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A CLINICAL STUDY ON MORPHOMETRIC ANALYSIS OF THE FIRSTCERVICAL VERTEBRA

Dr Sravanthi Repalle
Assistant Professor, Department of Anatomy, Kakatiya Medical College, Warangal, Telangana, India.
Corresponding author: Dr Sravanthi Repalle
Email: sravanthidasyam@yahoo.com

ABSTRACT:
BACKGROUND AND OBJECTIVE: Various decompressive and stabilising methods such atlas and axis vertebra (C1 and C2) transarticular screw fixation and posterior screw placement on the lateral mass are used in CVJ surgery. These operations usually target the C1, which is part of the CVJ's bony architecture.Thus, complete understanding of atlas vertebra anatomy is required for surgical planning and fracture analysis. The dimensions of the vertebral artery groove are rare in Indian literature, and even rarer in South Indian literature. This project will gather and give atlas anatomical data that may be useful for surgical planning and assessing C1 fractures.The current study sought to make the following findings:1. Examine and measure atlas vertebra specimens for morphological criteria.2. To offer anatomic data for surgical planning of the CVJ. **METHODOLOGY :** During 18 months, 120 human dry adult complete atlas vertebrae were gathered from the Department of Anatomy, Kakatiya Medical College.**R ESULTS:** The mean transverse diameter of the spinal canal was 27.012 mm, and the mean anteroposterior diameter of the vertebral canal was 26.17 mm.In the vertebral artery groove, the midline to lateral most point distance was 23.78 mm on the right and 23.87 mm on the left, while the midline to medial most point distance was 12.98 mm on both sides.The morphology revealed 4 SAF kinds. Oval (45%) and bi-lobed (26%) aspects (13.33 percent right and 7 percent).**ANALYSIS AND SUMMARY :**The current research adds to the existing knowledge of atlas vertebra anatomy. Understanding the normal structure of the atlas vertebra is critical for diagnosis and treatment.
KEYWORDS:*AtlasVertebra;Cervicovertebral Junction;FirstCervicalVertebra.*

INTRODUCTION

Head posture has a significant impact on the development of craniofacial features and the cervical vertebral column . The irregular vertical development of the face also influences head posture. Individuals suffering from in comparison to short faces, long faces carry their heads in an extended stance .The atlas bone, also known as the 1st cervical vertebra (C1), is an important subject of study due to its unique position as the link between the skull and the vertebral column. It is also known as the first cervical vertebra (C1) because of its unique position as the link between the skull and the vertebral column. As the transition zone between a mobile cranium and a rigid vertebral column, it is located in the middle of the body. [1]

Atlas draws its name from the Primordial Titan of Greek Mythology, who was punished by Zeus for rebelling against the gods and sentenced to hold up the heavenly spheres forever.The structure of the atlas vertebra is distinct from the structure of the other vertebrae. Neither a body nor a spinous process can be found on it. The atlas is composed of two lateral masses that are joined by an anterior arch that is shorter and a posterior arch that is longer. Located behind the superior articular facet on the superior edge of the posterior arch is a large groove that accommodates the third section of the vertebral artery (vertebral artery III). [2]

Current surgical procedures for correcting the instability of the cervicovertebral junction produced by a variety of traumatic and non-traumatic situations, such as interspinous wiring, interlaminar clamp, plate and screw fixation, are employed to stabilise the joint. For the same reason, transarticular and transpedicular screws fixation are also commonly utilised in the stabilisation and rehabilitation of the vertebral column. Despite the advantages provided by the techniques described above, there are risks associated with them. The majority of these risks are associated with incorrect pedicle screw insertion, which can result in injury to vital structures such as the cranial and spinal nerves, spinal cord, and vertebral arteries. Injury to the vertebral artery as a result of surgery on the posterior approach to the cervicovertebral junction is also an uncommon complication that can occur during these procedures (CVJ). [3]

Another type of atlas fracture occurs via the articular facets and lateral masses as well as through the posterior and anterior arches, accounting for 3 to 12 percent of all neck fractures. Despite the fact that anterior arch fractures are uncommon, they can occur in other locations of the atlas, with Jefferson's bursting fracture being a typical example. [4]

During clinical practise, congenital anomalies such as occipitalization of atlas, which is the most common aberration involving the cervical vertebra, Klippel-Feil syndrome, and others are encountered[5].

