Original Article

Morphometric Anatomy of the Atlas and Axis Vertebrae

ABSTRACT

OBJECTIVE: In this study, forty dried specimens of atlas and axis vertebrae were examined using direct anatomical measurements.

METHODS: Various dimensions of the atlas and the axis vertebrae were quantitatively measured, with special emphasis on their relationship with the vertebral artery foramen.

RESULTS: As the vertebral artery foramen was present entirely in the transverse process of all specimens, screw implantation in the facet of atlas proved relatively safe.

CONCLUSIONS: The anatomy of the atlas and axis vertebrae exhibits complex, three-dimensional structures, showing extensive variability in morphology. Characteristics of the atlas and axis vertebrae must be noted before any spinal operation such as transpedicular screw fixation, transarticular screw fixation, screw fixation of dens axis, interspinous wiring, and interlaminar clamp.

KEY WORDS: Anatomy, Atlas, Axis, Vertebral artery

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INTRODUCTION

The first two cervical vertebrae, namely the atlas (C1) and the axis (C2), have different anatomical features from other cervical vertebrae. Various surgical techniques such as interlaminar clamp, interspinous wiring, plate and screw fixation have been currently employed to correct the instability of the atlantoaxial complex or occipitocervical junction caused by numerous traumatic and non-traumatic conditions. Recently, transarticular and transpedicular screws fixation have been widely used in stabilizing the cervical column (1, 2, 5, 6, 12, 13). In spite of the benefits conferred by transpedicular screw fixation in the cervical column, controversy exists regarding its potential risks. Incorrect insertion of pedicle screws can cause damage to adjacent vital structures such as the spinal cord, nerve roots, cranial nerves, and vertebral arteries. Clinically, iatrogenic injury to the vertebral artery during an approach to the atlantoaxial region is rare, but has a potential hazard (3). There are few reports on the quantitative anatomy of the atlas and axis (3, 4, 7, 9). This study aims to evaluate the various dimensions of the first two vertebrae quantitatively and analyze their relationship with the vertebral artery foramen, in addition to determining the safe sites for different surgical approaches.

MATERIALS AND METHODS

Forty human C1 and C2 vertebrae from the anatomy department were examined. All samples were inspected to ensure that the vertebrae were intact and free from osteophytes or metastatic tumors before measurements were made. All parameters were measured using a caliper accurate to 0.1 mm for linear measurements; angular

measurements were made with a standard goniometer accurate to 1 degree. Different parameters for C1 and C2 as described in (Figures. 1-5 and Tables I and II) were defined and measured.

Statistical Analysis. The data were evaluated by the descriptive statistics and paired sample test using the SPSS statistics program. Significance was accepted at probability values of less than 0.005.

RESULTS

Atlas Measurements

Dimensions of the articular surface of inferior and superior facets:

The inferior facet of atlas was circular or slightly drop-shaped. No significant difference was observed in the mean antero-posterior (A-P) and transverse dimensions on the two sides of the C1 vertebrae. The mean A-P dimension of the articular surface of the superior facet was 14.85 mm, and the mean transverse dimension was 14.3 mm. Inferior facets of C1 always pointed towards the vertebral foramen. No statistical difference was observed in the mean thickness and angles on either side of all C1 vertebrae. The superior facet of atlas was oval or kidney-shaped. Oval-shaped superior facets were observed in 72% of atlas vertebrae, and kidney-shaped superior facets were seen in the remaining 28%. No statistical difference was calculated in the data of A-P dimensions of superior articular facet surfaces on both sides of the atlas. The superior articular facets of C1 vertebrae were not as symmetric as the other side. The mean A-P dimension was 19.68 mm. Superior articular facets of C1 also pointed towards the vertebral foramen as well as the inferior facets. The anterior point of the superior facets was nearer to the midline than their posterior point. The mean transverse dimension of the articular surface of the superior facet of C1 was 10.21 mm, which was longer than the mean A-P dimension.

