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MORPHOMETRIC ANALYSIS OF THE AXIS VERTEBRA IN INDIAN POPULATION: MANOEUVRING THROUGH THE CRANIOVERTEBRAL JUNCTION

Radiology

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ABSTRACT

Aims: Axis vertebra (C2) is involved in various pathologies which lead to instability at the craniovertebral junction. Pre-operative morphometric analysis of axis is important since various surgical interventions rely on different anatomical details which vary widely in the population.

Methods: We retrospectively analyzed different radiological parameters of normal C2 vertebra in the CT scans of 100 subjects; namely anterior height of axis vertebra, its body and dens, Antero-posterior (AP) and transverse dimensions (TD) of dens, dens sagittal angle and various pedicle characteristics like pedicle width, height, pedicle superior angle (PSA) and pedicle median angle (PMA).

Results: We found that the mean heights of axis vertebra, dens and body of axis were 31.07mm, 14.73mm and 16.33mm respectively. The mean AP and transverse diameters of dens were 10.82 mm and 9.8 mm respectively, with the mean dens sagittal angle being 16.02 degrees. The mean pedicle width and height were 7.06 mm and 7.86 mm respectively, pedicle superior angle and pedicle median angle were 26.04 degrees and 33.41 degrees respectively. We found that these parameters varied significantly in males and females ($p<0.05$), except dens sagittal angle ($p=0.129$) and pedicle superior angle ($p=0.28$). The number of subjects who had the minimum dens TD less than 9 mm were 35 % [10 males (21.7 %), 25 females (46.2 %)], being significantly more in females ($p=0.01$).

Conclusion: Morphometric analysis of axis vertebra assumes importance prior to all craniovertebral junction interventions since there is significant variation in its anatomical parameters in the population.

KEYWORDS:

Axis vertebra, morphometric analysis, dens, pedicle

INTRODUCTION:

Axis vertebra (C2) is atypical in its shape and morphological characteristics and forms an integral part of the craniovertebral junction [1- 3]. It has various distinct anatomical features like dens or odontoid process, two lateral masses with obliquely oriented articulating facets, transverse processes with foramina transversarium and a usually bifid spinous process. It is related to various vital structures like the cervico-medullary junction, cranial nerves, cervical spinal nerve roots and vertebral arteries. Various pathological processes like congenital skeletal dysplasias, trauma, infection, neoplasm etc. affect the axis vertebra [2-6], which leads to instability at the cranio-vertebral junction. Various surgical procedures aimed to correct these pathological processes require a thorough anatomical knowledge and complete pre-operative morphometric details of the vertebrae.

METHODS AND MATERIALS:

A retrospective evaluation of 100 CT scans of the neck and cervical spine performed in our department over a period of 1 year (January 2016 to December 2016) was done, which showed no radiologically detectable abnormality in the axis vertebra. Subjects showing any congenital or acquired abnormality of the craniovertebral junction were excluded from the study. All CT examinations were carried out on a Philips Brilliance 64 –Slice MDCT scanner V.2.6, (Philips Healthcare, Netherlands).

Morphometric analysis of axis vertebra was done in the patients included in the study. The radiological parameters which were evaluated are as follows:

1. **Height of axis vertebra:** Distance from the anterior inferior edge of the body of axis vertebra in the midline to the tip of the dens (Figure 1)
2. **Height of axis body:** Measured at the anterior inferior edge of the body of axis vertebra in the midline to the superior border (which was defined by an arbitrary line drawn at the superior aspect of the superior articular processes) (Figure 1).
3. **Height of dens:** Measured as the distance from tip of dens upto arbitrary line drawn at the superior aspect of the superior articular processes (Figure 1)
4. **Dens dimensions:** Anteroposterior (AP) and transverse dimensions (TD) of dens were measured on axial sections from the base and at 1 mm intervals upward. Mean AP and TD were then determined. The base of the odontoid process was defined as the caudal-most axial CT image, with most well- delineated dens cortex. (Figure 2)

- Mean transverse diameter of dens (TD)
- Mean AP diameter of dens (AP)
- Dens sagittal angle: angle between an imaginary line passing through the dens axis and the vertical line on a sagittal plane (Figure 3)

5. **Axis pedicle:**

- Pedicle width: was measured as the distance from the external surface of pedicle to its internal surface at the level of foramen transversarium (Figure 4)
- Pedicle height: was measured in a para-sagittal section from its superior surface to inferior surface at the level of foramen transversarium (Figure 5)
- Pedicle superior angle (PSA): was measured as the angle between the pedicle axis and a line drawn perpendicular to the body of the axis (Figure 6)
- Pedicle Median angle (PMA) : was measured as the angle between the pedicle axis and line passing through the midline of the vertebral body and the spinous process (Figure 7)

The distribution characteristics were calculated for each of the above

mentioned parameters. The means of each of these parameters were compared in males and female using Student's t test.

