ORIGINAL RESEARCH

Morphometric Analysis of the First Cervical Vertebra – A Clinical Perspective

G.Rohini Devi[1]

[1]Assistant Professor, Department of Anatomy,Govt Medical College, Suryapet, Telangana, India.

ABSTRACT

Background:Craniovertebral junction (CVJ) surgery includes several decompressive and stabilising operations, including transarticular screw fixation of the atlas vertebra and axis vertebra (C1 and C2) and posterior screw placement on the lateral mass. These operations, in turn, usually target the C1, which is a critical component of the CVJ's bony architecture and is regularly targeted. This study will attempt to collect and offer anatomical data of the atlas, which may be necessary for planning a surgical approach and assessing C1 fractures, among other purposes. AIM: The present study was aimed at making the following observations; To observe and measure specimens of the atlas vertebra to obtain morphological parameters and the second objective was to provide anatomic data for planning of a surgical approach to the CVJ.

Materials and Methods: The study was conducted on 120 human dry adult intact atlas vertebrae collected from the Department of Anatomy, Govt Medical College Suryapet&VIswabharati Medical College Kurnool, over 18 months.

Results: The transverse process of the atlas has a distance of 58.04 mm to 81.51 mm. The atlas' mean width was 70.8 mm. The majority of the atlas was 65-74.42 mm wide (51 percent). The foramen transversarium measured 5.14-8.55 mm in diameter on the right and 5.21-9.27 mm on the left. The difference was not statistically significant. The superior articular facet shape varied widely. Superior articular facets were oval, kidney, bi-lobed, and dumb-bell shaped. The most prevalent kind was oval-shaped (65 percent right and 75 percent left). The least prevalent kind was the bi-lobed superior articular facet, with 7.5% on the right and 3.335% on the left. The inferior articular facets were round and uniform in outline.

Conclusion: The present study adds up to the existing knowledge regarding the anatomy of the atlas vertebra. Knowledge of the normal anatomy of the atlas vertebra is essential for the diagnosis and management of CVJ disorders.

Keywords: Atlas Vertebra; Cervicovertebral Junction; First Cervical Vertebra.

Corresponding Author: Dr. G.Rohini Devi, Assistant Professor, Department of Anatomy, Govt Medical College, Suryapet, Telangana, India.

INTRODUCTION

The Atlas bone, also known as the 1st cervical vertebra (C1), is an important subject of study due to its unusual location as the link between the skull and the vertebral column. It is located at the crossroads of a movable skull and a rigid vertebral column.[1]

Atlas is named after the Primordial Titan of Greek Mythology, who was punished by Zeus for rebellion and sentenced to support the heavenly spheres for all eternity.The structure of the atlas vertebra differs from that of other vertebrae. It lacks a body and a spinous process. The atlas is made up of two lateral masses that are joined by a shorter anterior arch and a longer posterior arch. Behind the superior articular facet, the superior surface of the posterior arch has a large groove for the third section of the vertebral artery.[2]To treat the instability of the

cervicovertebral junction produced by various traumatic and non-traumatic situations, various surgical procedures such as interspinous wiring, interlaminar clamp, plate and screw fixation are now used. Transarticular and transpedicular screw fixation are also commonly employed in vertebral column stabilisation. Despite the benefits provided by the aforementioned treatments, there are risks that can develop, most notably from incorrect pedicle screw insertion, which can result in harm to critical tissues such as the cranial and spinal nerves, spinal cord, and vertebral arteries. Iatrogenic vertebral artery damage is a rare complication encountered during posterior approach cervicovertebral junction procedures (CVJ).[3]Furthermore, atlas fractures, which account for 3 to 12% of all cervical fractures, occur through the articular facets and lateral masses, as well as the posterior and anterior arches. Although uncommon, anterior arch fractures can be connected with other sections of the atlas, with Jefferson's bursting fracture being a prime example.[4]During clinical practise, congenital anomalies such as occipitalization of atlas, the most common anomaly involving the cervical vertebra, Klippel-Feil syndrome, and others are encountered.[5]
As a result, a thorough grasp of the morphometric properties of the atlas vertebra is critical in detecting congenital abnormalities and fractures, as well as designing surgical procedures. In order to avoid artery injuries during posterior approach surgical procedures of the cervicovertebral junction, it is also critical to understand the relationship between the vertebral artery and the atlas, especially when the former passes through the foramen transversarium (FT) and is close to the vertebral artery groove (VAG).[6]

Source of Data
The present study was performed on 120 dry adult human atlas vertebrae of South Indian origin collected from the Department of Anatomy, Govt Medical College Suryapet&Viswabharati Medical College Kurnool, over a period of 18 months (February 2019 to July 2021).