The distance between both tips of the transverse processes of the atlas ranged from 29.8 to 84.9 mm (mean 74.6 mm). The transverse foramen was found to be in the transverse process lateral to the lateral mass in all C1 vertebrae. The mean distance between both innermost edges of the transverse foramen was 48.6 mm (44.1-59.5 mm). The mean distance between both outermost edges of the transverse foramen was 59.5 mm (50.1-69.3 mm). The mean maximum A-P dimension of the vertebral canal was 46.2 mm (38.2-

77.5 mm); the mean minimum A-P dimension of the vertebral canal was 31.4 mm (23.7-46.3 mm); the mean maximum transverse dimension of the vertebral canal was 28.7 mm (25.2-33.5 mm). The mean thickness of the vertebral artery groove was 8.7 mm (5.8-12.2 mm). The mean distance from midline to the innermost edge of the vertebral artery groove on the inner cortex was 10.3 mm (7.1-17.7 mm); the mean distance from the midline to the outer edge of the vertebral artery groove on outer cortex was 16.0 mm (11.3-21.9 mm). No significant difference was observed between the data of two sides (Figures.1-2, Table I).
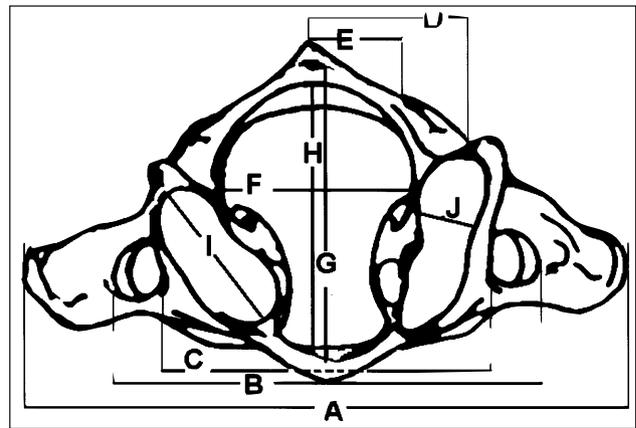

Figure 1: Description of atlas measurements taken from the superior aspect.

The width of atlas was measured as the distance between both tip of transverse process (**A**). Outer distance of vertebral artery foramen was measured as the distance between both lateral-most edges of the transverse foramen (**B**). Inner distance of vertebral artery foramen was measured as the distance between both lateral-most edges of the transverse foramen (**C**). Outer distance of vertebral artery groove was measured as the distance from midline to the lateral-most edge of the vertebral artery groove on outer cortex (**D**). Inner distance of vertebral artery groove was measured as the distance from midline to the medial-most edge of the vertebral artery groove on inner cortex (**E**). The maximum transverse diameter of the vertebral canal was measured along the frontal plane passing through the canal's midpoint (**F**). The maximum A-P diameter of the vertebral canal was measured along the midsagittal plane passing through the canal's widest point (**G**). The minimum A-P diameter of the vertebral canal was measured along the midsagittal plane passing through the canal's narrowest point (**H**). The length of superior articular facets was measured as the A-P dimension of articular surface (**I**). The width of superior articular facets was measured as the transverse dimension of articular surface (**J**).
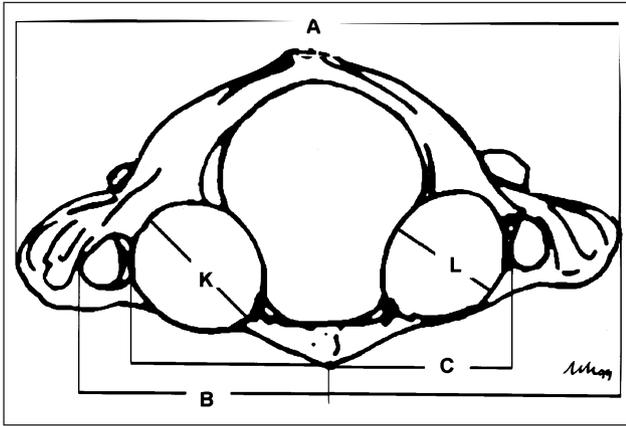
Figure 2: Description of atlas measurements taken from the inferior aspect.

