International Journal of Research in Medical Sciences
Patel NP et al. Int J Res Med Sci. 2016 Oct;4(10):4380-4386
www.msjonline.org
pISSN 2320-6071 | eISSN 2320-6012

DOI: http://dx.doi.org/10.18203/2320-6012.ijrms20163297

Research Article

A morphometric study of adult human atlas vertebrae in South Gujarat population, India

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Received: 25 July 2016
Revised: 26 July 2016
Accepted: 30 August 2016

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ABSTRACT

Background: The atlas (C1) has undergone many structural modification and located at critical point close to the vital centres of the medulla oblongata which can get compressed by a dislocation of the atlanto axial complex or instability of the atlanto axial joint. Knowing of various dimensions of atlas vertebrae are very important for the development of instrumentation related to atlas vertebrae.
Methods: In this study, total 100 dried, unbroken atlas vertebrae of unknown age and sex were evaluated in department of anatomy of medical colleges of South Gujarat. All dimensions were measured in bilateral manner using Digital Vernier Callipers with 0.01mm resolution.
Results: The mean width of atlas was 71.19 mm. The mean distance between lateral margins of both transverse foramina was 55.48 mm and the inner distance was 44.77 mm. The mean for anteroposterior diameter of vertebral canal of atlas was 28.16mm and transverse diameter was 26.63 mm. The height of anterior arch was 10.21 mm and posterior arch was 8.68mm. The mean for height of facet for dens was 8.96mm and width was 9.18 mm. The mean of anteroposterior diameter of right and left superior articular facet was 20.73 mm and 20.86 mm and transverse diameter was 11.34mm and 11.39mm. The mean of anteroposterior diameter of right and left inferior articular facet was 17.89mm and 17.77mm and transverse diameter was 14.97mm and 15 mm. The mean thickness of vertebral artery groove (VAG) for right and left side was 4.15mm and 3.99mm and width was 8.26 and 8.1 mm. The length of VAG-inner edge (D1) for right and left side was 10.34mm and 10.3mm and length for outer edge (D2) was 14.93mm and 15.1mm.
Conclusions: The observations of present study helps in improving understanding of various bony dimensions which could facilitate diagnosis and preoperative planning while operating close to important structures like nerve roots and the vertebral artery and will allow for more accurate modelling of South Gujarat, India.

Keywords: Foramina transversarium, Vertebral artery groove, Anterior arch, Posterior arch

INTRODUCTION

The anatomy of the atlas (first cervical vertebrae, C1) exhibits complex, three- dimensional structures, showing extensive variability in morphology from other cervical vertebrae.[1] It is located at critical point close to the vital centers of the medulla oblongata which can get compressed by a dislocation of the atlanto axial complex or instability of the atlanto axial joint.[2] The atlas holds the globe of the skull and is devoid of body and spine. It has two lateral masses links by an anterior and posterior arch. Each lateral mass has superior and inferior articular facets.[1]

The VAG (vertebral artery groove) is situated on the superior surface of posterior arch behind the lateral mass lodging the third part of vertebral artery. It shows transverse foramen for the vertebral artery. Dislocation of

the atlanto- axial complex or instability of the atlanto-occipital joint which may be caused by rheumatoid arthritis, C1-C2 fractures, transverse ligament disruption, os odontoid and tumour. Therefore, reduction and rebuilding of the stability of this complex is important.[2] The stabilization procedures include wiring, transarticular screw fixation and plate fixation, iatrogenic injuries to the vertebral artery is the most frequent peroperative complication which lead to catastrophic intraoperative bleeding.[3]

This compromise the blood flow which can lead to unpredictable neurological deficits. So knowing the dimension of the vertebral elements is very important for the development of instrumentation related to cervical spine. Ethnic variations have been reported in these dimensions. Aim of present study was to evaluate the various dimensions of the atlas quantitatively and analyze their relationship with the vertebral artery foramen, in addition to determining the safe sites for different surgical approaches.

METHODS

In this study 100 dried macerated atlas vertebrae of unknown age and sex without any obvious pathology were collected from department of anatomy of medical colleges of South Gujarat region. The specimens were measured by using vernier caliper for linear measurement which provides accurate resolution up to 0.01mm. Each measurement was taken two times to minimize error. All measurements were performed by first author for the sake of consistency. The study was conducted as per the protocol laid down below and different parameters for atlas as described in Figure: 1 and 2 were defined and measured. The data were evaluated by the descriptive statistics and the mean, range and standard deviation were calculated for all vertebrae.