As a result, a thorough knowledge and comprehension of the morphometric characteristics of the atlas vertebra is necessary in the diagnosis of congenital malformations and fractures, as well as in the design of surgical procedures. Furthermore, it is critical to understand the relationship between the vertebral artery and the atlas, particularly when the latter passes through the foramen transversarium (FT) and in close proximity to the vertebral artery groove (VAG), in order to avoid injuries to the artery during posterior approach surgical procedures of the cervicovertebral junction.

MATERIALS AND METHODS

SOURCEOFDATA

The present study was performed on 120 dry adult human atlas vertebrae ofSouth Indian origin collected from the Department of Anatomy, Kakatiya Medical College over a period of 18 months (February2013toJuly2014).

Inclusioncriteria

Intactdryadulthumanatlasvertebrae.

Exclusioncriteria

1. Brokenorincompletespecimen
2. Osteophytes,tumorsoranyotherdeformities.

METHODOFCOLLECTIONOFDATA

ThespecimenwillbemeasuredusingVernierCaliperforlinearmeasurementsand surgical Caliper for thickness. The study will be conducted as per the protocollaiddownbelow.

ParametersStudied

1. Widthofatlas

FIGURE6: FIGURESHOWINGTHEWIDTHOFATLAS

2. Distancebetweenbothlateral-mostedgesoftransverseforamina

FIGURE7:FIGURESHOWINGTHEDISTANCEBETWEENBOTHL ATERAL-MOSTEDGESOFTRANSVERSEFORAMINA

3. Distancebetweenbothmedial-mostedgesoftransverseforamina

FIGURE8:FIGURESHOWINGTHEDISTANCEBETWEENBOTH MEDIAL-MOSTEDGESOFTRANSVERSEFORAMINA

4. Distancefrommidlinetothelateral-mostpointonthevertebralarterygrooveontheoutercortex,bothleftandri

ghtside

FIGURE9:FIGURESHOWINGTHEDISTANCEFROMMIDLINETOTHE LATERAL-MOST POINT ON THE VERTEBRAL ARTERYGROOVEOFRIGHTSIDE

5. **Distancefrommidlinetothemedial-mostpointonthevertebralarterygroove,bothleftandrightside.**

FIGURE 10: FIGURE SHOWING THE DISTANCE FROM MIDLINE TOTHEMEDIAL-MOSTPOINTONTHEVERTEBRALARTERYGROOVEOFLEFTSIDE

6. **Lateral-mostpointonthetransverseprocesstothelateraledgeofforamentransvers**

ariumbothleftandrightside

FIGURE11:FIGURESHOWINGTHEDISTANCEFROMLATERAL-MOSTPOINTONTHETRANSVERSEPROCESSTOTHELATERALEDGEOFFORAMENTRANSVERSARIUMOFL

EFTSIDE

7. Maximumtransversedimensionofthevertebralcanal

FIGURE12:FIGURESHOWINGTHEMAXIMUMTRANSVERSEDIMENSIONOFTHEVERTEBRALCANAL

8. Maximumantero-posteriordimensionofthevertebralcanal

FIGURE13:FIGURESHOWINGTHEMAXIMUMANTERO-

POSTERIORDIMENSIONOFTHEVERTEBRALCANAL

9. Lengthofthesuperiorarticularsurface,bothleftandrightside

FIGURE14:FIGURESHOWINGTHELENGTHOFTHESUPERIORARTICULARSURFACEOFLEFTSIDE

10. Widthofthesuperiorarticularsurface,bothleftandrightside

FIGURE15:FIGURESHOWINGTHEWIDTHOFTHESUPERIORARTICULARSURFACEOFLEFTSIDE

11. Lengthoftheinferiorarticularsurface,bothleftandrightside

12. Widthoftheinferiorarticularsurface,bothleftandrightside

FIGURE16:FIGURESHOWINGTHELENGTHANDWIDTHOFTHEINFERIORARTICULARSURFACEOFRIGHTSIDE

13. Thicknessofthevertebralarterygroove

FIGURE 17: FIGURE SHOWING THE THICKNESS OF THE VERTEBRALARTERYGROOVEONTHELEFTSIDE

14. Maximumantero-posteriordiameterofforamentransversarium

15. Maximumtransversediameterofforamentransversarium

FIGURE 18: FIGURE SHOWING THE MAXIMUM TRANSVERSEDIAMETEROFLEFTFTANDAPDIAMETER OFRIGHTFT

16. Shapeofsuperiorarticularfacet
INSTRUMENTSUSED

FIGURE19:INSTRUMENTSUSEDFORDISSECTIONANDMEASUREMENTS

Instruments used: Digital Caliper for linear measurements and surgical Caliper tomeasurethickness.