The length of inferior articular facets was measured as the A-P dimension of articular surface (**K**). The width of inferior articular facets was measured as the transverse dimension of articular surface (**L**).

Table I: Anatomic Parameters of the Atlas

Letters on the illustrations	Description of Parameter	Mean (mm)± SD	Range mm
A	Distance between both tip of transverse process	74.6 ± 9.7	29.8-84.9
B	Distance between both lateral-most edge of the transverse foramen	59.5 ± 3.7	50.1-69.3
C	Distance between both medial-most edge of the transverse foramen	48.6 ± 2.9	44.1-59.5
D	Distance from midline to the lateral-most edge of the vertebral artery groove on outer cortex	16.0 ±2.4	11.3-21.9
	L	15.8 ±2.4	11.3-20.1
	R	16.2 ±2.5	11.7-21.9
E	Distance from midline to the medial-most edge of the vertebral artery groove on inner cortex	10.3 ±1.8	7.1-17.7
	L	10.4 ±2.0	7.2-17.7
	R	10.3 ± 1.6	7.1-13.3
F	The maximum transverse dimension of the vertebral canal	28.7 ± 1.8	25.2-33.5
G	The maximum A-P dimension of the vertebral canal	46.2 ± 6.0	38.2-77.5
H	The minimum A-P dimension of the vertebral canal	31.4 ± 3.5	23.7-46.3
I	Length of the superior articular facet	19.2 ±3.4	10.5 ±29.8
	L	18.6 ± 3.2	11.7-29.8
	R	19.9 ± 3.4	10.5-23.0
J	Width of the superior articular facet	9.7 ±1.7	7.0-19.9
	L	9.8 ± 1.5	7.0-17.3
	R	9.6 ± 1.9	7.3-19.9
K	Length of the inferior articular facet	17.3 ±2.5	10.5-20.1
	L	17.5 ± 2.4	10.7-20.1
	R	17.1 ± 2.6	10.5-19.8
L	Width of the inferior articular facet	14.6 ±2.5	7.3-19.3
	Thickness of the vertebral artery groove	8.7 ±1.5	5.8-12.2
	L	8.5 ±1.5	6.1-11.9
	R	8.8 ±1.5	5.8-12.2

L: Left   R: Right

Axis Measurements

Dimensions of dens axis

The widest diameter of dens axis on the coronal plane varied from 7.9 to 16.9 mm (mean 11 mm). The mean distance from the tip of dens axis to the horizontal line which arbitrarily passed superior to the superior articular facets of axis (height of dens on coronal plane) was 14.5 mm. The mean width of the articular surface of dens axis on the coronal plane was 8.6 mm, and its mean height was 11 mm. The long axis of dens axis generally formed an angle according to vertical axes of C2 body from the lateral view. The angle of dens axis was measured to be narrow between an axis that was supposed to pass longitudinally to dens axis and the vertical line on a sagittal plane. The mean angle was 9.6 degrees (0-18 degrees) (Figure.3, Table II).
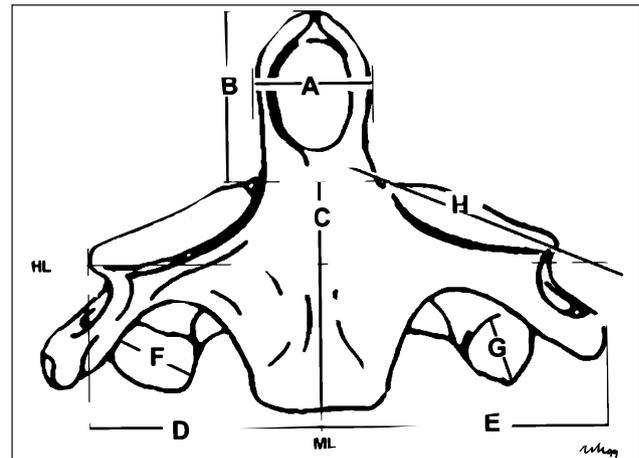

Figure 3: Description of axis measurements taken from the anterior-posterior aspect.

