Original Article

Vertebral Artery Groove in the Atlas and Its Clinical Significance

Anatomy Section

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ABSTRACT

Introduction: The vertebral artery groove is located on the superior surface of the posterior arch of atlas vertebra lodging the third part of the vertebral artery. The morphometric data of the groove including the groove length, width and thickness of the bone forming the floor of the groove is scarce in Indian literature. The distance between the groove and the posterior midline is of surgical importance. Iatrogenic injury to the vertebral artery is common in posterior approaches of the atlas vertebra. The objective of the present study is to obtain the morphometric data of the groove and to assess the distance of the groove from the posterior midline for providing a safety guideline to the surgeons.

Materials and Methods: 75 dry human atlas vertebrae were measured manually using vernier calipers. The morphometry of VAG and its distance from midline were evaluated through eight linear measurements. The results were analysed stastically using SPSS 16 version.

Results: The inner groove length was 7.71 mm and 7.49 mm on the right and left sides respectively. The outer groove length was 8.1 mm on the right and 8.24 mm on the left side. The mean width was 7.89 mm on the right and 8.08 mm on the left side. The mean thickness was 4.7 mm on the right and 4.55 mm on the left side. The safe zone from the midline during posterior approach to C1 to avoid potential injury to vertebral artery was found to be 11.26mm.

Discussion: Iatrogenic injury to vertebral artery is the most commonest per-operative complication during a posterior approach. The distance of the groove from the posterior midline and knowledge of the morphometric data of the groove is important for instrumentation procedures in the atlas vertebra.

Conclusion: The present study reveals the morphometry of the vertebral artery groove and recommends a safe zone of 11.26 mm from the midline in posterior approach for atlas vertebrae.

Key Words: Atlas, Vertebral artery, Morphometry, Safe zone, Surgical approach

KEY MESSAGE

- The morphometric data of the vertebral artery groove in the atlas in Indians and the safe zone from the posterior midline was assessed as 11.26 mm for a posterior surgical approach in the atlas vertebrae.

INTRODUCTION

The surgical treatment of pathologies in the skull- the cervical region is one of the complex areas in the field of orthopaedics and neurosurgery. Cervical instability which results from fractures often requires stabilization. The stabilization procedures include wiring, transarticular screw fixation and plate fixation. Iatrogenic injuries to the neurovascular structures including the vertebral artery, the hypoglossal nerve, the internal carotid artery and the second cervical sympathetic ganglion are possible in the instrumentation of the posterior arch of the atlas [1]. Of these, injury to the vertebral artery is the most frequent peroperative complication [2]. The foramen arcuale, a rare anatomical accident which occurs in the atlas, might further complicate the surgical access in this region, thus resulting in damage to the vertebral artery [3,4]. The foramen arcuale is an osseous bridge which converts the groove of the vertebral artery into an osseous tunnel through which the vertebral artery traverses.

The third part of the vertebral artery runs in the vertebral artery groove (VAG) which is situated behind the lateral mass of the atlas. The groove is an impression which is caused by the third part of the vertebral artery on the superior surface of the posterior arch of the atlas. It extends horizontally from the medial edge of the foramen transversarium to the medial edge of the posterior arch. The groove is also called as the sulcus arteriae vertebralis or the sulcus for the vertebral artery. It is reported to be thicker and wider on the left side due to the vertebral artery dominance on the left side (42% dominance on the left side, 32% dominance on the right side and 26% symmetrical) [5]. Sometimes, the distal part of the groove forms a full bone bridge to the upper edge of the superior articular facet of the atlas, thus forming the foramen arcuale or the retroarticular canal for the vertebral artery. The incidence of this variation has been variedly reported to be ranging from 5.14% to 51% [5]. The geometrical description of the groove including its length and width and the thickness of the bone which forms the floor of the groove in the Indian literature, is scarce. The objective of the present study was to measure the morphometric parameters of the groove, including the length, width and the thickness of the bone which formed the floor of the groove in the human atlas

vertebra in the Indian population and to provide a safety guideline for the surgeons to avoid potential injury to the vertebral artery.

