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MORPHOMETRIC EVALUATION OF ANTERIOR ASPECT OF ATLAS AND AXIS

Anatomy

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ABSTRACT

Background: Median atlanto-axial joint dislocation and fracture of dens may require the surgical decompression by anterior approach in certain cases.

Aim and objective: To evaluate the dimensions of anterior part of atlas and axis vertebrae quantitatively and discuss its clinical importance.

Material and Methods: Morphometric measurements were done for forty atlas (thickness, transverse distance, height of anterior arch) and forty axis vertebrae (odontoid height, widest odontoid diameter in coronal plane, height and width of facet on dens). Mean, standard deviation, standard error and 95% confidence interval were calculated for each parameter.

Results: The mean anterior arch thickness and height were 5.81 +/- 1.19 mm and 11.45+/-2.79 mm respectively. The distance between medial margins of lateral masses was 15.58 +/- 2.75mm. The height and widest odontoid diameter were 15.26+/-2.51mm and 10.68+/- 0.78 mm respectively.

Conclusions: Our study provides the useful data on dimensions of atlas and axis for anterior approach surgery at c1-c2 junction.

KEYWORDS

Atlas, Axis, Dens, Morphometry

Introduction

The first two cervical vertebrae, Atlas and Axis, differ from other cervical vertebrae in their anatomical features. Odontoid process of axis forms the median atlanto-axial joint with anterior arch of atlas. Different pathological disorders may produce atlanto-axial translocation with ventral compression of the brain stem or spinal cord resulting in spinal cord contusion with rapidly progressive myelopathy. Different surgical techniques like inter-laminar clamp, inter-spinous wiring, plate and screw fixation, are used for correction of the unstable atlanto-axial complex or occipito-cervical junction caused by various traumatic and non traumatic conditions. In recent times trans-articular and trans-pedicular screws fixation for the stabilization of cervical column have been used widely(Madawi et al., 1997; Dickman & Hurlbert, 1998; Mandel, Kambach, Petersilge, Johnstone, & Yoo, 2000),but these procedures carry a probable risk of damage to nearby vital structures in the absence of accuracy.(Sengul & Kadioglu, 2006) .Besides these, the posterior approach fixation of axis and atlas, is accompanied by restricted rotatory movement of atlas. Type II and type III fractures of dens may require screw fixation by anterior transoral route. In some cases brainstem ventral decompression is done by removal of odontoid process through transoral route.(Tun et al., 2008) For this procedure, knowledge of dimensions of anterior atlanto-axial complex will be definitely useful for surgeons. There is dearth of literature on the quantitative anatomy of atlas and axis. With this aim, the paper presents the morphometric analysis of anterior arch of Atlas and Dens of axis.

Material and Methods:

Macerated dried atlas and axis vertebrae (40 each), of unknown sex and age, kept in the museum of department of Anatomy were subjected to measurements with the help of fixable manual caliper and Vernier caliper. The following dimensions of the atlas and axis were measured as shown in figure1.

- A. Thickness of anterior arch of atlas at mid point
- B. Maximum horizontal diameter of anterior arch (Distance between medial margins of lateral masses)of atlas
- C. Height of anterior arch of atlas in midline
- D. Widest odontoid diameter in coronal plane
- E. Height of odontoid process
- F. Height of facet (for anterior arch) on dens
- G. Width of facet (for anterior arch) on dens

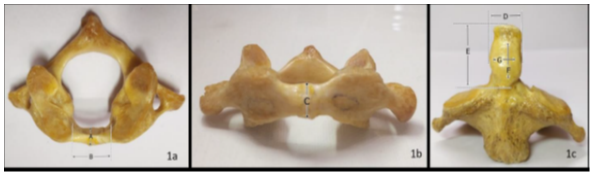


Figure 1: Linear measurements taken on atlas and axis

Statistics: The data was analyzed in Excel. With Descriptive statistics mean, standard deviation, standard error and 95% confidence interval were calculated for each parameter.

Observations and Results: The results of all the parameters of atlas and axis were as shown in table I.