The width of dens axis was measured as the widest diameter of dens axis on coronal plane (**A**). The height of dens axis was measured as the distance from the tip of dens axis to the horizontal line, which arbitrarily passed superior to superior articular facets of axis (**B**). The height of the anterior corpus axis was measured as the distance from the line, which arbitrarily passed superior to superior facets to the lowest point corpus of axis on midline (**C**). The distance of the superior articular facet was measured as the distance from the most lateral border of the superior articular facets of axis to the midline (**D**). The distance of transverse process was measured the distance from the most lateral border of the transverse processes of axis to the midline (**E**). The length of inferior articular facets was measured as the A-P dimension of the articular surface (**F**). The width of inferior articular facets was measured as the transverse dimension of articular surface (**G**). The superior articular facet frontal angle was measured as an opening supposed to be superior facets and the line, which arbitrarily passed superior to them on transverse plane (**H**). **HL**: Horizontal line, **ML**: Midline.

Table II: Anatomic Parameters of the Atlas

Letters on the illustrations	Description of Parameter		Mean (mm)± SD	Range mm
A	Width of the dens axis		11.02 ± 1.8	7.9-16.9
B	Height of the dens axis		14.5 ± 2.3	10.2-18.0
C	Height of the anterior corpus axis		22.1 ± 2.6	14.8-26.7
D	Distance from lateral most edge of the superior articular facet to midline		21.5 ±3.1	9.1-29.8
		R	21.0 ± 3.7	9.1-29.8
		L	21.9 ± 2.3	17.6-27.4
E	Distance from tip of the transverse process to midline		27.3 ±2.8	22.8-34.2
		R	27.3 ± 2.8	22.9-32.2
		L	27.2 ± 2.8	22.8-34.2
F	Maximum length of the inferior articular facet		11.6 ±1.5	8.5-16.2
		R	11.7 ± 1.7	8.5-16.2
		L	11.4 ± 1.3	8.5-14.8
G	Maximum width of the inferior articular facet		9.5 ±1.6	4.9-13.3
		R	9.6 ± 1.7	5.2-13.3
		L	9.4 ± 1.5	4.9-12.7
H	Superior articular facet frontal angle		27.1 ±5.4	17-42
		R	26.2 ± 5.1	17-40
		L	28.0 ± 4.5	18-42
I	Pedicle horizontal angle		21.0 ±5.0	13-30
		L	20.8 ± 4.8	15-30
		R	21.2 ± 5.0	13-30
J	Maximum A-P dimension of the vertebral canal		20.8 ± 2.7	11.5-28.9
K	Minimum A-P dimension of the vertebral canal		20.8 ± 2.7	11.5-28.9
L	Maximum transverse dimension of the vertebral canal		24.7 ± 2.6	16.5-28.9
M	Minimum transverse dimension of the vertebral canal		24.5 ± 1.7	20.7-28.3
N	Maximum length of the surface of the superior articular facet		17.5 ±1.5	14.5-20.3
		L	17.5 ± 1.5	14.5-20.3
		R	17.5 ± 1.4	14.9-20.1
O	Maximum width of the surface of the superior articular facet		14.0 ±1.5	10.0-18.0
		L	14.0 ± 1.5	10.5-17.4
		R	14.1 ± 1.6	10.0-18.0
P	Width of the pedicle from its internal surface to its external surface at the level of transverse foramen		9.5 ±2.3	4.0-12.5
		L	9.5 ± 2.2	4.0-12.2
		R	9.6 ± 2.4	4.0-12.5
R	Pedicle sagittal angle		21.9 ±5.5	11-40
		L	20.1 ± 6.2	11-40
		R	23.7 ± 3.9	15-30
Ra	Dens axis sagittal angle		9.7 ± 4.0	0-18

L: Left   R: Right

Dimensions and angles of corpus axis

The height of corpus axis on the coronal plane was measured to be distant from the line which arbitrarily passed superior to the superior facets to the lowest point on the corpus of axis midline, and it ranged from 14.8 mm to 26.7 mm (mean 22 mm).