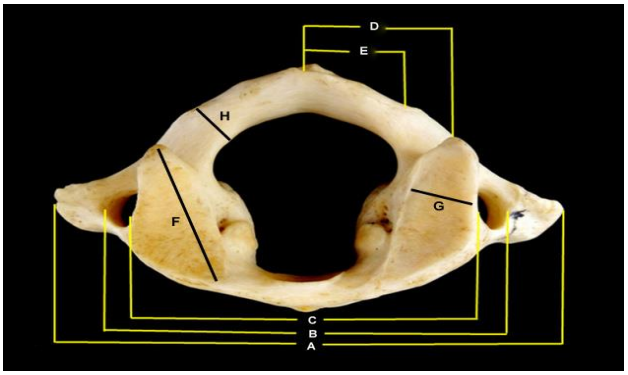

Figure 1: Depicts description of atlas measurements taken from the superior aspect.

The width of atlas was measured as the distance between both tips of transverse process (A). Outer distance of vertebral artery foramen was measured as the distance between both lateral-most edges of the transverse foramen (B). Inner distance of vertebral artery foramen was measured as the distance between both medial-most edges of the transverse foramen (C). Outer distance of vertebral artery groove was measured as the distance from midline to the lateral-most edge of the vertebral artery groove on outer cortex (D). Inner distance of vertebral artery groove was measured as the distance from midline to the medial-most edge of the vertebral artery groove on inner cortex (E). The length of superior articular facets was measured as the A-P dimension of articular surface (F). The width of superior articular facets was measured as the transverse dimension of articular surface (G).The width of vertebral artery groove was measured between the inner and outer edges at the middle of the groove (H).

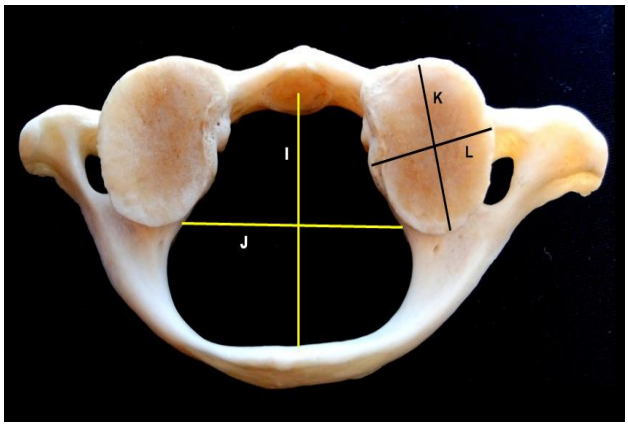

Figure 2: Depicts description of atlas measurements taken from the inferior aspect.

The maximum A-P diameter of the vertebral canal was measured along the midsagittal plane passing through the canal's widest point (I). The maximum transverse diameter of the vertebral canal was measured along the frontal plane passing through the canal's midpoint (J). The length of inferior articular facets was measured as the A-P dimension of articular surface (K). The width of inferior articular facets was measured as the transverse dimension of articular surface (L).

Protocol of study

The following parameters were worked out in the present study on atlas vertebrae.

- The width of atlas (TD): Distance between the tips of the two transverse processes of the atlas.
- The outer distance of vertebral artery foramen (OD): distance between lateral-most margins of both the foramina transversaria.
- The inner distance of vertebral artery foramen (ID): distance between medial- most margins of both foramina transversaria.
- The maximum inner antero-posterior (A-P) diameter of the vertebral canal measured in the sagittale plane.
- The maximum inner transverse diameter of the vertebral canal.

- The height of anterior arch: measured between superior border to inferior border at midline.
- The height of posterior arch: measured between superior border to inferior border at midline.
- The maximum vertical height of the facet of the dense: measured at midline.
- The maximum transverse width of the facet of the dense.
- The length of the superior articular facet: measured as the antero-posterior dimension on both right and left superior articular facet.
- The width of the superior articular facet: measured as the transverse dimension of on both right and left superior articular facet.
- The length of the inferior articular facet: measured as the antero-posterior dimension on both right and left inferior articular facet.
- The width of the inferior articular facet: measured as the transverse dimension of on both right and left inferior articular facet.
- The thickness of the vertebral artery groove (VAG): measured at the thinnest part of the groove on both right and left side.
- The width of vertebral artery groove (VAG): measured between the inner and outer edges at the middle of the groove both on right and left side.
- Inner distance of vertebral artery groove (D1): measured as the distance from midline to the medial-most edge of the vertebral artery groove on inner cortex.
- Outer distance of vertebral artery groove (D2): measured as the distance from midline to the lateral-most edge of the vertebral artery groove on outer cortex.