RESULTS

TABLE1:WIDTHOFTHEATLAS

NUMBER OFBONES	RANGE (mm)	MINIMUMWIDTH (mm)	MAXIMUMWIDTH (mm)	MEAN (mm)	STANDARD DEVIATION
120	23.01	58.95	80.75	70.20	5.213

Theabovetableshowsthemeasuredvaluesofthewidthofatlas.Thedistancebetweenboththe tipsofthetransverseprocessofatlasrangedfrom58.95 mmto80.75mm.Themeanwidthoftheatlaswas70.20mm.Widthofmajorityoftheatlaswasi ntherangeof58.95 – 80.75 mm(51 %).

TABLE2:DISTANCEBETWEENTHEMEDIALMOSTEDGESOFFORAMENTRANSVERSARIUM

NUMBE ROFBO NES	RANG E (mm)	MINIMU M (mm)	MAXIMU M (mm)	MEAN (mm)	STANDARD DEVIATION
120	12.08	38.11	51.91	44.78	3.092

Themeandistancebetweentheinnermostedgesofforamentransversariumwas12.08 mm.Minimumdistancewas38.11 mmandmaximumwas51.91 mm.

TABLE3:DISTANCEBETWEENTHELATERALMOSTEDGESOFFORAMEN TRANSVERSARIUM

NUMBE ROFBO NES	RANG E (mm)	MINIMU M (mm)	MAXIMU M (mm)	MEAN (mm)	STANDARD DEVIATION
120	16.13	44.74	65.01	57.03	4.21

Themeandistancebetweentheoutermostedgesofforamentransversariumwas57.03 mm.

TABLE4:MAXIMUMTRANSVERSEDIAMETEROFVERTEBRALCANAL

NUMBE ROFBO NES	RANG E (mm)	MINIMUM (mm)	MAXIMU M (mm)	MEAN (mm)	STANDARD DEVIATION
120	12.67	22.08	34.12	27.012	2.645

Themeantransversediameterofthevertebralcanalwas27.012.

TABLE5:MAXIMUMANTEROPOSTERIORDIAMETEROFVERTEBRALCANAL

NUMBE ROFBO NES	RANG E (mm)	MINIMUM (mm)	MAXIMU M (mm)	MEAN (mm)	STANDARD DEVIATION
120	10.61	19.87	30.81	26.17	2.91

Maximum anteroposterior diameter of vertebral canal was 30.81 mm and theminimumwas19.87 mm.

TABLE 6: DISTANCE FROM MIDLINE TO THE LATERAL-MOST POINTONTHEVERTEBRALARTERYGROOVE

NUMB EROFB ONES	SIDE	RANG E (mm)	MINIMU M (mm)	MAXIM UM (mm)	MEA N (mm)	STANDA RDDEVIA TION	p-VALU E
120	RIGH T	17.86	12.78	30.76	23.78	2.42	**0.363**
	LEF T	24.47	18.61	42.67	23.87	2.78	

The distance from the midline to the lateral most point on the vertebral arterygroove ranged from 12.78 -30.76 mm on right side and 18.61-42.67 mm on the leftside.Thisdifferencewasstatisticallynotsignificant.

TABLE7:DISTANCEFROMMIDLINETOTHEMEDIAL-MOSTPOINTONTHEVERTEBRALARTERYGROOVE

NUMB EROFB ONES	SIDE	RANG E (mm)	MINIMU M (mm)	MAXIM UM (mm)	MEA N (mm)	STANDA RDDEVIA TION	p-VALU E
120	RIGH T	27.23	4.67	18.97	12.98	2.62	**0.018**
	LEF T	13.41	4.38	18.12	11.63	2.81	

Thedistancefromthemidlinetothemedialmostpointonthevertebralarterygrooverangedfro m4.67-18.97mmonrightsideand4.38-18.12mmontheleftside.Thisdifferencewasstatisticallysignificant(p=0.016).

