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Evaluation of the First Cervical Vertebra Anatomy for Screw Fixation

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ABSTRACT

AIM: To conduct a morphometrical analysis of the atlas to facilitate the development of atlas-related treatment methods and demonstrate the variations in atlas anatomy to aid surgical approaches and reduce complications.

MATERIAL and METHODS: The present study was conducted on 58 dry human atlas vertebrae supplied by the Ege University Faculty of Medicine, Department of Anatomy. Morphometrical analysis was performed using digital calipers.

RESULTS: The quantitative measurements were analyzed for screw fixation. The variations in the atlases were identified as spina bifida (1.7%), accessory foramen (on the right and left sides in 8.6% and 1.7%, respectively), canal for vertebral artery (1.7%, each on the right and left sides, and bilateral in 5.2%), and bipartite superior articular surface (on the right and left sides in 5.2% and 1.7%, respectively).

CONCLUSION: Some of these anatomical variants may explain certain previously described clinical symptoms. The measurements obtained from the 58 atlas vertebrae and the variations observed during the study were discussed. The primary outcome of the present study was that the measurements of the vertebrae are different for every individual. Therefore, it is important to use imaging methods and examinations before screw placement and other surgical approaches.

KEYWORDS: Anatomical variations, Atlas, Screw fixation

INTRODUCTION

Fractures of the first cervical vertebra (atlas, C1), especially in the elderly population, account for approximately 2-3% of all acute cervical spine fractures. Acute C1 vertebra fractures comprise a large variety of fracture types, with treatment options based on the fracture type (9,10,12,16,17,19,33). The treatment for C1 instability can range from using a simple strap to undergoing upper posterior stabilization surgery. C1–C2 transarticular screw fixation, C1 lateral mass screwing, and C1 pedicle screwing are the surgical techniques used for stabilization (12). Apart from atlas fractures, other atlas-related pathologies like atlantoaxial dislocation, which can be observed in congenital craniovertebral junction anomalies, rheumatoid arthritis, infections, and tumors, and following trauma, can necessitate screw placement (10,12). The vertebral artery runs through the spinal column in the transverse foramen and bilaterally on the vertebral artery groove of C1 lamina (24,30,31), complicating surgical procedures in this area (24,30). This study aims to perform a morphometrical analysis of C1 vertebrae and demonstrate variations in its anatomy to aid in the development of surgical approaches and reduce complications.

MATERIAL and METHODS

The present study included 58 dry human atlas vertebrae supplied from the osseous collection of the Ege University Faculty of Medicine, Department of Anatomy. The specimens were of unknown sex and age and were free of fractures and

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deformities. Morphometrical analysis was performed using a digital caliper (accurate up to 0.01 mm). The means and standard deviations of the measurements were calculated. The measured distances are shown in Figure 1.

Anatomical variations of the C1 vertebra such as spina bifida, unilateral or bilateral accessory foramen, bifurcated superior articular surface, and canal for vertebral artery were also noted during these measurements.

The present study was conducted in accordance with the principles of the 1964 Declaration of Helsinki and its later amendments.

RESULTS

The quantitative measurements were analyzed for screw fixation. The quantitative measurements are provided in Table I.

Detailed measurements of the entry zone for screw fixation were made for both sides. The mean area of the entry zone was 33.6 ± 7.2 mm^2, width (A) was 8.2 ± 1.1 mm, and height (B) was 4.0 ± 0.7 mm. The anterior and posterior heights of the lateral mass were also measured. The mean posterior height of the lateral mass (C) was 16.9 ± 2.5 mm, whereas the mean anterior height (D) was 17.8 ± 1.8 mm. The mean length between the medial edge of the groove for the vertebral artery and the midpoint of the posterior arch (E) was 11.2 ± 3.6 mm. Another measurement performed on the lateral mass was the length (F) of the path followed by the screw. This length was 17.3 ± 1.5 mm.

The variations in the C1 vertebrae were identified as spina bifida (1.7%) (Figure 2), accessory foramen (on right and left sides in 8.6% and 1.7%, respectively) (Figure 3), canal for vertebral artery (1.7%, each on the right and left sides, and

Table I: The Quantitative Measurements of the Atlas for Screw Fixation in This Study