RESULTS

Seventeen parameters were studied for the hundred atlase. Measurement's results were analysed, tabulated in Tables 1-3 and standard statistical analysis was done.

Table 1: Anatomical parameter of atlas.

Parameter		Mean (mm)	SD	Range (mm)
Width of atlas		71.19	4.51	59.6-79.34
Outer distance b/w lateral margin of both transverse foramina (OD)		55.48	3.83	46.68-64.02
Inner distance b/w medial margin of both transverse foramina (ID)		44.77	4.34	37.02-53.98
Vertebral canal	Max. A-P diameter	28.16	2.05	22.92-33.54
	Max. Trans. diameter	26.63	2.05	22.84-34.56
Height of anterior arch		10.21	1.64	7.34-17.14
Height of posterior arch		8.68	1.82	6.06-14.43
Height of facet for dens		8.96	1.63	5.8-14.88
Width of facet for dens		9.18	1.61	5.02-15.54

(Max: Maximum, A-P: Anterioposterior, Trans: Transverse)

In present study Table 1-3 depicted that observed mean value for width of atlas was 71.19 mm. Maximum and minimum value was 79.34 mm and 59.6mm respectively. The mean value for outer distance between lateral margins of both transverse foramina (OD) was 55.48 mm and maximum and minimum value was 64.02 mm and 46.68 mm.

Table 2: Diameters of articular facets of atlas.

Parameter		Mean (mm)	SD	Range (mm)
Length of superior articular facet	RT	20.73	1.68	15.64 -25.26
	LT	20.86	1.97	16-26.28
Width of superior articular facet	RT	11.34	1.82	5.98 - 16.24
	LT	11.39	1.5	5.78-15.9
Length of inferior articular facet	RT	17.89	1.63	13.1 - 22.04
	LT	17.77	1.53	12.74-21.82
Width of inferior articular facet	RT	14.97	1.89	9.66 - 19.26
	LT	15	2.03	10.62-19.02

The mean value for inner distance between medial margins of both transverse foramina (ID) was 44.77 mm with maximum and minimum value observed as 53.98 mm and 37.02 mm respectively. The mean calculated value for anterio-posterior diameter of vertebral canal of atlas was 28.16mm and maximum and minimum values observed for anterio-posterior diameter were 33.54 mm and 22.92 mm. The mean value for maximum transverse diameter of vertebral canal of atlas was 26.63 mm with maximum and minimum value was 34.56 mm and 22.84 mm respectively.

In present study the mean value for height of anterior arch was 10.21 mm and for posterior arch was 8.68 mm. The observed maximum and minimum values for height of anterior arch were 17.14 mm and 7.34 mm, for posterior arch were 14.43 mm and 6.06 mm. The mean observed value for height of facet for dens was 8.96mm and width of facet for dens was 9.18 mm. The observed maximum and minimum values for height of facet for dens were 14.88 mm and 5.8 mm, for width of facet for dens were 15.54 mm and 5.02 mm.

Table 3: Parameters of vertebral artery groove.

Parameter		Mean (mm)	SD	Range (mm)
Thickness of vertebral artery groove	RT	4.15	1.28	1.1 - 10
	LT	3.99	0.98	1.48-6.56
Width of vertebral artery groove	RT	8.26	1.51	6.0 - 12.15
	LT	8.1	1.32	5.28-11.10
Length of vertebral artery groove inner edge (D1)	RT	10.34	1.94	6.24 - 14.06
	LT	10.3	1.72	6.14-15.16
Length of vertebral artery groove outer edge (D2)	RT	14.93	2.3	9.5 - 18.62
	LT	15.1	2.26	9.8-19.9

(RT: Right, LT: Left)

The mean value of anterioposterior diameter of right and left superior articular facet were measured as 20.73 mm and 20.86 mm respectively. The maximum and minimum values observed as 25.26 mm and 15.64mm for right side and 26.26 mm and 16mm for left side respectively. The mean value for transverse diameter of right and left superior articular facet were 11.34mm and 11.39 mm respectively. The maximum and minimum values observed as16.24 mm and 5.98 mm for right side and 15.9 mm and 5.78 mm for left side respectively.

The mean value of anterioposterior diameter of right and left inferior articular facet were calculated as 17.89 mm and 17.77 mm respectively. The maximum and minimum values were observed as 22.04 mm and 13.01 mm for right side and 21.82 mm and 12.74 mm for left side respectively. The mean value of transverse diameter of right and left inferior articular facet were observed as 14.97 mm and 15 mm respectively. The maximum and minimum values were 19.26 mm and 9.66 mm for right side and 19.02 mm and 10.62 mm for left side respectively.