Inclusion Criteria
Intact dry adult human atlas vertebrae.

Exclusion Criteria
a) Broken or incomplete specimen
b) Osteophytes, tumors or any other deformities.

MATERIALS & METHODS
The specimen will be measured using Vernier Caliper for linear measurements and surgical Caliper for thickness. The study will be conducted as per the protocol laid down below.

RESULTS

Table 1: Width of the Atlas

Number of bones	Range(mm)	Minimumwidth(mm)	Maximumwidth(mm)	Mean(mm)	Standard deviation
120	22.02	58.4	81.51	70.8	5.23

The above table shows the measured values of the width of atlas. The distance between both the tips of the transverse process of atlas ranged from 58.04 mm to 81.51 mm. The mean width of the atlas was 70.8 mm. Width of majority of the atlas was in the range of 65-74.42 mm (51%).

Table 2: Distance Between the Medial Most Edges of Foramen Transversarium

Number Of Bones	Range (Mm)	Minimum (Mm)	Maximum (Mm)	Mean (Mm)	Standard Deviation
120	12.9	39.26	52.55	45.02	3.14

The mean distance between the inner most edges of foramen transversarium was 45.02 mm. Minimum distance was 39.26 mm and maximum was 52.55 mm.

Table 3: distance between the lateral most edges of foramen transversarium

Numberofbones	Range (mm)	Minimum (mm)	Maximum (mm)	Mean (mm)	Standarddeviation
120	18.01	46.2	64.55	56.21	3.72

The mean distance between the outer most edges of foramen transversariumwas56.21 mm.

Table 4: maximum transverse diameter of vertebral canal

Numberofbones	Range(mm)	Minimum(mm)	Maximum(mm)	Mean(mm)	Standarddeviation
120	12.55	23.32	36.24	26.09	2.34

The mean transverse diameter of the vertebral canal was 26.09.

Table 5: maximum anteroposterior diameter of vertebral canal

Numberofbones	Range(mm)	Minimum(mm)	Maximum(mm)	Mean(mm)	Standarddeviation
120	10.63	20.76	31.39	27.732	2.14358

Maximum anteroposterior diameter of vertebral canal was 31.39 mm and the minimum was 20.76 mm.

Table 6: distance from midline to the lateral-most point on the vertebral artery groove

Numberofbones	Side	Range(mm)	Minimum(mm)	Maximum(mm)	Mean(mm)	Standarddeviation	P-value
120	Right	17.74	13.50	30.32	23.022	2.32	0.367
	Left	25.05	18.06	43.75	24.11	2.24	

The distance from the midline to the lateral most point on the vertebral arterygroove ranged from 13.50-30.32 mm on the right side and 18.06-43.75 mm on the left side. This difference was statistically not significant.

Table 7: distance from midline to the medial-most point on the vertebral artery groove

Numberofbones	Side	Range (mm)	Minimum (mm)	Maximum (mm)	Mean (mm)	Standarddeviation	P-value
120	Righ	27.25	4.66	18.33	11.23	2.56	0.015

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	Left	13.78	4.04	17.88	10.48	2.89	

The distance from the midline to the medial most point on the vertebral artery groove ranged from 4.66-18.33 mm on right side and 4.04-17.88 mm on the left side.This difference was statistically significant (p=0.015).

Table 8: distance from lateral-most point on the transverse process to the lateral edge offoramen transversarium

Numberofbones	Side	Range(mm)	Minimum(mm)	Maximum(mm)	Mean(mm)	Standarddeviation	P-value
120	Right	7.64	4.72	12.39	8.75	1.42	0.952
	Left	7.45	4.98	12.43	8.72	1.45	

Distance from lateral-most point on the transverse process to the lateral edge of foramen transversarium ranged from 4.72-12.39 mm on right side and 4.98-12.43 mm on left side. The difference between the two sides was statistically notsignificant.

Table 9: length of superior articular facet

Numberofbones	Side	Range(mm)	Minimum(mm)	Maximum(mm)	Mean(mm)	Standarddeviation	P-value
120	Right	10.82	17.65	28.58	21.023	2.01	0.651
	Left	9.83	17.72	27.65	22.092	1.81	

Length of the superior articular facet ranged from 17.82-28.58 mm on right side and 17.72-27.72 mm on left. The difference between the two sides was not statistically significant.

Table 10: width of superior articular facet

Number of bones	Side	Range (mm)	Minimum (mm)	Maximum (mm)	Mean (mm)	Standard deviation	P-value
120	Right	7.85	7.78	14.82	10.032	1.532	0.0071
	Left	6.07	8.81	14.86	11.921	1.232	

Width of the superior articular facet ranged from 7.78-14.82mm on the rightside and 8.81-14.86 on the left side. The difference between the two sides was statisticallysignificant (p=0.007).

