Dr. Kajan RanabhatMD
Consultant Radiologist, Department of Radiology
Upendra Devkota Memorial National Institute of Neuro-
logical and Allied Sciences
Bansbari, Kathmandu, Nepal
ORCID iD: https://orcid.org/0000-0002-3689-3889

Dr. Suresh Bishokarma MS
MCh Neurosurgery Resident, Department of Neurosur-
gery
Upendra Devkota Memorial National Institute of Neuro-
logical and Allied Sciences
Bansbari, Kathmandu, Nepal
ORCID iD: https://orcid.org/0000-0001-9448-842X

Prity Agrawal, MD
Consultant Radiologist, Department of Radiology
Upendra Devkota Memorial National Institute of Neuro-
logical and Allied Sciences
Bansbari, Kathmandu, Nepal
ORCID iD: https://orcid.org/0000-0001-7878-1861

Ram Kumar Ghimire, MD
Consultant Radiologist
Department of Radiology
Upendra Devkota Memorial National Institute of Neuro-
logical and Allied Sciences
Bansbari, Kathmandu, Nepal

Address for correspondence:
Dr. Kajan Ranabhat
Department of Radiodiagnosis
Upendra Devkota Memorial National Institute of Neuro-
logical and Allied Sciences
Bansbari, Kathmandu, Nepal
E-mail: kajanranabhat@gmail.com
Contact number: +9779851210364

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Morphometric Measurements of Cranio-Vertebral Junction among Nepalese Population

The craniovertebral junction area refers to the osseous structures consisting of the occipital bone that surrounds the foramen magnum, the atlas, and the axis vertebrae. There is sparse literature about the morphometric measurement of craniovertebral junction region. We aim to derive a range of various measurements in craniovertebral junction area.

This is a hospital based single center retrospective study conducted in our center among 100 consecutive computed tomography scans of craniovertebral junction obtained in adult patients who were admitted to our tertiary hospital for treatment of non-craniovertebral junction conditions between 2017 and 2018. Various craniovertebral junction morphology parameters were measured and confidence interval at 95% were obtained the range at 2 standard deviation.

Among 100 patients studied, 51% of them were males while 49% were females. Mean age was 35.1±10.4 years with range from 15 to 50 years. Computed tomography measurement of craniovertebral junction revealed mean dens height of 30.8±2.5 mms, dento-clival distance was 5.9±1.6 mms and mean McRae's distance of 34.2±2.49 mms. Similarly, anterior atlantodental interval was calculated to be 1.83±0.47 mms andposterior atlantodental interval was 17.72±0.21 mms while Modified RW distance was 24.43±2.09 mms and Redlund Johnell distance was calculated to be 31.5±4.29 mms.

Normal morphometric measurements of craniovertebral junction can be useful for evaluating abnormalities of the craniovertebral junction which can potentially improve the diagnostic criteria of most abnormalities.

Key words: Chamberlain, Craniovertebral junction, McGregor**,** Nepalese, Ranawat distance

The craniovertebral junction (CVJ) area is a complex balance of different elements and can be considered anatomically unique. It is composed of osseous structures articulated with synovial joints, muscles, extrinsic and intrinsic ligaments, and membranes[1]. Proper knowledge of the anatomy of CVJ is crucial for the management of various pathologies of CVJ including basilar invagination (BI) and Atlanto-axial dislocation (AAD). Craniometric relationships and measurements of the normal CVJ in Nepali population have been poorly explored. This study performed a craniometric evaluation of the CVJ in 100 Nepalese population without known CVJ anomalies based on measurements obtained from CT scans to establish the normal range of their measurements in the Nepalese population.

Methods

This is a hospital based single center retrospective study conducted in our center among 100 consecutive CT scans of CVJ obtained in adult patients who were admitted to our tertiary hospital for treatment of non-CVJ conditions between 2017 and 2018. Patients older than 14 years who have undergone a head CT scan that included complete CVJ for various other causes were included. Patient with a CVJ malformation, congenital anomaly, Chiari Malformations, Basilar Invagination, rheumatoid arthritis, spondyloarthropathies or upper cervical spine trauma were excluded. Computed tomography measurements viz anterior atlantodental interval (AADI), posterior atlantodental interval (PADI), Dens height (DH), Dentoclival distance (DCD), Redlund Johnell distance (RJD), Modified Ranawat distance (mRWD), McRae's Distance (MD) were measured by consultant radiologist and registered in excel sheet. Data were analyzed in SPSS ver 23. Proportion and Mean were deduced for categorical data and continuous variables respectively.