Number of individuals with transverse diameter of dens being less than 9 mm and 7.4 mm was calculated in male and female subjects. The difference was assessed using Chi Square test.

Figure 1: Coronal image of the cranio-vertebral junction demonstr ating the measurement of the height of axis vertebra (ce), height of dens (cd) and height of axis body (de). The line ab represents an arbitrary line passing through the cranial aspect of superior articulating facets.

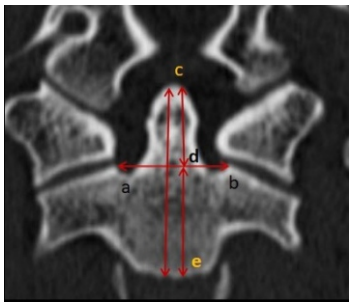


Figure 2: Axial image of the atlas and axis vertebra at the level of the waist of dens demonstrating the measurement of the Anteroposterior (AP) and transverse dimensions (TD) of dens.

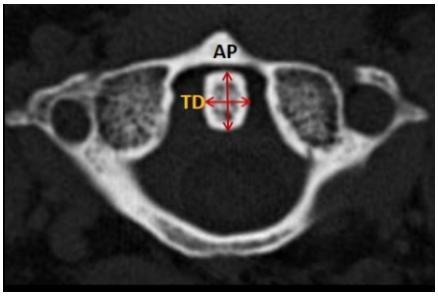


Figure 3: Sagittal image of the dens demonstrating the dens sagittal angle.

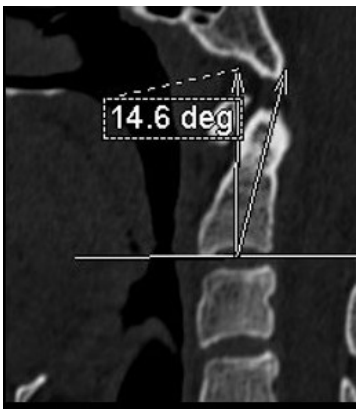


Figure 4: Axial image of the axis vertebra demonstrating the measurement of pedicle width (red double arrow)

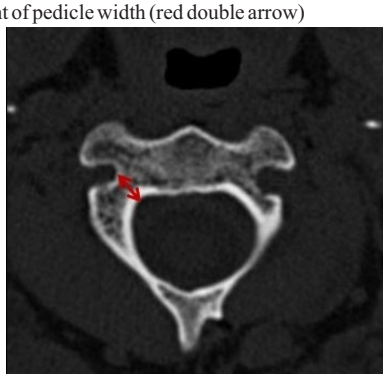


Figure 5: Sagittal image of the axis vertebra demonstrating the measurement of pedicle height (red double arrow)

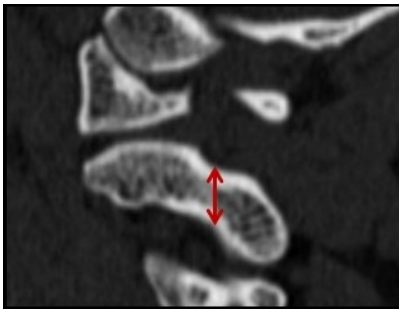


Figure 6: Sagittal image of the axis vertebra demonstrating the measurement of pedicle superior angle

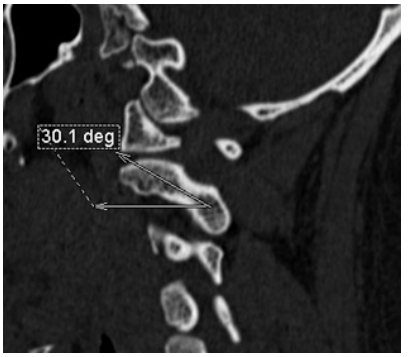
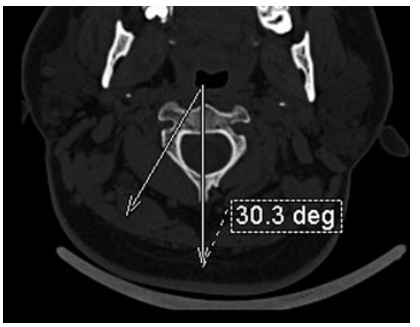


Figure 7: Sagittal image of the axis vertebra demonstrating the measurement of pedicle median angle



RESULTS:

100 CT scans were evaluated in subjects with mean age of 40.8 + 1.4 years (18-70 years). 46 (46%) CT scans evaluated in the study were that of males with mean age of 35.5 + 1.36 years (18-65 years) and 54 (54%) were that of females with mean age of 45.4 + 1.3 years (20-70 years).