The shape of the superior facet of C2 was varied. The superior articular facet was directed laterally to join with the inferior facet of atlas and was convex from a lateral view. It was oval-shaped in 86% of facets and circular in the remaining 14%. In 24.4% of superior facets that were oval-shaped, A-P dimension was more than the transverse dimension, while the transverse dimension was more than the antero-posterior dimension in 75.6% of superior facets that were oval-shaped. No significant statistical difference was observed in the mean dimensions of the superior articular facets on both sides of the C2 vertebrae. The mean distance from the outermost border of the superior articular facets of axis to the midline was 21 mm. Distances from the outermost border of transverse processes of axis to the midline ranged from 22 to 34 mm (mean 22.7 mm). The mean width of the pedicle from its internal surface to the external surface at the level of the transverse foramen was 9.5 mm (4-12.5 mm). No statistical difference was found between the two sides. The shape of the inferior facet of C2 was not very different from the superior facet. The inferior facet of axis as well as other vertebrae always projected from the junction of pedicle and lamina downwards. The inferior facet was generally circular in shape. It was circular in 96% of facets and ovoid in 4%. In inferior facets that were oval-shaped, the transverse dimension was more than the A-P dimension. The mean A-P dimension was 11.6 mm (8.5-16.2 mm) and the mean transverse dimension was 9.5 mm (4.9-13.3 mm). No significant statistical difference was found between the two sides. Maximum A-P diameters of the vertebral canal was 20.8 mm on average, and the mean narrowest A-P diameter was 17.7 mm. The maximum transverse diameter of the vertebral foramen was 24.7 mm, and the mean minimum transverse diameter of the vertebral canal was 24.5 mm. The mean width of the pedicle on the transverse plane (the distance from axis' external surface to the internal surface at the level of transverse foramen) was 9.5 mm. The width of the C2 pedicle was less than 5 mm in 7.5% of specimens. The axial angle of the superior facet was an opening supposed to be the superior facets and the line which arbitrarily passed superior to them on the transverse plane. The mean angle was 27 degrees (17-42 degrees) superior to the horizontal line. No significant statistical difference was found on either side. The angles of the pedicle were measured: one

was a trajectory from the back of the pedicle to the superior facet, the farthest to the vertebral artery foramen, localized in the thickest part of the pedicle, according to a parasagittal midline on the transverse plane and a horizontal line on the sagittal plane. The most agreeable angle was found to be 20 degrees superior to the transverse plane and 20 degrees medial to the sagittal plane. No significant statistical difference was found between the two sides (Figures.3-5, Table II).
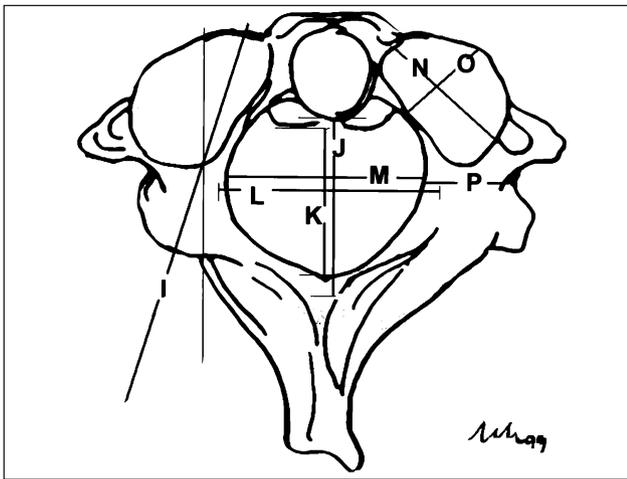

