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Original Research Article

Morphometric Study of Atlas Vertebrae in South Indian Population

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ABSTRACT

Introduction- A three dimensional understanding of the anatomy of atlas vertebra is crucially important for any kind of surgery in the cranio-vertebral region. Various authors have reported incidence of vertebral artery injury during surgery in this region. The present investigations were undertaken to establish the criteria by which it may be possible to identify the variations in the superior articular facets and also in dimensions of the antero posterior and transverse diameter.
Methodology- The material for the present study consists of 100 adult intact human atlases of unknown sexes, collected from the department of anatomy, MS Ramaiah Medical College, Bangalore.
Results - Out of 100 atlas vertebrae the external antero-posterior diameter observed in the present study was 40.68 mm on an average, internal antero-posterior diameter was 26 mm on an average, the transverse external diameter was 69.05 mm on an average, transverse internal diameter was 28.4 mm on an average. In the present study the superior articular facets surface area on the left side was more (292.50 sq.mm) as compared to right (280.80 sq.mm).Superior articular facets showed medial constriction in 39, lateral constriction in 25, constrictions on both sides (medial and lateral) were observed in 18 and no constrictions were noted in 18 atlas vertebrae.
Conclusion - The three dimensional anatomy of atlas vertebra is of importance for any kind of surgery in the cranio-vertebral junction. This study will be useful for the anatomists, forensic experts, physical anthropologists, radiologists, neurosurgeons and orthopedic surgeons.

Key Words– morphometric, atlas vertebrae, south Indian.

INTRODUCTION

Atlas vertebra is the first cervical vertebra, which supports the cranium and helps in the transmission of weight to the axial skeleton. [1] The atlas vertebra is the first of the seven cervical vertebrae, and is called so because it bears the direct weight of the skull, just as the mythical Greek Titan Atlas bore the world on his shoulders. The atlas vertebra meets with the occipital condyles, which flank the foramen magnum in the basilar part of the occipital bone of the skull. This junction forms the atlanto-occipital joint, and is responsible for the primary articulation between the spine and the skull. It is the only vertebra in the spine, which has no vertebral body. The atlas vertebra, in turn rests upon the axis vertebra, which is the second cervical vertebra in the spine, with the articulation between these two vertebrae occurring at lateral articular surfaces and a unique juncture between a concave facet (on the atlas) and an upward protruding structure on the axis called the dense. [2]

A three dimensional understanding of the anatomy is crucially important for any kind of surgery in the cranio-vertebral region. Various authors have reported incidence of vertebral artery injury during transoral surgery, lateral mass and trans articular screw implantation for atlanto-axial fixation and during lateral approaches to the foramen magnum region. The C-1 and C-2 vertebrae are called atypical vertebrae and have an unusual shape and architecture and a clinically complex and important vertebral artery relationship. Various authors have written about the danger of injury to the vertebral artery during surgery in this region. The injury to the artery during surgery can lead to catastrophic intra-operative bleeding and compromise to the blood flow can lead to unpredictable neurological deficits, which will depend on the adequacy of blood flow from the contra-lateral vertebral artery. The third part of vertebral artery is closely related to the lateral and superior surface of atlas vertebra on each side. During injury to the cervical part of the vertebral column, the effect of the injury to the atlas vertebra may damage the vertebral arteries, thereby affecting the arterial supply to the brain.

Many authors have been studied about retroarticular canals, where the vertebral artery passes over the posterior arch of atlas vertebrae. These canals are unilateral or bilateral. When present, they reduce space available for the vertebral artery and compromise the blood flow in the vessel. [3] The retroarticular canal has been implicated in compression of the vertebral artery, where it passes over the posterior arch of the atlas vertebra, during extreme rotational movements of the head and neck. [4]

The present investigations were undertaken to establish the criteria by which it may be possible to identify the variations in the superior articular facets and also in dimensions of the antero posterior and transverse diameter. Finally, other variations of atlas vertebra such as bifid spine, the variations in the foramina transversorium etc have been extensively studied. It is hoped that the data will be valuable particularly for orthopedic surgeons to manipulate during surgery in this region and also useful for anatomists, anthropologists, and experts in the field of forensic medicine.