Various morphological features of axis vertebra that were analyzed with the results of the study are mentioned in Table 1.

The mean height of axis vertebra was 31.07 + 2.4 mm, being 32.46 + 2.21 mm in males and 29.89+1.87 mm in females. The mean height of dens was 14.73 + 1.52 mm, being 15.52 + 1.34 mm in males and 14.06 +1.35mm in females. Mean height of body of axis vertebra was16.33 +1.76 mm, being 16.93 +1.63 mm in males and 15.8 +1.7mm in females. The difference between mean height of axis vertebra, its body and dens in males and females was highly significant (mean height of axis vertebra: $p < 0.00001$; mean height of dens: $p<0.00001$; mean height of axis body: p0=0.0014).

Various dens characteristics were then evaluated. The mean AP and transverse diameter of dens was 10.82 +0.99 mm and 9.8 +1.25 mm respectively, being 11.1 +0.81 mm (AP) and 10.15 +1.41 mm (Transverse) in males and 10.58 +1.07 mm (AP) and 9.50 +1.02 mm (Transverse) in females respectively. The difference between mean AP and TD of dens in males and females was highly significant (AP: p0= 0.009; TD: p0= 0.01).

The number of subjects who had the minimum transverse diameter less

than 9 mm were 35 % [10 males (21.7 %), 25 females (46.2 %)], being significantly more in females (p=0.01). The number of subjects having minimum transverse diameter less than 7.4 mm were 2 % [0 males, 2 females (3.7 %)]. The mean dens sagittal angle was 16.02 +3.09 degrees, being 16.5 +3 degrees in males and 15.58 +3.12 degrees in females. The difference between mean dens sagittal angle in males and females was not significant (p=0.129).

The axis pedicles were then evaluated with the mean pedicle width being 7.06 +1.10 mm, being 7.6 +0.95 mm in males and 6.5 +0.99 mm in females. The mean pedicle height was 7.86 +1.10 mm, being 8.17 +1.12 mm in males and 7.59 +1.01 mm in females. The pedicle superior angle was 26.04 +3.64 degrees, being 26.47 +2.83 degrees in males and 25.68 +4.2 degrees in females. The pedicle median angle was 33.41 +3.04 degrees, being 32.53 +3.28 degrees in males and 34.16 +2.63 degrees in females. The difference between pedicle width, height and pedicle median angle in males and females was highly significant (pedicle width: p<0.00001; pedicle height: p0= 0.008, pedicel median angle: p0 =0.006). The difference between mean pedicle superior angle in males and females was not significant (p0=0.28).

Table 1: Results

	Parameter	Characteristics	Total	Male	Female	P-value
1.	Height of axis vertebra (mm)		31.07+2.4 (25-37)	32.46+/2.21 (28-37)	29.89+1.87 (25-33)	< 0.00001
2.	Height of dens (mm)		14.73+1.52 (11-18]	15.52+1.34 (13-18]	14.06+1.35 (11-16.4]	< 0.00001
3.	Height of axis body (mm)		16.33+1.76 (11-21)	16.93+1.63 (14-21)	15.8+1.7 (11-20)	0.0014
4.	Dens	i. AP diameter (mm)	10.82+0.99 (7.5-13)	11.1+0.81 (9-13)	10.58+1.07 (7.5-12.2)	0.009
		ii. TD (mm)	9.8+1.25 (6.7-12.7)	10.15+1.41 (7.6-12.7)	9.50+1.02 (6.7-12)	0.01
		iii. Dens Sagittal Angle (degrees)	16.02+3.09 (9-21)	16.5+3 (9-21)	15.58+3.12 (9-20)	0.129
5.	Pedicle	I. Width (mm)	7.06+1.10 (3.7-9.2)	7.6+0.95 (5.8-9.2)	6.5+0.99 (3.7-7.8)	< 0.00001
		ii. Height (mm)	7.86+1.10 (5-12)	8.17+1.12 (6-12)	7.59+1.01 (5-9.5)	0.008
		iii. PSA (degrees)	26.04+3.64 (17-35)	26.47+2.83 (20-32)	25.68+4.2 (17-35)	0.28
		iv. PMA (degrees)	33.41+3.04 (26-39)	32.53+3.28 (26-38)	34.16+2.63 (30-39)	0.006

DISCUSSION:

The morphological characteristics of axis vertebra are crucial in managing various pathologies of the craniovertebral junction [7]. Various anatomical features of axis vertebra make it unique and hence variations in morphological parameters assume importance. Varied surgical procedures are performed to address the pathologies of the craniovertebral junction such as interlaminal clamping, interspinous wiring, plate and screw fixation etc.