Computed tomography measurement

Measurements were performed by 2 experienced radiologists (K.R and P.A) and were recorded upon mutual agreement. The studies were obtained on a 16-row multi-detector CT (MDCT) scanner (Emotion 16, Siemens Healthineers Germany), using a rotation time of 600 msec, tube voltage of 130 kV, and tube current of 160–230 mA. The images were reconstructed into 0.75mm-thick slices with space between slices of 0.1 mm. All scans were analyzed on a present bone window setting: level 450 HU and width 1500 HU.

The images were assessed on the radiological workstation center, and all the measurements were performed using the Syngo.Via, Siemens. The following measurements were obtained:

Craniovertebral measurements

Anterior atlantodental interval (AADI) is the distance from the posterior margin of the anterior arch of C1 to the anterior margin of the dens measured along the transverse axis of C1.

Posterior atlantodental interval (PADI) is obtained by measuring from the posterior margin of the dens to the anterior margin of the posterior arch of C1 (Fig 1A).

McRae line: A line is drawn across the foramen magnum from the basion to the opisthion. Protrusion of the odontoid-tip above this line was represented with a negative number [2] (Fig 1CB)

McGregor line connects the hard palate with the most caudal point of the occipital curve. If the tip of the dens lies more than 4.5 mm above this line it is indicative of basilar invagination.[3] (Figure 1C)

Redlund-Johnell method: The perpendicular distance between the McGregor line and the midpoint of the caudal margin of the second cervical vertebra body is measured (Figure 1C).[4]
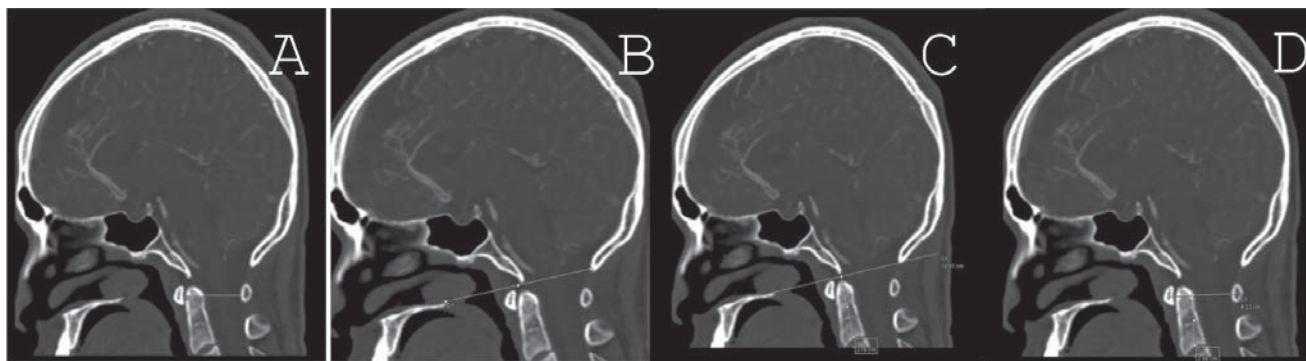

Figure 1: Measurements in craniovertebral junction

A. Anterior atlantodental interval (AADI), Posterior atlantodental interval (PADI), B. McRae line, C. Redlund Johnell distance D. Modified Ranawat Distance.