MATERIALS AND METHODS

Seventy five atlas (C1) vertebra without any obvious pathology and belonging to the bone banks of Vinayaka Mission's Kirupananda Variyar Medical College, Salem, Tamil Nadu, Annapoorana Medical College, Salem, Tamil Nadu, Vinayaka Mission's Homeopathy Medical College, Salem and the Govt. Mohan Kumaramangalam Medical College, Salem, Tamil Nadu were utilized for the study. The gender and the age of the bones were not considered in the present study.

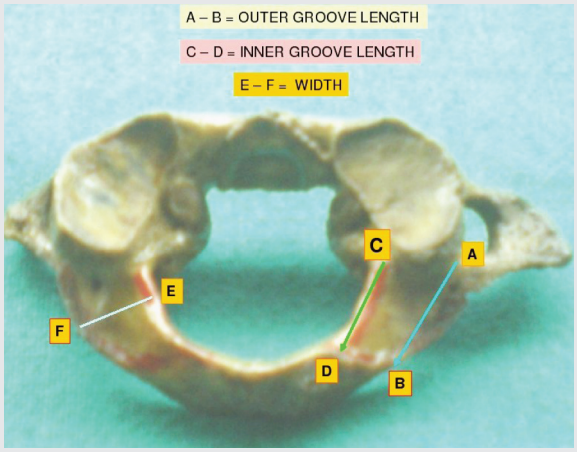
Eight linear measurements were taken bilaterally (right and left) by using a vernier caliper. The measurements were repeated by an independent second observer with the first results being blinded to the second observer. Both the observers were qualified anatomists (first and second authors) The anatomical parameters which were measured were groove length (inner and outer), groove width, thickness of the bone which forms the floor of the groove, proximal medial projection (D1), proximal lateral projection (D2), distal medial projection (D3) and distal lateral projection (D4).

The VAG was identified. All the parameters were measured according to the instructions which were given by Max Franco et al[5] at the appropriate places [Table/Fig-1 & 2] . The length of the groove was taken as the maximum anteroposterior distance along the inner and outer edges of the groove. The width of the groove is the distance between the inner and outer edges at the middle of the groove. The thickness of the bone which formed the floor of the groove is the distance between the superior and inferior surfaces of the posterior arch at the middle of the groove. The proximal medial projection (D1) is the distance between the midline and the inner edge of the groove at the initial portion of the groove. D2 is the distance between the midline and the outer edge of the groove at the initial portion of the groove. D3, the distal medial projection is the distance between the midline and the inner edge of the groove at the final portion of the groove. D4 is the distance between the midline and the outer edge of the groove at the final portion of the groove.

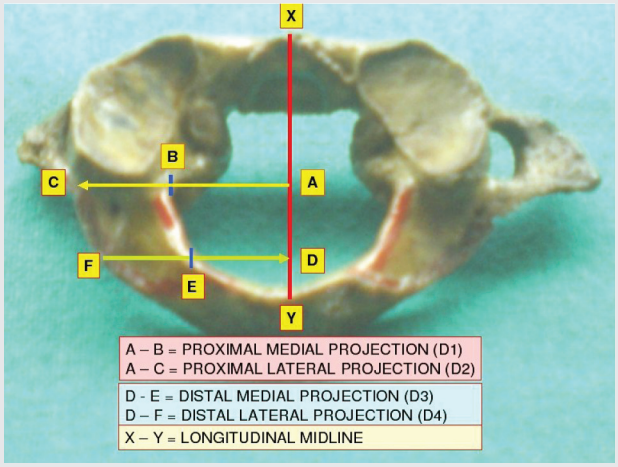
The mean measurements of each of the parameters were compared separately between the two readers by using ANOVA paired 't' tests and correlation coefficients and the 'p' values were calculated. For each of the measurements, the right side values and the left side values of the two observers were compared individually. The SPSS version 16 statistical package was used for analysis.