Dens fractures are common, with the most common type being Anderson and D' Alonzo type II [8]. Surgical fixation is considered in type II dens fracture to prevent atlanto-axial instability and hence further neurological deficits. One of the approaches of surgical fixation of odontoid fracture is the anterior trans-oral approach. In this anterior screw fixation technique, one or two screws are inserted from the inferior edge of the axis through the body of axis and into the dens [9, 10]. Two screws inserted in coronal plane give better stability than a single screw; however, insertion of the second screw can be difficult as the dens may be too narrow in some individuals [9, 11- 15]. The minimum transverse diameter (TD) that can accommodate two 3.5 mm screws is 9.0 mm, while the minimum transverse diameter (TD) that can accommodate two 2.7 mm screws is 7.4 mm [9, 16]. In our study, the mean AP and transverse diameter of dens was 10.82 +0.99 mm and 9.8 +1.25 mm respectively, being 11.1 +0.81 mm and 10.15 +1.41 mm in males and 10.58 +1.07 mm and 9.50 +1.02 mm in females respectively. The number of subjects who had the minimum transverse diameter less than 9 mm were 35 % [10 males (21.7 %), 25 females (46.2 %)] being significantly more in females (p=0.01). The number of subjects having minimum transverse diameter less than 7.4 mm were 2 % [0 males, 2 females (3.7 %)].

In a study done by Kulkarni et al., they found that the mean AP and mean TD of the odontoid process were 11.52 mm and 9.85 mm respectively in Indian subjects. Fifty five (55%) patients had at least one TD < 9.0 mm. Five (5%) patients had at least one TD < 7.4 mm [11]. As compared to that, we found lesser percentage of subjects with TD less than 9 mm and 7.4 mm. Singla et al. evaluated anatomical parameters of axis vertebrae of Indian origin, and found the mean A-P and transverse diameter of odontoid process was 10.1 mm and 9.32 mm respectively. The mean value of anterior height of axis was 34.33±2.69mm and mean anterior height of the odontoid process was 14.66mm. Mean of dens axis sagittal angle was 13.23 degree [17]. In our study, the mean height of axis vertebra was 31.07+2.4 mm, which is marginally less than that found by Singla et al. The mean height of dens in our study was 14.73+1.52 mm being marginally more than their study. The mean dens sagittal angle was 16.02+3.09 degrees being more than their study.

The anterior C2 body may be used for anterior craniovertebral fixation. In our study, the mean height of body of axis vertebra was 16.33+1.76mm, being 16.93+1.63 mm in males and 15.8+1.7mm in females. Singla et al. found that the mean anterior height of body of axis was 19.67 mm [17]. Lang [18] measured the same parameter with its value 22.1mm and Lu et al., [19] found this parameter as 20.4 mm. In our study, the mean height of body of axis vertebra was16.33+1.76 mm, which is less than that found in previous studies.

Pedicle of axis vertebra is defined as the portion beneath the superior facet and antero-medial to the foramen transversarium. Evaluation of pedicle is required when transpedicular screw insertion is planned for pedicle fracture fixation. Patients with narrow pedicle are at a risk of vertebral artery injury. In our study, we found that the mean pedicle width was 7.06+1.10 mm while the mean pedicle height was 7.86+1.10 mm. Gupta & Goel reported that the mean screwable thickness of C2 pedicle was 7.8 mm, and that the mean height of the pedicle was 8 mm [20]. Lalit et al. found that the mean width and height of the axis pedicle in Northern India were 8.82 ± 2.43 mm, and 5.63 ± 2.06 mm [21]. Singla et al. found that the mean width of axis pedicle was 10.07mm (range 5.15-14.5mm) on right side and 10.52mm (range 6.37-14.48mm) on left side [17].

The trajectory of pedicle screws also depends on the pedicle angles. The pedicle superior angle (PSA) in our study was found to be 26.04 +3.64 degrees while the pedicle median angle was 33.41+3.04 degrees. Lalit et al. found that mean pedicle superior angle was 23.3 degrees and pedicle median angle was 32.2 degrees [21]. Xu et al. found that mean pedicle superior angle was 20 degrees and pedicle median angle was 33 degrees [22]. The pedicle median angle found in our study was comparable to other studies, however the pedicle superior angle found in our study was more than the other mentioned studies.

CONCLUSION:

Morphometric analysis of axis vertebra assumes importance prior to all interventions in the region of the craniovertebral junction. There is significant variation in the anatomical parameters of axis vertebra in the population. Hence, knowledge of the variations is necessary to pre-operatively assess the approach and appropriate management of different CVJ pathologies.

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