Objectives of the Study

- To measure the external and internal antero posterior and transverse diameters of atlas vertebra.
- To note the number, shape and size of superior articular facets, foramina transversaria and tubercles.
- To study the grooves for vertebral arteries.
- To note any additional foramina or tubercles.

MATERIALS & METHODS

The material for the present study consists of 100 adult intact human atlases of unknown sexes from the dissected cadavers. They were collected from the department of anatomy, MS Ramaiah Medical College, Bangalore.

Statistical Methods

Kolmogrove- Smirnov Z test has been used to fit the normal distribution for the study parameters. Reference range has been obtained at 2.5th and 97.5th percentile.

Statistical software namely SPSS 11.0 and Systat 8.0 were used for the analysis of data and Microsoft word and Excel have been used to generate graphs, tables etc.

Inclusion Criteria

1. Intact human atlases from the dissected cadavers.

Exclusion Criteria

1. Broken, undeveloped and porous bones.
2. Macerated bones

Measurements were taken using: Stainless steel sliding caliper, Silver foil paper, Graph paper in millimeter scale, Hand lens/thread counting lens, Micro tip lead pencil, pair of scissors.

The measuring was done on intact parts of normal bones. Bones showing wear and tear, fracture or any pathology were not considered. Each linear recording was taken to the nearest mille meter.

Parameters included were:

1. **Antero posterior diameter External (AP):** It measures distance from highest point of anterior tubercle to the highest point of posterior tubercle.
2. **Antero-posterior diameter Internal:** It measures the distance from the articular facet for the odontoid process to the internal surface of the posterior tubercle in the mid saggital plane.
3. **Transverse diameter External (TD):** It measures the distance between outer most ends of the right and left transverse processes.
4. **Transverse diameter Internal:** It measures the maximum distance of the vertebral canal.
5. Surface area, shape and number of Superior articular facets in 100 atlas vertebrae were identified and numbered.

An impression of each superior articular facet of atlas vertebrae was taken on the silver foil paper by placing and pressing the silver foil paper on each superior articular facet of atlas vertebrae. The margins of the facets were demarcated and impression of the facet was cut along the demarcated margin of the articular facet with a pair of scissors. The cut impression of the articular facet was placed on the graph paper in millimeter scale and the impression of the articular facet was drawn on the graph paper using a thin micro tip pencil. Then a silver foil paper impression of the superior articular facet was removed. It was repeated in all the atlas vertebrae. The right and the left impressions were arranged on the graph paper for measurement. In the impression of each superior articular facet on the millimeter scale graph paper – full squares, 3/4 squares, ½ squares with in the outline of the facets were taken into account. Less than ½ squares were ignored. Then the total surface area of each impression of the articular facet was calculated.

RESULTS

An observational descriptive study consisting 100 atlas vertebrae is undertaken to study external and internal Anteroposterior and transverse diameters of atlas vertebrae, surface area of superior articular facets, presence of retro articular canals, symmetry of foramina transeversaria and to find the reference values of theses parameters for the South Indian population.

Table 1 Descriptive statistics

Parameters	Minimum	Maximum	Mean±SD	Mode
AP diameter-External (mm)	32	50	40.68±3.20	42
AP diameter- Internal (mm)	2	34	26.13±4.16	26
Transverse diameter External (mm)	52	85	69.05±7.23	69
Transverse diameter Internal (mm)	2	34	24.48±4.60	28
Superior Articular facet Right(sq.mm)	119	280	187.37±31.58	188
Superior Articular facet Left(sq.mm)	114	292	192.85±30.81	162.50

Table 2 Reference value for Study parameters

Statistical parameters	AP diameter		Transverse diameter		Superior Articular Facet	
	External (mm)	Internal (mm)	External (mm)	Internal (mm)	Right	Left
N	100	100	100	100	100	100
Mean ± SD	40.68±3.20	26.13±4.16	69.05±7.23	24.48±4.60	187.37±31.58	192.85±30.81
Median	41.0	26.0	70.0	25.0	186.87	192.50
Kolmogrove-Smirnov Z	1.027	1.126	1.161	1.178	0.698	0.579
Goodness of fit	Normal	Normal	Normal	Normal	Normal	Normal
P value	0.242	0.158	0.135	0.125	0.714	0.891
Reference value	35.0-47.7	20-33	52.58-81.0	11.78-32.43	129.59-259.71	134.08-258.00