TABLE8:DISTANCEFROMLATERAL-MOSTPOINTONTHETRANSVERSEPROCESSTOTHELATERALEDGEOFFORAMENTRANSVERSARIUM

NUMBEROFBONES	SIDE	RANGE (mm)	MINIMUM (mm)	MAXIMUM (mm)	MEAN (mm)	STANDARDDEVIATION	p-VALUE
120	RIGHT	7.83	4.51	12.01	8.67	1.36	**0.810**
	LEFT	7.41	4.65	12.13	8.46	1.41	

Distancefromlateral-mostpointonthetransverseprocesstothelateraledge of foramen transversarium ranged from 4.51 -12.01 mm on right side and4.65-12.13mmonleftside.Thedifferencebetweenthetwosideswasstatisticallynotsignificant.

TABLE9:LENGTHOFSUPERIORARTICULARFACET

NUMBEROFBONES	SIDE	RANGE (mm)	MINIMUM (mm)	MAXIMUM (mm)	MEAN (mm)	STANDARDDEVIATION	p-VALUE
120	RIGHT	9.81	17.10	26.61	20.12	2.012	**0.612**
	LEFT	9.01	17.31	25.17	21.93	1.810	

Length of the superior articular facet ranged from 17.10 -26.61 mm on rightsideand17.31-25.17mmonleft.Differencebetweenthetwosideswasnotstatisticallysignificant.

TABLE10:WIDTHOFSUPERIORARTICULARFACET

NUMBEROFBONES	SIDE	RANGE (mm)	MINIMUM (mm)	MAXIMUM (mm)	MEAN (mm)	STANDARDDEVIATION	p-VALUE
120	RIGHT	7.01	7.23	14.63	10.73	1.435	**0.056**
	LEFT	6.02	8.24	14.65	10.97	1.281	

Width of the superior articular facet ranged from 7.01 -14.63 mm on the rightsideand8.24 -14.65 ontheleftside.Differencebetweenthetwosideswasstatisticallysignificant(p=0.006).

TABLE11:LENGTHOFINFERIORARTICULARFACET

NUMBEROFBONES	SIDE	RANGE (mm)	MINIMUM (mm)	MAXIMUM (mm)	MEAN (mm)	STANDARDDEVIATION	p-VALUE

120	RIGHT	14.12	10.09	25.13	17.23	2.01	**0.574**
	LEFT	8.17	11.92	19.83	16.99	1.66	

Length of the inferior articular facet ranged from 10.09-25.13 mm on rightside and 11.92 – 19.83 mm on left. Difference between the two sides was statisticallynotsignificant.

TABLE12:WIDTHOFINFERIORARTICULARFACET

NUMBEROFBONES	SIDE	RANGE (mm)	MINIMUM (mm)	MAXIMUM (mm)	MEAN (mm)	STANDARDDEVIATION	p-VALUE
120	RIGHT	9.23	9.83	19.01	13.19	1.63	**0.213**
	LEFT	7.01	10.01	17.28	14.27	1.31	

Widthoftheinferiorarticularfacetrangedfrom9.83 – 19.01 mmontherightside and 10.01 -17.28 mm on the left side. Difference between the two sides wasstatisticallynotsignificant.

TABLE13:THICKNESSOFVERTEBRALARTERYGROOVE

NUMBEROFBONES	SIDE	RANGE (mm)	MINIMUM (mm)	MAXIMUM (mm)	MEAN (mm)	STANDARDDEVIATION	p-VALUE
120	RIGHT	4.40	2.23	6.21	3.62	0.781	**0.569**
	LEFT	4.12	1.23	5.16	3.16	0.872	

The thickness of the vertebral artery groove ranged from 2.23- 6.21 mm onright side and 1.23-5.16 mm on the left side. The difference between the two sideswasstatisticallynotsignificant.

TABLE14:TRANSVERSEDIAMETEROFFORAMENTRANSVERSARIUM

NUMBEROFBONES	SIDE	RANGE (mm)	MINIMUMDIAMETER (mm)	MAXIMUMDIAMETER (mm)	MEAN (mm)	STANDARDDEVIATION	p-VALUE
120	RIGHT	3.98	4.11	8.91	5.97	1.01	**0.624**
	LEFT	4.65	3.12	7.98	5.91	1.03	

Transverse diameter of the foramen transversarium ranged from 4.11- 8.91 mmontherightsideand3.12-7.98mmontheleftside.Differencebetweenthetwosideswasstatisticallynotsignificant.