Table I: Descriptive statistics of the parameters of atlas and axis (n=40)

Parameters	Definition	Mean ± SD(mm)	Range (mm)		S.E.	95%Confidence limits	
			Min.	Max.		Lower	Upper
A	Atlas anterior arch thickness	5.81 ± 1.19	2.7	8.92	0.191	5.43	6.19
B	The distance between medial borders of lateral masses of atlas	15.583 ± 2.75	12.26	23.21	0.435	14.70	16.46
C	Atlas anterior arch height	11.45 ± 2.79	5.34	19.24	0.44	10.56	12.34
D	Widest odontoid diameter	10.68 ± 0.78	9.06	11.94	0.123	10.427	10.923
E	Height of odontoid process	15.26 ± 2.51	12.04	21.28	0.396	14.457	16.061
F	Height of facet (for anterior arch) on dens	9.64 ± 1.31	6.48	11.68	0.207	9.228	10.068
G	Width of facet (for anterior arch) on dens	7.37 ± 1.19	5.34	9.42	0.188	6.993	7.755

SD: Standard Deviation ; SE: Standard Error

Discussion:

First and second cervical vertebrae are atypical. Atlas does not have body and axis has a tooth shaped process known as odontoid process or Dens. Dens articulates with the anterior arch of atlas to form a pivot joint which acts as an axle for rotation of head and atlas. Occasionally, severe traumatic and non-traumatic conditions can cause instability of atlanto-axial joint or occipito-cervical complex. In some cases surgical correction is required which may involve plate and screw fixation by anterior approach, for which dimensions of anterior aspect of atlas and axis are noteworthy to prevent injury to spinal cord, spinal nerve roots, and vertebral artery. The midline anterior arch thickness of atlas vertebra has been reported to vary from 6 mm to 7.0 mm in previous studies. (Christensen, Eastlack, Lynch, Yaszemski, & Currier, 2007; B. Doherty & Heggeness, 1994; Tun et al., 2008). In our study it was 5.81+/-1.19 with 95% confidence limits being 5.43 and 6.19. The slight difference could be because of ethnic or racial variation. The difference with the Kagantun study was not significant statistically ($p>0.05$).

The transverse distance between medial borders of lateral masses of atlas was 15.583 +/- 2.75 mm. The frequency distribution graph showed that in about 52.5% bones, this distance was between 12-15 mm. In previous studies, Kagantun reported it to be 16.1+/-1.5 mm and Rocha et al found it 22.9 mm (Rocha et al., 2007) . The 95% confidence interval for normal height of anterior arch of atlas in the midline were 10.56 (lower) and 12.34(upper) mm respectively. In the studied sample, about 67.5 % bones had the anterior arch height between 9 to13 mm. (Figure 2)

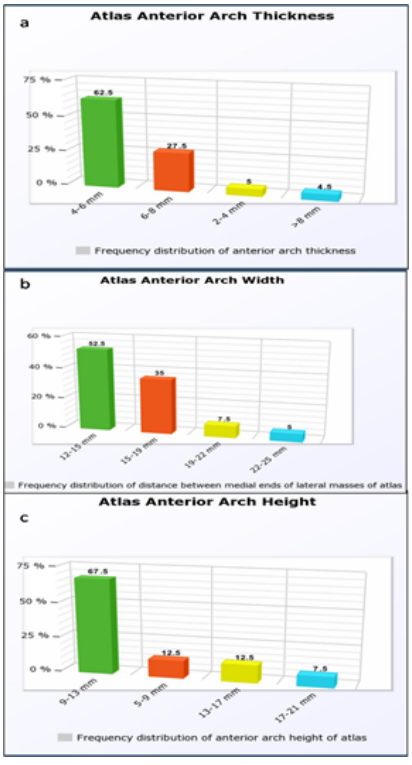


Figure :2: Bar charts showing the frequency distribution of Atlas parameters : a) For anterior arch thickness; b) For distance between the medial ends of lateral masses; c) For anterior arch height