Table 3 Retroarticular canals

Incidence	Retroarticular canals	
	Right	Left
Nil	94 (94.0%)	96 (96.0%)
Complete	3 (3.0%)	2 (4.0%)
Incomplete	3 (3.0%)	2 (2.0%)
Total number of incidence of retroarticular canals	6 (6.0%)	4 (4.0%)

Table 4 Symmetry of foramina transversarium

Symmetry of foramina transversarium	Wider Number	Percentage 95%CI
Right. Prominence	15	15.0 (9.31-23.28)
Left. Prominence	29	29.0 (21.01-38.54)
No changes	56	56.0

Table 5 Incidence of Grooves and additional foramina/tubercles

Incidence	Number (n=100)	% (95% CI)
Grooves for vertebral arteries	Nil	-
Additional foramina or tubercles	1	1.0 (1.8-5.5)

Table 7 Tendency to complete separation in the superior articular facets

Tendency to complete separation	Left facet only	Right facet only	Both facets
Presence	2 (2.0%)	2 (2.0%)	-
Absence	98 (98.0%)	98 (98.0%)	-

Table 8 Comparison of Retro transverse canal (Retroarticular canals)

Studies	Right	Left
Bilodi et al (2005) (n=34)	-	1 (2.94%)
Veteanu et al. (1997) (n=71)	15 (21.13%)	5 (7.04%)
Gupta et al (1979) (n=123)	13 (10.57%)	8 (6.50%)
Present study (2006) (n=100)	6 (6.0%)	4 (4.0%)

Table 6 Presence of constrictions in the superior articular facets

Side of facets	No constriction	Constriction on medial side only	Constriction on lateral side only	Constrictions on both sides	Total
Left facets	16(16.0%)	28(28.0%)	31 (31.0%)	25 (25.0%)	100
Right facets	18 (18.0%)	39 (39.0%)	25(25.0%)	18 (18.0%)	100

Table 9 Presence of Constrictions in the Superior Articular Facets (Shamer Singh) [9]

	No Constrictions	Constriction on Medial Side Only	Constriction on Lateral Side Only	Constrictions on Both Sides	Total
Left Facets	12	6	14	138	200
Right Facets	53	8	5	134	200
Present study	No Constrictions	Constriction on Medial Side Only	Constriction on Lateral Side Only	Constrictions on Both Sides	Total
Left Facets	16	28	31	25	100
Right Facets	18	39	25	18	100

DISCUSSION

In the present study an effort has been made to note various parameters of atlas vertebra and surface area of superior articular facets on right and left sides. The study was made in 100 dried and processed atlas vertebrae. The parameters, which have been selected, are available in the well known anatomy text books and published articles.

As has been mentioned in the observations 5 parameters were noted. The Association between the dimensions of atlas vertebra and craniofacial and postural variables do exist which are low but significant co-relations. Therefore although the correlations were low, the dimensions of atlas vertebra reflect association between craniocervical posture and cranio-facial morphology. (Table 1 and 2).

The external antero-posterior diameter observed in the present study showed 40.68 mm on an average out of 100 atlas vertebrae. Internal antero-posterior diameter seen in 100 atlas vertebrae showed 26 mm on an average. The transverse external diameter observed among 100 atlas vertebrae showed the mean value as 69.05 mm on an average. The transverse internal diameter is 28.4 mm on an average in 100 atlas vertebrae.

In a study by Goksin et al. The external antero-posterior diameter ranged from 38.2- 77.5 mm (mean46.2 mm). The internal antero-posterior diameter ranged from 23.7-46.3 mm (mean 31.4 mm). The transverse external diameter ranged from 29.8 to 84.9 mm (mean 74.6 mm). The internal transverse diameter ranged from 25.2-33.5 mm (mean 28.7 mm). [5]

Articular facet asymmetry of the upper human cervical spine has been recognized for over 30 years (Singh 1965). Gottlieb in 1994 was the first to consider this issue, based on observations of cadaveric specimens. According to K Ross et al, it is evident that, had this joint complex to be present in vivo and clinician challenged the joint further. They may have concluded that there was a joint restriction on the left side as compared to right. Hence, manipulation or mobilization during the treatment would have applied in that direction to reach over the apparent limited motion. [6]

The surface area of superior articular facets of atlas vertebra showed asymmetry which has been reported by Mysorekar et al in 1986. [7] The same study was conducted by Usha Dhall et al in 1984 and asymmetry was observed which showed greater surface area on the left side than on the right side in contrast to the observations made by Mysorekar et al. [8]

In the present study the superior articular facets surface area on the left side was more (292.50 mm) as compared to superior articular surface area of the right (280.80 mm).