RESULTS

The results of the measurements of observer 1 are tabulated in [Table/Fig-3]. The mean values (± SD) for the inner groove length



[Table/Fig-1]: Shows Parameters – Groove Length (Outer and Inner) and Width of the Vertebral Artery Groove



[Table/Fig-2]: Shows The Parameters D1, D2, D3 & D4

Parameter	Mean	Minimum	Maximum
Inner groove length (Rt.)	7.71	5	10
Inner groove length (Lt.)	7.49	5	10
Outer groove length (Rt.)	8.1	6	11
Outer groove length (Lt).	8.24	5.8	11.5
Width (Rt.)	7.89	4	10
Width (Lt.)	8.08	4	11
Thickness Rt.	4.7	2.5	7
Thickness Lt.	4.55	2	6
Proximal medial projection (D1) Rt. Side	11.46	8	15
Proximal medial projection (D1) Lt. Side	11.06	9	15
Proximal lateral projection (D2) Rt. Side	17.04	13	20
Proximal lateral projection (D2) Lt. Side	17.82	14	21
Distal medial projection (D3) Rt. Side	14.26	11	18
Distal medial projection (D3) Lt. Side	14.30	12	20
Distal lateral projection (D4) Rt. Side	22.70	19	26
Distal lateral projection (D4) Lt. Side	23.14	20	26

[Table/Figure-3]: Vertebral artery groove measurement of right and left side average , minimum and maximum (Observer 1)

on the right side was 7.71 ± 1.16 mm and on the left side, it was found to be 7.49 ± 1.33 mm. The outer groove length on the right side was 8.1 ±1.58 mm and on the left side, it was 8.24 ± 1.37 mm.

The mean width (± SD) on the right side was 7.89 ± 1.29 mm and on the left side, it was 8.08 ± 1.37 mm.

The mean thickness of the bone which formed the floor of the groove (± SD) on the right side was 4.7 ± 0.98 mm and on the left side, it was 4.55 ± 0.84 mm.

The mean (± SD) D1 on the left side was 11.06 ± 1.61 mm and on the right side, it was 11.46 ± 1.62 mm. The mean (± SD) of the projection D2 on the left side was 17.82±1.70 mm and on the right side, it was 17.04 ± 1.97 mm. The mean (± SD) D3 on the left and right sides were 14.3 ± 2.03 mm and 14.26 ± 1.69 mm respectively. The mean (± SD) D4 on the left side was 23.14 ± 1.65 mm and on the right side, it was 22.7 ± 1.84 mm.

The parameters D1 and D2 alone showed a statistically significant difference between the right and left sides ($p = 0.036$ and 0.002 respectively). All the other parameters (length, width, thickness, D3 and D4) did not show significant differences between the sides.

The inter observer variation between observers 1 and 2 was not statistically significant ($p > 0.05$). The measurements for all the parameters correlated highly with the correlation co-efficient of 0.97 to 0.99 ($p < 10^{-5}$). The results of the analysis of the inter-observer variation are presented in [Table/Fig-4].

DISCUSSION

The third part of the vertebral artery, after its exit from the foramen transversarium produces an impression on the superior surface of the posterior arch of the atlas, behind the lateral mass of the atlas vertebra. This groove is called as the vertebral artery groove (VAG) [5]. In the superior view, the groove appears to be curved from the lateral to the medial view [6,7]. The morphology of the VAG, including the length, width and the thickness of the bone which formed its floor has scarcely been reported in the Indian literature.

The length, width and the thickness of the groove did not show any statistically significant difference between the right and left sides in the present study. The outer groove length was found to be significantly longer on both the sides (p values, rt < 0.05 and lt < 0.001)) than the inner groove length. A comparison of our morphometric results with that of another author (Max Franco de Carvalho) is presented in [Table/Fig-5].

The distance between the longitudinal midline of the atlas vertebra and the VAG carries surgical importance. Surgeries involving the