	Right side (mean±SD)	Left side (mean±SD)	Bilateral (mean±SD)
Entry zone area (mm^2)	33.8±7.2 (min-max: 18.9-52.2)	33.4±7.2 (min-max: 13.6-50.0)	33.6±7.2 (min-max: 13.6-52.2)
Entry zone width (A) (mm)	8.4±0.7 (min-max: 6.9-9.9)	8.1±1.2 (min-max: 2.9-10.2)	8.2±1.1 (min-max: 2.9-10.2)
Entry zone height (B) (mm)	3.9±0.7 (min-max: 2.3-5.9)	4.1±0.7 (min-max: 2.5-6.1)	4.0±0.7 (min-max: 2.3-6.1)
Height of lateral mass (posterior) (C) (mm)	17.1±2.5 (min-max: 11.5-23.9)	16.7±2.2 (min-max: 10.3-20.8)	16.9±2.5 (min-max: 10.3-23.9)
Height of lateral mass (anterior) (D) (mm)	17.9±1.6 (min-max: 12.9-20.2)	17.6±1.6 (min-max: 12.6-19.9)	17.8±1.8 (min-max: 12.6-20.2)
Distance between the vertebral artery groove and median line (E) (mm)	11.6±3.5 (min-max: 4.8-19.9)	10.7±3.8 (min-max: 3.8-19.6)	11.2±3.6 (min-max: 3.8-19.9)
Lateral mass screw length (F) (mm)	17.4±1.4 (min-max: 15.1-21.2)	17.2±1.6 (min-max: 13.7-21.3)	17.3±1.5 (min-max: 13.7-21.3)

Figure 1: A: Entry zone width **B:** Entry zone height **C:** Height of lateral mass, posterior **D:** Height of lateral mass, anterior **E:** Distance between the vertebral artery groove and median line (ML) **F:** Lateral mass screw length.

Figure 2: The case with spina bifida arrowhead: spina bifida, *****: superior articular surface.

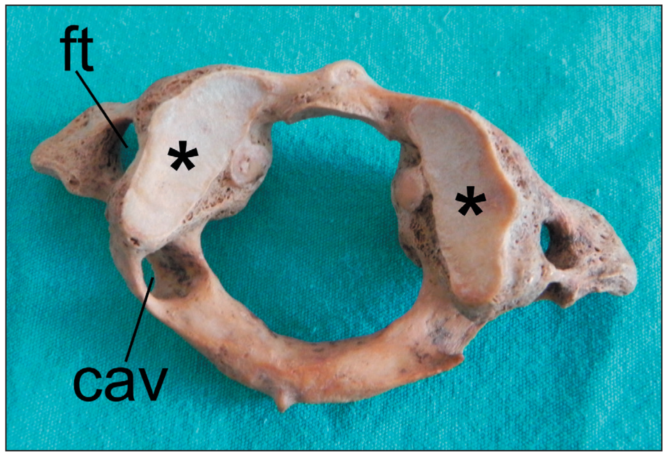

Figure 4: An example of a canal for vertebral artery. **cav:** canal for vertebral artery, **ft:** transverse foramen, *****: superior articular surface.

Figure 3: An example of an accessory foramen arrow: accessory foramen, **ft:** transverse foramen, *****: superior articular surface.

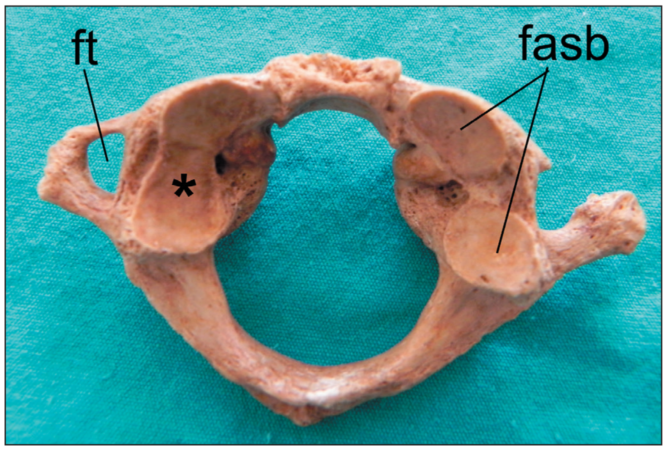

Figure 5: An example of a bipartite superior articular surface fasb: bipartite superior articular surface, **ft:** transverse foramen, *****: superior articular surface.

Table II: The Variations of C1 Vertebra in this Study

	Right side	Left side	Bilateral
Accessory foramen, n (%)	5 (8.6)	1 (1.7)	0 (0.0)
Canal for vertebral artery, n (%)	1 (1.7)	1 (1.7)	3 (5.1)
Two-piece superior joint surface, n (%)	3 (5.1)	1 (1.7)	0 (0.0)

bilateral in 5.1%) (Figure 4), bipartite superior articular surface (on the right and left sides in 5.1% and 1.7%, respectively) (Figure 5) (Table II).

DISCUSSION

Given that atlas fractures represent approximately 25% of all craniocervical injuries and 2% to 13% of all cervical spine injuries, various surgical procedures have been described for screw fixation (18,19). For these screw fixations, it is imperative to consider anatomical variations and morphometric measurements of the atlas (12,13,19,20,31).

Bipartite superior articular surface could be an asymptomatic variation whose potential outcomes remain undemonstrated in clinical studies. Kavaklı et al. found bipartite superior articular surface in 12.8% of their study population (20). In our study, bipartite superior articular surface was found on the right and left sides of the C1 vertebrae at a rate of 5.1% and 1.7%, respectively.