Table 11: length of inferior articular facet

Numberofbones	Side	Range(mm)	Minimum(mm)	Maximum(mm)	Mean(mm)	Standarddeviation	P-value
120	Right	15.19	11.45	26.65	17.176	2.143	0.576

	Left	8.43	12.41	20.70	17.332	1.876	

Length of the inferior articular facet ranged from 11.45-26.65 mm on right side and 12.41-20.70 mm on left. Difference between the two sides was statistically not significant.

Table 12: Width of inferior articular facet

Numberofbones	Side	Range(mm)	Minimum(mm)	Maximum(mm)	Mean(mm)	Standarddeviation	P-value
120	Right	9.42	10.75	20.11	14.165	1.721	0.263
	Left	7.23	11.06	18.34	14.387	1.334	

Width of the inferior articular facet ranged from 10.75-20.11 mm on the right side and 11.06-18.34 mm on the left side. The difference between the two sides was statistically not significant.

Table 13: thickness of vertebral artery groove

Numberofbones	Side	Range(mm)	Minimum(mm)	Maximum(mm)	Mean(mm)	Standarddeviation	P-value
120	Right	4.64	2.26	6.87	3.87	0.767	0.530
	Left	4.56	1.32	5.74	3.78	0.878	

The thickness of the vertebral artery groove ranged from 2.26-6.87 mm on right side and 1.32-5.74 mm on the left side. The difference between the two sides was statistically not significant.

Table 14: transverse diameter of foramen transversarium

Numberofbones	Side	Range(mm)	Minimumdiameter(mm)	Maximumdiameter(mm)	Mean(mm)	Standarddeviation	P-value
120	Right	4.85	4.21	9.14	6.21	1.14	0.7921
	Left	5.62	3.37	8.78	6.32	1.18	

The transverse diameter of the foramen transversarium ranged from 4.21-9.14 mm on the right side and 3.37-8.78 mm on the left side. The difference between the two sideswas statistically not significant.

Table 15: anteroposterior diameter of foramen transversarium

Numberofbones	Side	Range(mm)	Minimumdiameter(mm)	Maximumdiameter(mm)	Mean(mm)	Standarddeviation	P-value

120	Right	3.42	5.14	8.55	7.121	0.634	0.936
	Left	4.12	5.21	9.27	7.132	0.945	

Antero-posterior diameter of the foramen transversarium ranged from 5.14-8.55 mm on the right side and 5.21-9.27 mm on the left side. Difference between the two sides was statistically not significant.

Table 16: shape of superior articular facet

Number of bones	**Side**	**Oval**	**Kidney**	**Bi- lobed**	**Dumb- bell**
120	Right	78(65%)	21(17.5%)	9(7.5%)	12(7.5%)
	Left	90(75%)	15(12.5%)	4(3.33%)	11(3.33%)

The shape of the superior articular facet varied greatly. There were 4 types of superior articular facets; oval, kidney, bi-lobed and dumb-bell shaped. Most common type was oval shaped superior articular facet (65 % right and 75 % left). Least common type was bi-lobed superior articular facet with a prevalence of 7.5 % on the right side and 3.33% on the left side. Inferior articular facets were circular in shape and showed very little variation.

DISCUSSION

The atlas is one of the atypical cervical vertebrae due to its uncommon design and is important because of its complex relationship with the second and third part ofVA.[8] Atlas has been extensively studied to understand the danger of injury to the VA during surgeries involving the CVJ.[11] As surgical methods and procedures to treat traumatic or congenital cervical spine disorders have evolved, comprehensive knowledge of the anatomy of CVJ has become essential.

According to our study the mean distance between the tips of the transverse process of the atlas was 71.01 mm. The following table shows the comparison of mean width of atlas with other published studies.

Table 17: comparison of width of atlas with other studies

Studies	**Number ofatlas studied**	**Place of study**	**Mean width of the atlas(mm)**
Sengul et al.[3]	40	Turkey	74.6
Gosavi et al.[6]	100	India	69.37
Gupta et al.[7]	35	India	72.5
Present study	120	India	71.01

The findings of the present study with regard to the width of the atlas are in line with the other published studies. Irrespective of the place of study or race there was no significant difference in the width of the atlas.