TABLE15:ANTEROPOSTERIORDIAMETEROFFORAMENTRANSVERSARIUM

NUMBEROFBONES	SIDE	RANGE (mm)	MINIMUMDIAMETER (mm)	MAXIMUMDIAMETER (mm)	MEAN (mm)	STANDARDDEVIATION	p-VALUE
120	RIGHT	3.14	4.17	7.58	6.19	0.58	**0.812**
	LEFT	3.98	4.88	8.19	7.58	0.81	

Antero-posteriordiameteroftheforamentransversariumrangedfrom4.17- 7.58 mmontherightsideand4.88-8.19mmontheleftside.Differencebetweenthetwosideswasstatisticallynotsignificant.

TABLE16:SHAPEOFSUPERIORARTICULARFACET

NUMBEROFBONES	SIDE	OVAL	KIDNEY	BI-LOBED	DUMB-BELL
120	RIGHT	**54 (45%)**	22 (18.33%)	**16(13.33 %)**	32 (26.66%)
	LEFT	**63 (52.5%)**	32 (26.66%)	**6(4%)**	18(15 %)

Theshapeofthesuperiorarticularfacetvariedgreatly.Therewere4typesofsuperiorarticular facets;oval,kidney,bi-lobedanddumb-bellshaped.Mostcommontype was oval shaped superior articular facet (45 % right and 52.5 % left). Leastcommon type was bi-lobed superior articular facet with a prevalence of 13.33 % on theright side and 7 % on the left side. Inferior articular facets were circular in shape andshowedverylittlevariation.

DISCUSSION

TheatlasisoneoftheatypicalcervicalvertebraeduetoitsuncommondesignandisimportantbecauseofitscomplexrelationshipwiththesecondandthirdpartofVA.[18] Atlas has been extensively studied to understand the danger of injury to the VAduring surgeries involving the CVJ.[5,6,7] As surgical methods and procedures to treattraumaticorcongenitalcervicalspinedisordershaveevolved,comprehensiveknowledgeoftheanatomyofCVJhasbecomeessential.

According to our study the mean distance between the tips of the transverseprocess of the atlas was 70.20 mm.

The above table shows comparison of mean distance between the inner andouter most edges of foramen transversarium with other published studies. In thepresent study, the mean distance between the innermost and outermost edges offoramentransversariumwas44.78mmand57.03 mmrespectively.Thefindingsof the present study were in agreement with other published studies as shown in thetable.ThesedistancesareofsignificancewhilelocatingthepositionofsecondpartoftheVAduringposteriorapproachsurgeriesofCVJ. [3,8,9].

Theabovetableshowscomparisonofmeanmaximumtransverseandanteroposterior diameter of the vertebral canal of atlas with other published studies.Themeananteroposteriorandtransversediameterofthevertebralcanalwere26.17 mm and 27.01 mm respectively. There was no significant difference between thepresentstudyandotherauthorsirrespectiveofplaceofthestudy.Dohertyetal.[10] havesuggestedthatthedimensionsofthevertebralcanalareremarkablyconstantindicating crucial functional constraints on the size of vertebral ring of the atlaslimitingitsvariability.

Thefindingsofthepresentstudywereinagreementwithotherstudiesexcept Sengulet al.[3] in which the mean distance from midline to the lateral most point on the VAgroove was 7-9 mm shorter. The actual incidence may be higher due to low survey response andunrecognised VA injuries. The risk of neurological deficit was found to be 0.2%.[3]HenceexactlocalisationofVAduringCVJproceduresiscrucialtoavoiditsinjury.

Senguletal.[3] recommendedthatduringtheposteriorapproachCVJSurgeries,dissection should be limited to within 10 mm from the midline. Other authors havesuggested a safe zone of 11.26 mm,[11] 15 mm,[12] 11.2 mm[22] and in the present study itwas 10.89 mm. However, Cacciolaet al.[13] have recorded the position of VA withrespect to the medial most edges of VA groove where the former bends anteriorly toenterthespinalcanal.AtthispositiontheVAismedialtothevertebralgrooveinthisposition byadistanceof4.24mm.ThismedialoverhangingoftheVAshouldalsobetakenintoaccount duringsurgicalproceduresofCVJ.