The greater area of the superior articular facets of atlas vertebra on one side is likely to be related to the inclined posture of head on that side.

The different shapes of the superior articular facets of atlas vertebra have been variously described as concave, deeply concave, oval, elongated, kidney shaped, by many authors of various textbooks in anatomy.

The constrictions or notches on the inner or outer border or both borders of the facets tending to sub divide them are mentioned by some authors.

According to Shamer Singh a large number of variations were observed in shape, size and depth of superior articular of facets of atlas vertebrae and these indicate that the atlanto-occipital joint is correspondingly variable. He also observed pressure facets in the anterior and posterior parts of articular area, which seem to be due to greater pressure of the occipital condyles of these sites. [9]

In the present study, the constrictions in the superior articular facets of the atlas vertebrae were observed. On the right side in superior articular facets showed medial constriction in 39 atlas vertebrae, lateral constriction in 25 atlas vertebrae were observed. Constrictions on both sides (medial and lateral) were observed in 18 superior articular facets of atlas vertebrae and no constrictions were noted in 18 atlas vertebrae.

Similar observations were made on the left superior articular facets, in which medial constrictions were observed in 28 facets, lateral constrictions were found in 31 atlas vertebrae and constrictions on both sides were observed in 25 superior articular facets of atlas. No constriction was observed in left superior articular facets of 16 atlas vertebrae.

Shamer Singh made observations on 200 atlas vertebrae. Our values, when compared to the observations made by Shamer Singh showed the following comparison.

Among 100 atlas vertebrae in the present study on superior articular facets 2 right and 2 left vertebrae showed complete separation of superior articular facets and were unilateral in presentation.

The tendency of separations is almost found on both right and left superior articular facets, which coincided with the observations made by Shamer Singh. [9]

In the present study an observation was made on retro articular canals. 94 vertebrae on the right side (94%) and 96 vertebrae on the left side (96%) did not show the presence of retro articular canals, whereas 5 atlas vertebrae showed presence of retro articular canal on the right side (5%) and 3 atlas vertebrae showed presence of retro articular canal on left side(3%)unilaterally. The bilateral presence of retro articular canal was observed in 1 atlas vertebrae (1%).

The observations on retroarticular canals were made by Gupta et al in 1979 and they found 14 unilateral (11.40%) and 9 bilateral (7.33%) canals which are higher as compared to the present study (Table No. 3).

Mitchell J., made observations in 1354 atlas vertebrae, in which 9.8% of left /right sides were classified as having complete retro articular canals out of which 11.7% were right only, 24.6% were left only and 31.8% showed bilateral canals. [4]

The incidence did not increase with age and was lower in whites than in blacks with white males having the lowest and white and black females having the highest incidence of the canal. The observation in the present value coincides with the values in the whites. [4]

The difference in the dimensions of retro articular canals will decrease the cross sectional area of the space available for the vertebral artery passing through it and may compromise blood flow in the vessel.

In 1986 Taitz and Nathan mentioned that the external factors such as carrying heavy objects on the head could play a role in the development of bridges on atlas. [10]

Mahdi Hasan in 2001 stated that the presence of retroarticualr canals is a normal feature in monkeys and the other lower animals but its presence in human atlas vertebrae for the 3rd part of vertebral artery is not reported as normal. [11]

In lower animals especially in Quadrupeds the bony roof of the retroarticular canal is the lateral extrusion for the attachment of posterior atlanto occipital membrane where, the load of the head is supported by extensor muscles of neck and posterior atlanto occipital membrane. Where as in humans the weight of the head is borne by the vertical loading of the superior articular process of atlas, thus the roof of the tunnel has disappeared.