Morphometric measurement of craniovertebral junction in millimeters

Measurement	N	Minimum	Maximum	Mean	SD
Dens height	100	25.9	36.5	30.899	2.50
DCD	100	2.6	10.5	5.999	1.60
McRae	100	23.3	39.5	34.28	2.49
AADI	100	1.0	3.5	1.835	0.47
PADI	100	14.1	25.5	17.721	2.09
RJD	100	21.8	43.7	31.506	4.29
MRD	100	20.8	29.8	24.442	2.09

Abbreviation; DH: Dens height, DCD: Dentoclival distance, McR: McRea's distance, AADI: Anterior atlantodental interval, PADI: posterior atlantodental interval, RJD: Redlund Johnell distance, MRD: Modified Ranawat distance

Table 1. Morphometric measurement of craniovertebral junction

Modified Ranawat Distance: The perpendicular distance between the midpoint of the base of C2 end-plate and a line from the center of the anterior arch of C1 to the center of the posterior arch (Figure 1D).[5]

Clark station: The dens, as viewed on the lateral radiograph, is divided into three equal parts. If the anterior arch of the atlas is in the second or third station the process of cranial settling is ongoing.[6]

The results of all these measurements are presented in detail with descriptive statistics, reported as means, medians, ranges, and standard deviations. The normal range for the CVJ parameters was defined as the values within 2 standard deviations of the mean (2 SD), representing approximately 95% of patients in a normal distribution.

Results

Among 100 patients studied, 51% of them were male while 49% were female. Mean age was 35.1±10.4 years with range from 15 to 50 years. Computed tomography measurement of craniovertebral junction revealed mean dens height of 30.8±2.5mms with minimum height of 25.9mms and maximum height of 36.5mms. Mean Dentroclival distance was 5.9±1.6 mms with minimum distance of 2.6mm and maximum distance of 10.5mm. While measuring McRae's distance, mean was 34.2±2.49 mms while range was attained between 23.3mms to 39.5mms. AADI was calculated to be 1.83±0.47mms with minimum distance of 1mm to maximum distance of 3.5mms. Similarly, PADI was calculated to be 17.72±0.21mms with minimum distance of 14.1mm to maximum distance of 25.5mms.

Similarly, Modified RW distance was calculated to be 24.43±2.09 mms with minimum distance of 20.8 mms to maximum distance of 29.8mms. Similarly, Redlund Johnell distance was calculated to be 31.5±4.29mms with minimum distance of 21.8mms to maximum distance of 43.7mms. (Table 1)

Discussion

The craniovertebral junction (CVJ) defined as the occiput, atlas, and axis is a complex area that houses vital neural and vascular structures while achieving the most mobility of any segment within the spine.[7] Various pathologies viz. basilar invagination, atlantoaxial dislocation, cranial settling, sub axial subluxation heralds CVJ. Accurate CT based studies on the normal craniometry of the craniocervical junction can be helpful in improving the precision of such diagnosis criteria and improving the classification of CVJ anomalies. In light of the above considerations, we performed craniometrical evaluations among 100 individuals without CVJ abnormalities with the purpose of gathering information on the normal CT. The neural arches fuse posteriorly by around 3 years of age; the anterior body fuses to the neural arches and primary ossification center of the dens between 3 and 6 years of age, typically toward the latter end of the age range. A persistent remnant of the synchondrosis between the anterior body and dens can be seen throughout adolescence and into early adulthood, especially on magnetic resonance imaging. The ossiculum terminale fuses to the remainder of the dens by the early portion of the second decade of life. Most of the synchondroses of the occipital bone complete ossification by the age of 14 years in female and by 15 years in male. By and large

most of the ossification related to vertebrobasilar junction are complete by the age of 15 years[17]. Subjects enrolled in our studies are 15 tears and above and only 5 subjects are 17 years and less. This should not allow any confusion in the measurement due to lack of secondary ossification.

Chamberlain line is a line joining the posterior edge of hard palate with the back of the foramen magnum. The displacement of the tip of the dens by at least 3 mm above the line indicates basilar invagination.[8] McGregor line connects the hard palate with the most caudal point of the occipital curve. If the tip of the dens lies more than 4.5 mm above this line it is indicative of basilar invagination.[9] Ranawat criterion is based on two lines. One line connects the center of the anterior arch with the center of the posterior arch of C1 vertebra. The second line is drawn along the axis of the odontoid process, from the center of the base of C2 vertebra to the intersection with the first line. The smaller is the distance, the larger is the invagination. Values of Ranawat criterion that are larger than 13 mm in women and 15 mm in men are assumed to be normal.[5] Redlund-Johnell criterion is the distance between the center of the lower end plate of C2 to the McGregor's line. The distance of 34 mm in men and 29 mm or more in women is considered normal.[4] In the criterion developed by Clark, called Clark station, the dens, as viewed on the lateral radiograph, is divided into three equal parts. If the anterior arch of the atlas is in the second or third station the process of cranial settling is ongoing.[6]