Figure 4: Description of axis measurements taken from the superior-inferior aspect.
The pedicle horizontal angle was measured as a trajectory from back of pedicle to superior facet, farthest to vertebral artery foramen, localized in the thickest part of pedicle, according to parasagittal midline on transverse plane (**I**). The maximum A-P diameter of the vertebral canal was measured along the midsagittal plane passing through the canal's widest point (**J**). The minimum A-P diameter of the vertebral canal was measured along the midsagittal plane passing through the canal's narrowest point (**K**). The maximum transverse diameter of the vertebral canal was measured along the frontal plane passing through the canal's midpoint (**L**). The minimum transverse diameter of the vertebral canal was measured along the frontal plane passing through the canal's narrowest point (**M**). The length of superior articular facets was measured as the A-P dimension of articular surface (**N**). The width of superior articular facets was measured as the transverse dimension of articular surface (**O**). Pedicle width was measured as the distance from axis' external surface to internal surface at the level of transverse foramen (**P**).

DISCUSSION

As surgical techniques and instrumentation for treatment of unstable cervical spine as a result of traumatic, congenital, or neoplastic disorders continue to evolve, more knowledge about bones and surrounding anatomy is required. The
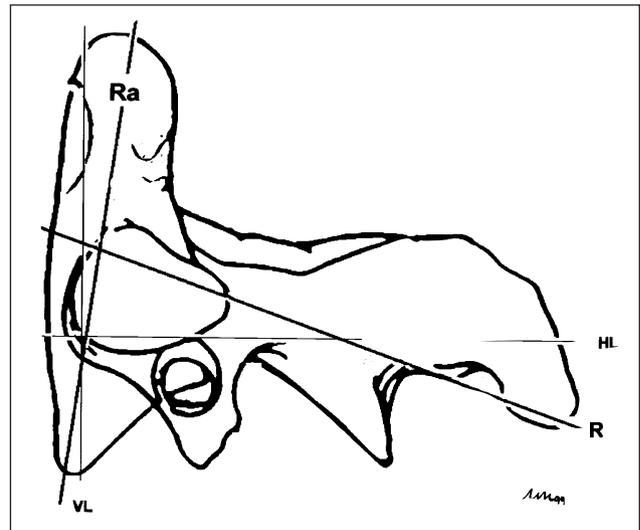

Figure 5: Description of measurements taken from the lateral view of the axis.
The pedicle sagittal angle was measured as a trajectory from back of pedicle to superior facet, the farthest to vertebral artery foramen, localized in the thickest part of pedicle, according to horizontal line on sagittal plane (R). Dens axis sagittal angle was measured as a narrow between an axle that was supposed to passing longitudinally to dens axis and vertical line on sagittal plane (Ra). HL: Horizontal line, VL: Vertical line.

relationship between the vertebral artery and C1-C2 vertebrae has a determining role in planning an operative approach. Various techniques such as interlaminar clamp and hook plating, lateral screw and plate fixation, and interspinous wiring have been described for treating cervical instability. Transpedicular screw fixation is one of the most sophisticated procedures currently in use to treat atlas and axis instabilities. Recently, screw fixation has gained popularity for treating dens axis fractures. Use of transpedicular screws has been reported for treating spinal trauma, extensive laminectomies, and destruction of bony elements by neoplasm. Although pedicle screws have been found to provide superior fixation with the least likelihood of hardware loosening in comparison with other surgical techniques, controversy exists regarding its potential risks (14). Pedicle screws can cause injury to vertebral arteries under the superior facets of axis during insertion. The rate of recognized vertebral artery injury was identified as 2% in Gupta and Goel's report (5), 4.1% in Wright and Lauryssen's study (15), and 8% in Madawi et al's paper (12). However, the actual incidence of vertebral artery injury may be higher than those reported because of

the low survey response and the possibility of unrecognized vertebral artery injury. The actual risk of neurological deficit was only 0.2% per patient because the contralateral uninjured vertebral artery circulation was adequate and ischemia did not occur (13). Gupta and Goel (5) reported that they encountered bleeding probably through a vertebral artery laceration in 2 of 106 cases in whom atlantoaxial facet fusions were performed using plate and screw technique, and bleeding stopped after screw tightening in both these cases.