Table 18: comparison of mean distance between the medial and lateral most edges of transverse foramina with other studies

Studies	**No. of atlas studied**	**Place ofstudy**	**Mean distance between the medial most edges of transverse foramina(mm)**	**Mean distance between the lateral most edges of transverse foramina(mm)**
Sengul et al.[3]	40	Turkey	48.6	59.5

Gosavi et al.[6]	100	India	45.93	55.66
Gupta et al.[7]	35	India	45.2	57.6
Present study	120	India	45.5755	56.71

The above table shows comparison of mean distance between the inner and outer most edges of foramen transversarium with other published studies. In the present study, the mean distance between the innermost and outermost edges of foramen transversarium was 45.5755 mm and 56.71 mm respectively. The findingsof the present study were in agreement with other published studies as shown in the table. These distances are of significance while locating the position of second part of the VA during posterior approach surgeries of CVJ.

The above table shows comparison of mean maximum transverse and anteroposterior diameter of the vertebral canal of atlas with other published studies. The mean anteroposterior and transverse diameter of the vertebral canal were 27.732 mm and 27.7241mm respectively. There was no significant difference between the present study and other authors irrespective of place of the study. Doherty et al.[8] have suggested that the dimensions of the vertebral canal are remarkably constant indicating crucial functional constraints on the size of vertebral ring of the atlas limiting its variability. Sengulet al.[3] recommended that during the posterior approach CVJ Surgeries, dissection should be limited to within 10 mm from the midline. Other authors havesuggested a safe zone of 11.26 mm,[9] 15 mm,[10] 11.2 mm and in the present study it was 10.89 mm.[11] However, Cacciolaet al have recorded the position of VA with respect to the medial most edges of VA groove where the former bends anteriorly to enter the spinal canal.[12] At this position the VA is medial to the vertebral groove in this position by a distance of 4.24 mm. This medial overhanging of the VA should also be taken into account during surgical procedures of CVJ.

In the present study, distance from lateral-most point on the transverse process to the lateral edge of foramen transversarium was 8.7231mm and 8.7647 mm on the right and left side respectively. This parameter has not been recorded by other authors in the available and accessible literature. Since the position of foramen transversarium with respect to the tip of the transverse process of the atlas is known the position of the VA can be located by tracing the attachment of obliquscapitis superior and obliquscapitis inferior muscles to the tip of the transverse process.

The stability of the atlanto-occipital joint depends on the reciprocal configuration of the occipital condyles with SAF of atlas. The SAF of atlas is horizontal in orientation during development and changes to concave by 6 years of development.[13] With advancing age the physical anthropometry of SAF of atlas may vary causing asymptomatic or symptomatic clinical conditions.

The appearance of dumb-bell shaped or a bi-lobed SAF actually indicates the tendency of the SAF to split into two separate facets and it can cause restriction in the movement of atlanto-occipital joint.18 The variations in the shape of SAF of atlas are clinically important because of the restrictions of movements they cause at the atlanto-occipital joint. And hence knowledge of prevalence of such variations is essential for the orthopedicians and neurosurgeons for the precise diagnosis of restricted cervical mobility and pain.

These differences in the measurements of the SAF and IAF could be attributedto the ethnic and racial differences between the study groups and is of anthropological importance. These measurements are also of clinical significance in procedures like trans-articular screw fixation.

The width of atlas was correlated with various parameters like dimensions ofthe SAF, IAF, VC, FT and distance between the tip of the transverse to the medial andlateral most point on the FT. Width of the atlas had highly significant ($p<0.001$) positive correlation with all the above-mentioned parameters except the mean anteroposterior diameter of FT on the right side of atlas. None of the previously available and accessible literature reveals the correlation between the various dimensions of the atlas. The present study is different from other published works since the correlations between various parameters have been described along with the morphometric details of the atlas.

The morphometry of atlas was studied in detail using various parameters. The measurements were remarkably consistent except for few a parameter like the shape of the SAF, thickness of the VA groove and mean distance form midline to the medial most point on the VA groove of atlas. These consistent findings were irrespective of ethnicity and race. Atlas is not only a unique vertebra because of its unusual design but also because of the consistent morphometry it has. The present study will be of help to surgeons who operate on the CVJ in better planning before the surgery, to reduce the complications during the surgery and to minimise the post-operative complications.

The present study can be extended further by comparing the morphometric details obtained by manual method with that of imaging methods like computed tomography or magnetic resonance imaging.

CONCLUSION

CVJ surgical procedures necessitate a clear understanding of atlas quantitative anatomy. This research adds to our understanding of the anatomy of the atlas vertebra and will be useful in the diagnosis of atlas fractures and congenital malformations, in the design of surgical methods, in visualising the dimensions of the atlas intraoperatively, and in assessing treatment outcomes.

Atlas morphology is very important in anthropology. Using morphometric data, the atlas' gender and racial identification can be identified with a reasonable degree of precision. This study also includes the most recent evolutionary data from an atlas belonging to the South Indian population.

Acknowledgment

The author is thankful to Department of Anatomy for providing all the facilities to carry out this work.

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