.23 ± 0.98
Karau Bundi et al	Kenyan	6.5	6.76	7.05	7.04
Rocha et al	American	6.6 ± 0.9	6.5 ± 0.9	7.3 ± 1.1	7.2 ± 1.1
Mehta G et al	Indian	5.90 ± 0.752	5.96 ±0.755	7.23±0.816	7.30 ±0.925
Present study	Indian	6.12 ± 0.97	6.02 ± 0.97	7.73 ± 1.04	7.62 ± 0.90

Table 3: Comparison of studies on the parameters of Atlas.

PARAMETER		Sengul et al (mm)	Rocha et al (mm)	Lalitha B et al (mm)	Gupta C et al (cm)	Patel NP et al (mm)	Present Study (mm)
Outer Distance of VAG		R16.2± 2.5 L15.8 ± 2.4	R 24.1± 1.8 L 23.8 ± 1.8	R 24.42±1.9 L 25.30±2.0	R 2.30 L 2.20	R 14.93 ± 2.3 L15.1 ± 2.26	R 26.22±2.32 L 25.84±1.85
Inner Distance of VAG		R10.3± 1.6 L10.4 ± 2.0		R 12.01±3.40 L 12.69±3.03	R 1.28 L 1.38	R 10.34± 1.94 L 10.3 ± 1.72	R 13.10±1.66 L 13.17±1.57
Distance between Lateral-Most Edge of both Foramen transversaria		59.5 ± 3.7		54.39±4.73	5.76	55.48± 3.83	56.37 ± 4.11
Distance between Medial-Most Edge of both Foramen transversaria		48.6 ± 2.9		44.50±4.57	4.52	44.77± 4.34	44.78 ± 3.67
SAF	**APD**	R19.9 ±3.4 L 18.6 ± 3.2	R 23.9 ±2.5 L 23.6 ± 2.5	R 22.47±2.40 L 22.81±2.44	R 2.15 L 2.18	R 20.73±1.68 L 20.86±1.97	R 21.52±2.36 L 21.51±2.07
	TD	R 9.6 ± 1.9 L 9.8 ± 1.5		R 10.10±1.70 L 9.95±3.17	R 1.18 L 1.15	R11.34±1.82 L11.39± 1.5	R 11.21±1.47 L11.32±1.53
IAF	**APD**	R 17.1 ±2.6 L 17.5 ± 2.4	R 18.8 ±1.7 L 18.7 ± 1.6	R 17.99±1.55 L 17.75±2.07	R 1.80 L 1.79	R 17.89±1.63 L17.77±1.53	R 17.54±1.50 L 17.70±1.60
	TD	R 14.6± 2.5 L 14.6 ± 2.5	R 16.6± 2.0 L 16.4 ± 2.0	R 15.15±1.48 L 15.01±1.43	R 1.46 L 1.52	R 14.97±1.89 L 15 ± 2.03	R 14.99±1.65 L 14.94±1.51
MTD of Atlas		74.6 ± 9.7	78.9 ± 6.4	70.25±6.86	7.25	71.19 ± 4.51	72.09 ± 5.59

instability. The trajectory and angulation while screw placements is crucial because of the surrounding neurovascular structures, i.e. vertebral artery on the lateral and spinal cord on the medial aspect of superior articular facets of atlas. The knowledge of the APD and TD dimensions of SAF can help in the safe planning of these screw placements. There is a dimensional equivalence amongst most of the Indian studies and the present study while comparing the diameters of the SAF and the IAF. Sengul et al [21] have observed lower value in the Turkish population.

The mean transverse diameter of atlas is one of the factors for cephalometric analysis. It is associated with head posture, cranial base angulation, mandibular shape, and girth and also important to know the MTD of atlas in spinal implants. Table 3 depicts that the measured dimension in present study is close to the studies done in Indian population. Sengul et al [21 and Rocha et al [14] have higher values which depicts racial and ethnic differences. This suggests that there is a wide variation of MTD amongst different races.

CONCLUSION

The overall goal of this study was to generate information that would be useful for geometric modelling of vertebrae and give necessary morphometric data on human atlas vertebra in of Indian population. This data may help in the development of spinal implants. In cases where destruction of vertebra is extensive due

to trauma or gross invasion by the tumour, the data will be necessary for sizing the replacement and reconstructing normal alignment.

Although specific requirements vary, it is hoped that data thus generated on the atlas morphometry will prove useful enough in a variety of studies.

ABBREVIATIONS

APD- Antero-posterior diameter

C1- Atlas Vertebra

C2 - Axis vertebra,

FT- Foramen Transversarium,

IAF- Inferior Articular Facet,

MTD- Maximum Transverse Diameter of Atlas,

SAF- Superior Articular Facet,

TD- Transverse diameter

VAG- Vertebral Artery Groove

Conflicts of Interests: None

Author Contributions

Dr Jasveen Kaur – Concept, designing and execution of the research

Dr Harpreet Singh Gulati- Data collection and writing

Dr Kamaljeet Kaur- Data collection and interpretation of results

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