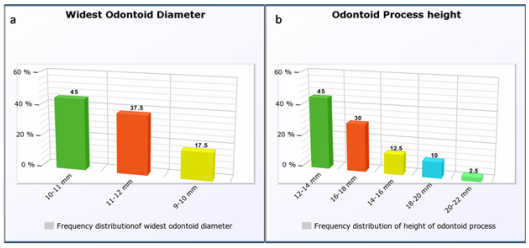
Most common indications for anterior approach for atlanto-axial complex are for the removal of odontoid process for chronic dens dislocation, pseudo basilar invagination caused by rheumatoid arthritis, ventrally located cranio-cervical tumors, injuries of the upper cervical vertebral column and congenital malformations at the skull base.(Kerschbaumer, Kandziora, Klein, Mittlmeier, & Starker, 2000). Chiari I malformations (cerebellar tonsillar descent greater than 5 mm below the foramen magnum) are often associated with congenital cranio-cervical anomalies such as platybasia, basilar invagination, and retroflexion of the odontoid process. Ventral brainstem compression associated with Chiari I malformation usually arises from basilar invagination or odontoid retroflexion and has a reported incidence of 4–31%.(Grabb, Mapstone, & Oakes, 1999). Anterior approach ventral decompression is done by removal of odontoid process by transoral odontoidectomy. It provides direct route to surgical field, with no neurovascular manipulation and no injury to major neurovascular structures, because it passes through oropharynx.(Tun et al., 2008). For these procedures the prior knowledge of dimension of dens of axis would be highly useful. In our study, the mean transverse widest odontoid diameter was 10.68+/-0.78 mm. In past studies, the widest odontoid diameter had been reported to be as 9.8+/-0.8mm(Tun et al., 2008), as 9.57+/- 0.85mm.(Kaur, Kaur, Singh, & Kumar, 2018) as11.02+/-1.8mm(Sengul & Kadioglu, 2006) and 10.5+/- 0.5 mm in Turkish population.(Naderi, Arman, Guvencer, Korman, & senoglu, 2006) In American population it was found to 10.5+/-1.0 mm and 10.8+/-10 mm respectively.(Mazzara & Fielding, 1988).(B. J. Doherty & Heggeness, 1995). An independent study on 44 CT-spine images of Caucasian patients, found maximum outer transverse diameter of odontoid peg to be 11.77+/-1.09 mm at the level of 66% of total odontoid peg length(Puchwein et al., 2013). The transoral approach is an effective surgical operation to decompress the cervicomedullary junction. Many surgeons recommend this approach for extradural lesions because it provides decompression between the midclivus and the upper cervical area (Goel & Laheri, 1994; Kingdom & Kaplan, 1995.). Kanavell and Le Fort first used the transoral approach for craniospinal malformations in 1918 (Laborde, Gilsbach, Bertalanffy, Harders, & Hardenack, 1992), afterwards, several authors modified a transoral approach for improving exposure and reducing complications.(Menezes & VanGilder, 1988;Crockard, 1985; Hadley, Spetzler, & Sonntag, 1989) .

The most common site of fracture in C-2 vertebra is odontoid process, which also accounts for 7-27% of all fractures of cervical spine.(Ochoa, 2005; Clark & White, 1985). In posterior approach for fixing the axis and atlas, there is restriction of rotation movement of atlas. Type II and type III fractures of dens may require screw fixation by anterior transoral route. To choose the instruments and screws of appropriate size, the prior knowledge of anatomical dimensions of dens may be helpful for the spine surgeons. In the present study, the height of odontoid process was 15.26 +/- 2.51mm. It was 15.4+/-2.4mm to 16.6 +/- 1.9mm in American population (B. J. Doherty & Heggeness, 1995; Mazzara & Fielding, 1988) and 14.5 +/- 2.3mm to 15.5.+/- 1.8mm in Turkish population. (Naderi et al., 2006.; Sengul & Kadioglu, 2006) . The difference may be attributed to the racial changes. It was 14.86+/-1.54 in Indian study by Gosavi, and 15.5mm by Xu et al. (Gosavi & Swamy, 2012; Xu, Nadaud, Ebraheim, & Yeasting, 1995)

The average height and width of facet on the dens was 9.64+/-1.31mm and 7.37+/-1.19mm respectively. In about 50% of bones, the height of facet was between 10-12mm and in about 63% of bones the width of facet was between 7 to 9 mm. (Figure 3). Gosavi et al found the measurements of height and width of articular facet on dens as 9.39 +/-1.95 and 7.47+/- 1.29 mm. respectively which is similar to our study. The internal structure of dens is not uniform. Its tip and body have intense cortical bone, neck has mainly cortical bone and base is made up of cancellous bone mainly.(Korres, Chytas, & Markatos, 2017) The region of neck has poor blood supply. The ossification process of dens is also complex. It has two primary and one secondary centre of ossification.(Akobo S et al 2015). These anatomical and embryological features together with the biomechanical forces of the injury at this region are responsible for different types of fractures of dens which recall for appropriate surgical or conservative treatment.

Conclusion:

Our study highlights the dimensions of anterior arch of atlas and dens of axis which are the prerequisites for safe planning anterior approach procedures on this region. The knowledge of these parameters should be helpful for the surgeons in avoiding and minimizing complications such as injury to vertebral artery or cranial nerve or to other vital structures while performing any surgical or interventional procedure around cranio-vertebral region.



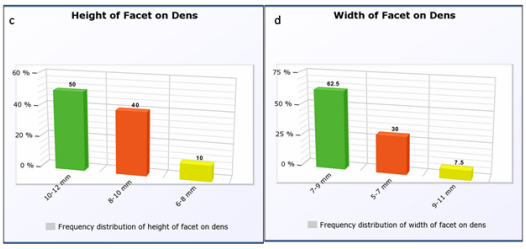


Figure:3: Bar charts depicting the frequency distribution of dens parameters :a) For widest odontoid diameter; b) For height of odontoid process; c) For height of facet on dens ; d) For width of facet on dens

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