According to our study, the mean distance between both transverse processes of atlas was 74.6 mm. The mean distance between the outermost edges of the transverse foramens was 59.5 mm; the mean distance between the innermost edges of the transverse foramens was 48.6 mm. Lang (10) found that the mean distance between the transverse processes was 78.2 mm; the mean distance between outermost edges of the transverse foramens was 64 mm, and the mean distance between the innermost edges of the transverse foramens was 52.3 mm. The transverse foramen through which the vertebral artery passes lies lateral to the transverse process of C1. Immediately behind the superior articular facet is a transverse groove for the vertebral artery. The articular process usually overhangs this groove anteriorly. There is often a bony bridge over the course of the vertebral artery (10). Ebraheim et al. (3) suggested that dissection of soft-tissue attachments on the posterior arch of C1 was limited to 8-12 mm. Anatomically, the bony groove on the superior surface of the posterior arch of C1 represents the exact location of the vertebral artery. Damage to the vertebral artery can be avoided if exposure of the posterior arch of C1 remains medial to the groove (3). The mean thickness of the vertebral artery groove on C1 was 5.05 mm in our study. This thickness is satisfactory for applying some fixation techniques such as clamp and hook plating, and atlantoaxial wiring. Thickness of the vertebral artery groove on the atlas was found by Ebraheim et al. to be 3-5 mm (3). Data obtained from the present study revealed that the range from the sagittal midline to the innermost edge of the vertebral artery was 11 mm for right side and 13 mm for left side, with a minimum of 9 mm for both sides. According to these data, we can say that dissection on the posterior arch of the C1 should be limited to 10 mm to prevent injury to the vertebral artery during dissection through a posterior approach.

The shape of the superior facet of the C1 was generally ovoid. Gottlieb et al (6) stated that a kidney-shaped facet of C1 was not frequent and they were not symmetric as mirror images on both sides. Gupta and Goel (5) found kidney-shaped superior facets in 24% of facets and they were not mirror-symmetric. In the present study, we found 72% of superior facets to be of oval-shaped; only 28% were kidney-shaped and none of the facets were mirror images in symmetry. Doherty and Heggeness (7) studied the vertebral canal and the arches of 88 dried human C1 vertebrae. They found that the canal diameter ranged from 32 mm in the transverse trajectory, and 29 mm in the A-P trajectory. In Lang's study (10), these dimensions were 30.2 mm and 34.5 mm, respectively. In the study presented here, the transverse dimension of the vertebral canal of C1 had a mean of 28.7 mm; and the maximum A-P dimension of the vertebral canal had a mean of 46.2 mm.

The length of the inferior facet of C2 was slightly more than its width. In other words, the shape of the inferior facet of C2 was slightly oval. Lu et al. (11) determined that the length of inferior facet of C2 was 20 mm in males and 19 mm in females; the width of the inferior facet of C2 was 20 mm in males and 18 mm in females. The best safe mean angle of the inferior facet of C1 (especially for screw implantation) was 15.7 degrees (varied from 10-20) medial to the sagittal plane and mean of 15 degrees (varied from 10-20) superior to the axial plane. Gupta and Goel (5) stressed that the thickness of the inferior facet under the lateral aspect of the posterior arch was 10.65 mm, providing adequate space for insertion of the screw with little danger of injury to the vertebral artery at the C1-C2 level. They advised that screws must be implanted from the middle of the posterior surface of the inferior facet and directed 15 degrees medial to the sagittal plane and 15 degrees superior to the axial plane.