Gupta considered 33.47 ± 8.56 mm^2 as the mean working area for screw placement (screw entry zone), with the smallest area being 14.4 mm^2 (12). This value was 33.60 ± 7.20 mm^2 in the current present study. Moreover, Gupta found no significant difference in the mean values of various parameters of the atlas vertebrae between the right and left sides, which was consistent with our findings (12).

The posterior and anterior heights of lateral mass are important for determining the length of the screw for fixation procedures. In many studies, including ours, the mean length of the entry zone for the screw was from 3.9 to 4.16 mm. Thus, many authors suggested using 3 mm diameter screw for safe surgery (11,12,24,28).

The mean length between the midpoint of the groove for the vertebral artery and the midpoint of the anterior arch is surgically importance for hemilaminectomy. Dağlıoğlu identified this distance as 14.4 mm (7). In our study, this distance was 11.6 ± 3.50 mm on the right side and 10.7 ± 3.8 mm on the left side.

Congenital variations of the atlas can result in craniovertebral junction and cervical spine instability, particularly in pediatric cases (2,5,6,25,26,32). Moreover, these variations can be misdiagnosed as fractures, subluxations, or osteolysis (2,4,14,29).

Some of the variations detected in our study may explain the clinical symptoms described in literature. Among these variations, spina bifida is an embryological defect. Since intrauterine interventions are rapidly gaining attention in recent times, it is important to define the defect size of spina bifida. In an anatomical study by Bodon et al., defects ranging 1–5.5 mm were reported in 7.5% of cases (3). Kim reported a 1.17% arcus posterior defect rate in his study on atlas variations (21). In our study, a 6.7 mm posterior arch defect was detected in 1/58 atlases (1.7%).

The presence of an accessory foramen transversarium in the cervical vertebra is a rare variation. In such cases, the size of the real transverse process is narrowed, potentially exerting pressure on the vertebral artery and the sympathetic plexus. Similarly, the narrowing of the transverse foramen may result in the formation of atheromatose plaque, which may result in thrombosis emboli or reflex spasm (1). Anas et al. reported an atlas with ellipsoid accessory transverse foramen on both sides (1). Lyrtzis et al. examined 141 dried atlas vertebrae, Thirty-seven of the 141 vertebrae (26.2%) had at least one accessory foramen. The accessory foramen was unilateral and bilateral in 67.6% and 32.4% of the cases, respectively. This prevalence was higher than those in most previous studies. The mean anteroposterior diameter (length) of this foramen was 4.2 ± 1.4 mm on the right and 3.8 ± 1.0 mm on the left side (23). In the present study, the accessory foramen was found in five atlases (8.6%) on the right side and in one atlas on the left side (1.7%). The authors considered that the foramina might transmit tributaries of the vertebral vein (1).

The existence of a canal for the passage of the vertebral artery (canalis vertebralis, Kimmerle's anomaly, Kimmerle's variant, foramen atlantoideum posterior, foramen retroarticular superior, or arcuate foramen) may exert external mechanical pressure on the vessel, especially during extension and rotation movements of the head. This variation has been associated with vertebrobasilar insufficiency symptoms, various types of headaches, and acute hearing loss (22). Many authors suggest that it is a congenital characteristic, whereas others suggested that it is a genetic trait given that a familial appearance of this variation is observed (22). In a study, a bridge on the groove of the vertebral artery was reported in 1.2% of the observed atlases (24). Dhall et al. observed that bridgings and canals on the left side the vertebral artery were more common (8). They hypothesized that this difference may result from unequal weight bearing (15). Unlikely the results of their study, in our study, the existence of the canal for the passage of the vertebral artery was observed in one atlas on the left side (1.7%), in one on the right side (1.7%), and bilaterally in three (5.2%).

The injury of vertebral artery is possible during procedures such as the insertion of screws in the lateral masses of the atlas. Thus, the existence of the vertebral canal should be identified before planning posterior approaches to the region of the craniovertebral junction to protect the vertebral artery (22,27).

CONCLUSION

Some of these anatomical variants are known to cause certain clinical symptoms that have been described in detail in the literature. The measurements obtained from the 58 atlas vertebrae and observed variations during present study were discussed. The main result of the present study was that the measurements of the vertebrae are different in every individual. Therefore, imaging methods, such as computed tomographic analysis, and examinations before surgical approaches should be used to evaluate the region's anatomy and to identify appropriately sized screws for screw fixation.

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Declarations

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Availability of data and materials: The datasets generated and/or analyzed during the current study are available from the corresponding author by reasonable request.

Disclosure: The authors declare no competing interests.

AUTHORSHIP CONTRIBUTION

Study conception and design: NF, ZAAI, HU

Data collection: NF

Analysis and interpretation of results: NF, ZAAI

Draft manuscript preparation: NF, ZAAI, HU

Critical revision of the article: ZAAI, HU

Other (study supervision, fundings, materials, etc...): NF, ZAAI, HU

All authors (NF, ZAAI, HU) reviewed the results and approved the final version of the manuscript.

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