In present study the mean thickness of vertebral artery groove (VAG) of atlas for right and left side was 4.15 mm and 3.99 mm respectively with maximum and minimum value observed as 10.0 mm and 1.1 mm for right side and 6.56 and 1.48 mm for left side respectively. The mean value for width of VAG of atlas for right and left side was 8.26 and 8.1 mm respectively. Maximum and minimum value observed as 12.15 and 6.0 mm for right side and 11.10 mm and 5.28 mm for left side respectively.

The mean length of vertebral artery groove –inner edge (D1) of atlas for right and left side was 10.34 and 10.3 mm with maximum and minimum value were observed as 14.06 mm and 6.24 mm for right side and 15.16 mm and 6.14 mm for left side respectively. The calculated mean length of vertebral artery groove –outer edge (D2) of atlas for right and left side was 14.93 mm and 15.1 mm respectively with maximum and minimum value were observed as 18.62 mm and 9.5 mm for right side and 19.9 mm and 9.8 mm for left side respectively.

DISCUSSION

The first cervical vertebra (atlas) supports the skull and is uniquely positioned in the atlantoaxial complex. As new surgical techniques and instruments for the treatment of unstable cervical spine continue to evolve, detailed knowledge about this bone becomes even more essential.[2] The relationship between the vertebral arteries and atlas vertebrae have a determining role in planning an operative approach.

Various techniques such as inter-laminar clamp and hook plating, lateral screw and plate fixation, and interspinous wiring have been described for treating cervical instability.[5] The rate of recognized vertebral artery injury

was identified as 2% in the report by Gupta and Goel, 4.1% in the study by Wright and Lauryssen and 8% in the study by Madawi et al.[6-8] However, the actual incidence of vertebral artery injury may be higher than those reported because of the low survey response and the possibility of unrecognized vertebral artery injury.[9]

Table 4: Comparison of different parameters with different authors.

Parameter	Segul and Kodiglu 2006	Lang 1995	Shilpa N Gosavi 2012	Ansari et al	Present study
Width of the Atlas	74.6	78.2	69.37	72.44	71.19
Outer distance b/w outer margin of f. transversarium	59.5	64	55.66	56.31	55.48
Inner distance b/w inner margin of f. transversarium	48.6	52.3	45.93	43.88	44.77
Vertebral foramen trans. Diameter	28.7	30.2	21.24	22.33	26.63
A-P diameter	46.2	34.5	10.36	8.74	28.16
SAF-right					
A-P diameter	19.9		21.02	22.26	20.73
Trans. diameter	9.6		10.47	9.57	11.34
SAF-left					
A-P diameter	18.6		16.57	17.99	20.86
Trans. diameter	9.8		14.01	14.84	11.39
IAF-right					
A-P diameter	17.1		16.57	17.99	17.89
Trans. diameter	14.6		14.02	14.84	14.97
IAF-left					
A-P diameter	17.5		16.5	17.82	17.77
Trans. diameter	14.6		14.42	14.49	14.97

(A-P Anterioposterior, Trans:Transverse, SAF- Superior Articular facet, IAF Inferior articular facet).

The actual risk of neurological deficit was only 0.2% per patient because the contralateral uninjured vertebral artery circulation was adequate and no ischemia was observed.[9] Table 4 gives a comparison of certain parameters of atlas in previously published studies to present study. From the Table 4 it is clear that there is some difference in such values for various parameters. This variation is perhaps due to the difference in the races to which the atlases belonged.[2] Textbooks of anatomy describes racial difference in bones, particularly the skull. It is therefore, not illogical to say that the differences noted above are due to racial differences in the atlas.[2]

In present study, the mean value for width of atlas was 71.19±4.51 mm with a range from 59.6 to79.34 mm. In previous studies sengul and Kodiglu et al calculated as 74.6mm, Gosavi SN in 2012 calculated as 69.37 mm and Sharma T observed as 77 and 68 mm for male and female Punjabi population.[2,5,10] The mean distance between the outermost edges of the transverse foramens (OD) was 55.48±3.83 mm with a range from 46.68 to 64.02 mm which is matched to the observation of Gosavi SN which was 55.66±6.57mm.[2] However observation is differed from other authors observation. The mean distance between both medical-most edge of the transverse foramen (ID) was 44.77±4.34 mm and matched with observation of Shilpa N Gosavi[2] and Gupta C which was reported as 45.93mm and 45.2mm but it is unmatched with other's study reported as 48.6mm by Sengul and Kodiglu and 52.3mm by Lang J et al.[1,5,11] The observed mean value for max. anterioposterior diameter of vertebral canal of atlas is 28.16±2.05 mm and max. transverse diameter was 26.63±2.05mm. Gosavi SN in 2012 measured as 27.89mm and 26.89mm.[2]

The height of the anterior arch was 10.21±1.64mm and posterior arch was 8.68 ±1.82 mm and these observation were more close to the study done by Gosavi SN who observed as 10.33±1.67mm and 8.61±1.77mm.[2] The mean height for facet for dens on atlas was 8.96±1.63mm and width was 9.37±2.19mm,this results are similar to Gosavi SN who noted as 8.96±1.63mm and 9.18±1.61mm respectively.[2]

The mean value of anterioposterior diameter superior articular facet for right and left was 20.73±1.68mm and 20.86±1.97mm respectively.