Mehadi Hasan et al made an observation on 350 dried and macerated North Indian atlas vertebrae of either sex and found a partial canal in 34 vertebrae and complete canal in 28 vertebrae, thus coinciding with the values of the present study.

Depending upon the depth of the groove for 3rd part of vertebral artery and length of the retro articular canal 6 classes could be identified.

I- Shallow impression for vertebral artery
II- Deep impression for vertebral artery
III- Presence of a partial posterior bridge on posterior arch of atlas.
IV- Complete posterior bridge converting into foramen.
V- lateral Bridge from lateral mass of atlas to transverse process.
VI- More extensive postero-lateral tunnel as a combination of complete posterior and lateral bridges. [11]

The origin of bridges, which form retroarticular canals, is a matter of much debate. Allen (1879), Cleland (1960) and Von-Torklus and Gehle (1975) suggested that it was congenital characteristic. Selby et al (1955) stated that it was a genetic trait, while Pyo and Lowman (1959), Epstien (1955), Breathnach (1965) and white and Panjabi (1978) said that it could be the result of ossification due to aging. [11]

Taitz and Nathan (1986) considered that the external mechanical factors such as carrying weight on the head could play a role in the development of bridges. [10] Lamberty and Zivanovic (1973) opined that it was due to activation of cartilaginous bridges which have been observed in fetuses and Children. [10]

Belodi AK et al (2005) reported that the retro articular canals were observed in 3 out of 34 atlas vertebrae, one atlas vertebra had unilateral canal and 2 bones had bilateral canals. [11] This indicates a higher value compared to present study. (Table No. 8)

The foramina transversaria were studied for the symmetry and duplication. None were found among the duplications where as asymmetry was noticed in many. Among the 100 atlas vertebrae left foramina transversaria are prominent on left side in 29% of cases and right prominent in 15 atlas vertebrae (15%). Foramina transversaria are equal in size on both sides in 60 atlas vertebrae (60%) (Table No. 4).

In the present study an observation was also made on grooves and additional foramina/tubercles. Additional foramen transversarium was observed in 1 case.

Retroarticular canals also were studied and compared to the values of other workers. The values coincided with the values in Indian studies. According to Usha Dhall et al, the posterior and lateral bridging and posterolateral tunnels were more commonly observed on left side. [8] The foramina transversaria also are more prominent on right side in 29 vertebrae as compared to left prominence, which was observed only in 15 atlas vertebrae. But in majority of cases (60 atlas vertebrae) the foramina transversaria are equal in size. The vertebral artery adopts a serpentine course in relationship to the cranio vertebral region. The artery has multiple loops and an intimate relationship with the atlas- especially over the posterior arch of atlas vertebra. Here it is vulnerable to injury during a posterior midline approach. The C1 roots travel inferiorly and posterior in relationship to vertebral artery during its course over the posterior arch of atlas. The multiple loops of vertebral artery and the buffer spaces of the artery in the bony grooves suggests a dynamic nature of the relationship of the artery with the groove and the possibility of changes in the location of the artery during neck movements.

CONCLUSION

The three dimensional anatomy of atlas vertebra is of importance for any kind of surgery in the cranio-vertebral junction. The anatomical measurements are important for transoral transpalatinal approaches to clivus, atlas and axis.

Various authors have reported the incidence of vertebral artery injury during transoral surgery, lateral mass and trans articular screw implantation for atlanto axial fixation to the foramen magnum region.

Even though not much literature was available on antero-posterior and transverse diameters, both internal and external, the observations on superior articular facets, retroarticular canals and symmetry of foramina transversaria did show significance. They are of great importance as these measurements help in describing the cortical thickness, which provides an anatomic basis for screw fixation. The parameters like surface area of superior articular facets help in knowing about the usage of the joint of that side. The surface area becomes more due to excessive usage of the areas of bones during movement. The size, shape and concavity or depth of the articular surfaces is subjected to adaptive changes.

Hence, an attempt is made to study the various parameters like external and internal diameters of atlas vertebra, surface area of superior articular facets of the vertebra, presence of retro articular canals and shapes and symmetry of foramina transversaria. This study will be useful for the anatomists, forensic experts, physical anthropologists, radiologists, neurosurgeons and orthopedic surgeons.

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