BI is a radiological finding diagnosed, as proposed by Chamberlain, when the tip of the odontoid process is located above a line from the posterior margin of the hard palate to the opisthion.[8,10] However, different thresholds, such as 2 or 5 mm above the line, have been proposed for diagnosis of this condition.[11,10] Considering atlantoaxial instability, anterior AAS is the most common form, followed by lateral AAS, which represents about 20% of cases, and posterior AAS, which represents about 7% of all cases of AAS in association with RA.[12] Posterior AAS generally occurs in the setting of an odontoid base erosion or fracture. Posterior subluxation is associated the highest rate of neurological deficits of all forms of AAS.[13,2]

When evaluating plain radiographs for cervical instability, several measurements can be made to assess for the presence and severity of disease. In order to evaluate for AAI, the anterior atlantodental interval (AADI) and the posterior atlantodental interval (PADI) can be measured. The AADI defined as distance from the posterior margin of the anterior arch of C1 to the anterior margin of the dens measured along the transverse axis of C1 in normal adults is less than 3mm. AAI is defined as an AADI that is greater than 3mm and not fixed with flexion and extension as it generally increases with flexion and may reduce with extension. Some authors consider that AADI > 5 mm is a sign of clinically significant AAS instability[14], and AADI > 8 mm is an indication for surgical treatment.[15] In our study, AADI was calculated to be 1.83±0.47mms with minimum distance of 1mm to maximum distance of 3.5mms, with 95% confidence interval of 1.74mms to 1.92mms

Posterior atlantodental interval is the distance between the dens and C1 posterior arch. The distance is the width of the spinal canal on the C1–C2 level. As the spinal cord at this level is 10 mm in diameter, 1mm is needed for the dura and 1 mm for CSF, PADI should not be smaller than 14 mm. Literature findings indicate that the reduction of this dimension below 14 mm negatively impacts the outcomes of surgical treatment.[15]In our study, PADI was calculated to be 17.72±0.21mms with minimum distance of 14.1mm to maximum distance of 25.5mms, with 95% confidence interval 17.3 to 18.14mms

A number of methods have been developed to assess the degree of dens displacement. The oldest diagnostic criteria are based on Chamberlain and McGregor line.[8,9] There have been numerous measures proposed to evaluate radiographs for the presence and severity of CS; however, these approaches have proven to be difficult to reproduce and as diseases like rheumatoid arthritis or other spondyloarthropathies progress, difficulty in visualizing landmarks complicates their use. Based on the work by Riew et al. the presence of CS is best evaluated using a combination of the Clark station, Modified/Ranawat criterion, and the Redlund-Johnell criterion.[16] When at least one of these measures is positive, the sensitivity for detecting CS is 94% with a negative predictive value of 91%. Values of Ranawat criterion that are larger than 13 mm in women and 15 mm in men are assumed to be correct.[5] In our study, Modified RW distance was calculated to be 24.43±2.09mms with minimum distance of 20.8mm to maximum distance of 29.8mms with range of 24.02mm to 32.35mm at 95% confidence interval. Redlund-Johnell criterion is the distance between the centre of the lower end plate of C2 to the McGregor's line. The distance of 34 mm in men and 29 mm or more in women is considered normal.[4] In our study, Redlund Johnell distance was calculated to be 31.5±4.29mms with minimum distance of 21.8mms to maximum distance of 43.7mmswith 95% confidence interval range of 30.6mm to 32.35mm. In the criterion developed by Clark, called Clark station, the dens, as viewed on the lateral radiograph, is divided into three equal parts If the anterior arch of the atlas is in the second or third station the process of cranial settling is ongoing.[6] Subluxation in the lower joints of cervical spine usually accompanies the instability in C1–C2.

Conclusions

We generated our results on normal craniometrical values obtained from Computed tomography in 100 asymptomatic Nepalese individuals. These data can be useful for evaluating anomalies of the CVJ in comparison with normal parameters, potentially improving the diagnostic criteria of most anomalies. When evaluating CVJ malformations, surgeons should take into account the normal ranges based on CT scan.

Conflict of Interest: None

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