Measurement of Reader 1	Mean Measurement (mm)	S.D (mm)	Paired t test- Sig. (2-tailed)	Correlation Coeffecient & Significance (2- tailed)	
Inner groove length (Rt.)	7.71	1.16	0.201	0.967	<0.01
Inner groove length (Lt.)	7.49	1.33	0.24	0.978	<0.01
Outer groove length (Rt.)	8.1	1.58	0.034	0.988	<0.01
Outer groove length (Lt.)	8.24	1.37	0.056	0.984	<0.01
Groove Width (Rt.)	7.89	1.29	0.645	1	<0.01
Groove Width (Lt.)	8.08	1.37	0.559	0.974	<0.01
Thickness of the bone forming the floor (Rt.)	4.70	0.98	0.136	0.984	<0.01
Thickness of the bone forming the floor (Lt.)	4.55	0.84	0.088	0.977	<0.01
Proximal medial projection (D1)Left side	11.06	1.61	1	0.976	<0.01
Proximal lateral projection (D2) Left side	17.82	1.7	0.42	0.979	<0.01
Distal medial projection (D3) Left side	14.30	2.03	1	0.986	<0.01
Distal lateral projection (D4) Left side	23.14	1.65	0.322	0.971	<0.01
Proximal medial projection (D1) Right side	11.46	1.62	0.182	0.981	<0.01
Proximal lateral projection (D2) Right side	17.04	1.97	0.322	0.977	<0.01
Distal medial projection (D3) Right side	14.26	1.69	0.42	0.979	<0.01
Distal lateral projection (D4) Right side	22.70	1.84	0.42	0.983	<0.01

[Table/Fig-4]: Vertebral Artery Groove Measurement comparison between observers

Author	Mean Length (± SD)	Mean Width (± SD)	Mean Thickness (± Sd)
Max Franco de Carvalaho (Only Dry bone results)	INNER: Right – 7.58 ± 1.50 Left – 7.29 ± 1.20 OUTER: Right – 9.68 ± 2.18 Left – 9.54 ± 1.77	Right – 8.49 ± 1.43 Left – 7.96 ± 1.57	Right – 3.87 ± 0.83 Left – 3.92 ± 1.10
Present study	INNER: Right – 7.71 ± 1.16 Left – 7.49 ± 1.33 OUTER: Right – 8.1 ± 1.58 Left – 8.24 ± 1.37	Right – 7.89 ± 1.29 Left – 8.08 ± 1.37	Right – 4.7 ± 0.98 Left – 4.55 ±0.84

[Table/Fig-5]: A Comparison of the morphometric results of the present study with the study of Max Franco de Carvalho et al (2009)

atlas include plate osteosynthesis, posterior cervical arthrodesis, wiring and lateral mass fixation. A posterior approach through a midline longitudinal incision is the commonly advocated approach to the upper cervical region [8]. When exposing the upper cervical spine, care has to be taken to avoid injury to the vertebral arteries. Iatrogenic injury to the vertebral artery is the most commonest intra-operative complication during a posterior approach [5,9,10,11].

Considering the more anterior position of the artery in the groove, the projection, D1 (proximal medial projection at the initial portion of the groove) would suggest the distance between the midline and the VAG. In our study, D1 was found to be 11.06 mm $\pm$ 1.61 on the left side and 11.46 $\pm$ 1.62 on the right side. Although the numerical difference which was noted between the right and left side values was statistically significant ($p = 0.036$), it does not carry much clinical significance. However, the values which were observed on both the sides were close to 11 mm. Therefore, the mean distance between the midline and the edge of the VAG as observed in our study would be 11.26 mm, which could be taken as the safe zone from the midline.

Various authors have quoted the safe zone for surgical manipulations on the posterior arch of the atlas to avoid iatrogenic injury to the vertebral artery. According to Simpson et al [12], the surgical exposure of the posterior arch should not exceed 15 mm from the midline in adults and 10 mm in children. Max franco[5] suggested that the posterior dissection of the posterior arch should be limited to a distance of 11.2 mm from the midline. Stauffer ES [13] recommends a safe zone of 10 mm from the posterior midline. Ebraheim et al [14] noted the safe zone as 10 mm for males and 9 mm for females from the posterior midline. All these data belong to the Western literature. Our results coincide with the results which were observed by Max franco [5]. However, the standard textbooks on posterior exposure suggest a safe distance of 15 mm from the midline [8].

The authors recommend future studies with a larger sample size, including the age and gender of the bones.

CONCLUSION

This study which was done on 75 atlas vertebra provides morphological data about the vertebral artery groove. The knowledge of the safe zone for surgical manipulations from the posterior midline in the local population is mandatory for the surgeons who operate in this area. The present study recommends a safe zone of 11.26 mm from the midline in the posterior approach for the atlas vertebra.

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