The mean transverse diameter of Superior articular process for right and left was11.34±1.82 and11.39±1.5 mm.

Gupta C et al observed the mean value of A-P in Indian population as 19.73 mm for both side. Kandziora et al

calculated as 25.3±2.22 mm in Korian population. Konig et al observed the mean value of transverse diameter of superior articular facet of right and left side as 11.6±2.0 and 11.2±1.5 mm in German population. Gosavi SN evaluate the mean value of transverse diameter of superior articular facet 10.36±1.72 mm and 10.47±1.61 mm respectively.[1,2,12]

The mean value of anterioposterior diameter of inferior articular facet for right and left was 17.89±1.63mm and 17.77±1.53mm respectively. The mean transverse diameter of inferior articular facet for right and left was 14.97±1.89mm and 15±2.03mm.Kaur et al evaluate the mean value of A-P diameter of right and left side inferior articular facet as 17.54±1.50 and 17.70 ±1.60 mm and for transverse diameter 14.99±1.65mm and 14.94±1.51, Gosavi SN calculated as 7.13±1.0 and 7.4±1.67 mm for right and left A-P diameter and 14.01 ±1.93 and 14.42± 1.67mm for right and left transverse diameter.[2,13]

The vertebral artery groove (VAG) on the superior surface of the posterior arch of atlas represents the exact location of the third part of the vertebral artery the thickness of the vertebral artery groove on atlas was 4.15±1.28 mm with a range of 1.1 to 10mm on right side and 3.99±0.98 mm with a range of 1.48 to 6.56 mm on left side. Whereas Ebraheim et al reported as 4.1±1.2mm, Sengual and Kodiglu as5.05mm and Gosavi SN observed as 3.72±1.06mm.[2,5,14]

Sengual et al described that this thickness is sufficient for some fixation technique such as clamp and hook plating and atlanto-axial wiring.[5]

Width of vertebral artery groove was 8.26±1.51mm for right side and 8.10±1.32mm for left side which was reported as 7.89±1.29mm and 8.08±1.37mm for right and left side by Ravichandan D.[3] In present study length of vertebral artery groove-inner edge (D1) was 10.34±1.94 mm on right side and 10.3±1.72mm on left side and length of vertebral artery groove-outer edge (D2) was 14.93±2.3 mm on right side and 15.1±2.26mm on left side.

Sengul and Kadioglu observed D1 as 10.3±1.6 for right side and 10.4±2.0 mm for left side and D2 16.2±2.5 for right side and 15.8±2.4 mm for left side and Gupta C et al[1] noted D1 as 12.8±1.5 and 13.8±1.8 for right and left side and D2 as 23±2.3 and 22±2.5 for right and left side.[5] Damage to vertebral artery can be avoided if the exposure of the posterior arch of atlas remains medial to the groove and suggested that the dissection on the posterior arch should remain within 12mm lateral to midline and dissection on the superior aspect of the posterior ring should remain within 8mm from the midline.[14,15]

CONCLUSION

The anatomy of the atlas vertebrae exhibits complex, three-dimensional structures, showing extensive variability in morphology. The observations of the present study will be important to understand the ergonomics of the craniovertebral joint. They will be helpful for academician, neurosurgeons, clinicians, and radiologists in day to day clinical practice, as new surgical techniques and instruments for the treatment of unstable cervical spine continue to evolve, and detailed knowledge about atlas vertebra becomes even more essentials.

ACKNOWLEDGEMENTS

Authors would like to thank the Head of the Anatomy department, Surat municipal institute of medical education and research (SMIMER), Government medical college (GMC) Surat and Government medical education and research society (GMERS) Valsad for giving them permission to perform bone study.

Funding: No funding sources
Conflict of interest: None declared
Ethical approval: The study was approved by the Institutional Ethics Committee

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Cite this article as: Patel NP, Gupta DS. A morphometric study of adult human atlas vertebrae in South Gujarat population, India. Int J Res Med Sci 2016;4:4380-6.