Inthepresentstudy,distancefromlateral-mostpointonthetransverseprocessto the lateral edge of foramen transversarium was 8.67 mm and 8.46 mm on therightandleftsiderespectively.Thisparameterhasnotbeenrecordedbyotherauthorsinthe availableandaccessibleliterature.Sincethepositionofforamentransversariumwith respect to the tip of the transverse process of the atlas is known the position ofthe VA can be located by tracing the attachment of obliquscapitis superior andobliquscapitisinferiormusclestothetipofthetransverseprocess.

Various authors have divided the SAF into oval shaped, kidneyshaped,dumb-bellorfigureof8shaped,bi-lobed,irregularandleaflikefacets.Inthepresent study the most common shape of SAF was oval (65%) followed by kidneyshapedfacets(16%).Thefindingsofthepresentstudyareinlinewiththatofotherauthor sexceptLalithetal.,[9]Motagietal.[14] andGuptaetal.[9]whodescribethe dumb-bell shaped or figure of 8 shape to be the commonest type of SAF. Thisdifference could be due to the difference in the number of specimens studied andenvironmentalfactors.Aswecanappreciatefromtheabovetableraceofthepopulationha slittleeffectontheshapeofSAF.Thedifferencebetweenthepercentage of types of shapes on the right and left side was found to be statisticallysignificant($p=0.01$).

Thestabilityoftheatlanto-occipitaljointdependsonthereciprocalconfiguration of the occipital condyles with SAF of atlas. The SAF of atlas ishorizontal in orientation during development and changes to concave by 6 years ofdevelopment.[19] With advancing age the physical anthropometry of SAF of atlas mayvarycausingasymptomaticorsymptomaticclinicalconditions.

The appearance of dumb-bell shaped or a bi-lobed SAF actually indicates thetendencyoftheSAFtosplitintotwoseparatefacetsanditcancauserestrictioninthemovement of atlanto-occipital joint.[18] The variations in the shape of SAF of atlas areclinically important because of the restrictions of movements they cause at theatlanto-occipital joint. And hence knowledge of prevalence of such variations isessential for the orthopediciansandneurosurgeons for the precise diagnosisofrestrictedcervicalmobilityandpain.

The width of atlas was correlated with various parameters like dimensions oftheSAF,IAF,VC,FTanddistancebetweenthetipofthetransversetothemedialandlateral most point on the FT. Width of the atlas had highly significant ($p<0.001$)positivecorrelationwithalltheabovementionedparametersexceptthemeananter oposterior diameter of FT on the right side of atlas. None of the previousavailableandaccessibleliteraturerevealsthecorrelationbetweenthevariousdimensions of the atlas. The present study is different from other published workssincethecorrelationsbetweenvariousparametershavebeendescribedalongwiththe morphometricdetailsoftheatlas.

Themorphometryofatlaswasstudiedindetailusingvariousparameters.Themeasurements wereremarkablyconsistentexceptforfewaparameterslikethe shapeoftheSAF,thicknessoftheVAgrooveandmeandistanceformmidlinetothemedialmost point on the VA groove of atlas. These consistent findings were irrespective ofethnicity and race. Atlas is not only a unique vertebra because of its unusual designbut also because of the consistent morphometry it has. The present study will be ofhelp to surgeons who operate on the CVJ in better planning before the surgery, toreduce the complications during the surgery and to minimise the post-operativecomplications.

The present study can be extended further by comparing the morphometricdetails obtained by manual method with that of imaging methods like computedtomographyormagneticresonanceimaging.

CONCLUSION

An in-depth grasp of the quantitative anatomy of the atlas is required for surgical treatments involving the CVJ. Adding to the existing knowledge of atlas vertebral anatomy, this study will be useful in the diagnosis of fractures and congenital anomalies of the atlas, in the planning of surgical techniques, in visualising the dimensions of the atlas intraoperatively, and in the evaluation of treatment outcomes, among other things.The morphology of the atlas is also significant from an anthropological standpoint. By analysing the morphometric data, it is possible to determine the gender and racial identity of the atlas with a reasonable degree of precision. This study also includes the most recent evolutionary data on the atlas of the South Indian population, which is presented in this paper.

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Conflict of Interest

None

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