Treatment of odontoid fractures, in which the fracture occurs across the base of the odontoid process at its junction with the corpus of axis, remains controversial. The most commonly used surgical treatment, either as initial therapy or when immobilization fails, is a posterior fusion between the arches of the atlas and the axis. Depending on the technique, this may require an additional period of external immobilization to increase the likelihood of success. This approach, while stabilizing the spine

well, results in elimination of the normal rotation between the atlas and the axis, which accounts for more than one-half of the normal axial rotation of the cervical spine (1). On the contrary, anterior screw fixation allows direct fixation across the fracture site and achieves immediate stability, while restoring and preserving normal movements of the cervical spine. In this technique, one or two screws are inserted under careful biplane fluoroscopic control from the inferior edge of the axis through the body of axis and into the odontoid to its apex (1,2). The trajectory of the screw for anterior screw fixation of odontoid is parallel to the vertical axes of the odontoid. In presented study, we observed that the mean widest diameter of dens axis on the coronal plane was 11 mm. The distance from tip of dens axis to the anterior inferior edge of corpus axis was approximately 36 mm. The sagittal dens angle was measured to be a mean of 10 degrees.

The height of the C2 vertebral body in the anterior spine was measured as a mean value of 22.1 mm by Lang (10) and 20.4 mm by Lu et al (11). Karaikovic et al (8) measured isthmus height and width of C2 in 53 cadavers' axis vertebrae. They found that approximately 92% of their 53 specimens had widths measuring more than 4 mm, and the heights were less than 5 mm in 12% of cases. Ebraheim et al. (4) reported the superior pedicle width to range from 4-11mm. In the study of Mandel et al. (13), who measured the C2 isthmus width and height using both direct anatomic and computed tomographic measurements in 205 human cadavers' C2 vertebrae, only five specimens (2.4%) had one or both isthmus widths of less than 5mm. Gupta and Goel (5) reported that the mean screwable thickness of C2 pedicle was 7.8 mm, and that the mean height of the pedicle was 8 mm. In the present study, the width of C2 pedicle ranged from 4 to 12.5 mm; 7.5% of specimens had isthmus widths of less than 5 mm. Mandel et al. (13) suggest that placing a 3.5 mm screw in a patient with C2 isthmus dimensions (smaller than 5 mm in either the height or width) is technically difficult. In the presence of a small C2 isthmus width and/or height, approximately 10% of patients may be at risk for a vertebral artery injury with placement of C1-C2 transarticular screws.

A condition that increases the risk of vertebral artery injury in this region is due to the presence of two characteristics of the superior facet of C2 vertebra, which differs from the facets of all other vertebrae. First is that the superior facet of C2 presents proximity to the corpus and the medial aspect of pedicle axis when compared to other facets, which are located in proximity to the junction of pedicle and lamina. The second and more crucial characteristic is that the vertebral artery foramen is present partially or completely in the undersurface of superior facet of axis while in other cervical vertebrae, vertebral artery foramen is located entirely in relation to the transverse foramen. This unusual location of vertebral artery can deem the artery prone to injury if the screw is directed straight ahead anteriorly in a sagittal plane (5,9).

We found the mean pedicle horizontal angle to be 21 degrees; and the mean pedicle sagittal angle to be 22 degrees. A relatively safe screw trajectory was found to be at 40 degrees medial to the sagittal plane and 20 degrees superior to the axial plane by Gupta and Goel (5). Madawi et al. (12) reported a screw trajectory through C2 vertebra meaning that a safe screw trajectory ranges between 0 degrees in the parasagittal and 14 degrees medial in the horizontal plane. We observed that the mean transverse dimension of the vertebral canal of C2 was 24.7 mm; and the mean maximum A-P dimension of the vertebral canal was 20.8 mm.

In conclusion, based on the examination of forty atlas and axis vertebrae, a detailed set of anatomical data on dimensions, angles and relations between the two have been presented. This information may be helpful in avoiding and minimizing complications such as vertebral artery injury, spinal cord injury, and cranial nerve damage during a C1-C2 stabilizing operation.

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