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Evaluation of Cranio-Vertebral Junction by Multidetector Computer Tomography

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1. Abstract

1.1. Introduction: Normal morphometric measurements of craniovertebral junction is useful for evaluating abnormalities of the craniovertebral junction which helps in diagnosis of most abnormalities.

1.2. Methods: This study was carried out to measure various morphometric distances and angles related with cranio vertebral junction (CVJ) in human body by multi detector computed tomography (MDCT). This quantitative cross-sectional retrospective study was performed in the Department of Radiology and Imaging, Tribhuvan University Teaching Hospital (TUTH), Maharajgunj, Kathmandu. Data were collected from January to April 2021 with total of 153 patients who underwent CT scan of C-spine, Neck and Cerebral Angiography without any abnormality related to craniovertebral junction. The measurement was done at mid sagittal section in Multiplaner Reconstruction (MPR). Various craniovertebral junction morphology parameters like patient's age, gender, Basion-Axial interval (BAI), Dens Height (DH), Basion Dens interval (BDI), Right and Left Atlanto-axial interval(R\LAOI), Anterior and Posterior Atlantodental interval(A\PADI), Power Ratio (PR), McRae line (MR), Redlund-Jonhel method (RLD) and modified Ranawat line(mRWD) were measured.

1.3. Results: Among 153 patients studied, 87 [57.9%] of them were males while 66 [43.1%] were females. Mean age was 48.61±18.690 years with range from 18 to 92 years. The measurement of craniocervical junction in computed tomography revealed the average BAI of 0.561±0.226cms. Mean DH of 3.477±0.263cms, BDI was 0.474±0.167cms, RAOI of 0.139±0.233cms. Similarly, the mean LAOI was 0.139±0.238cms, Average AADI was 0.149±0.422cms, and PADI was 1.767±0.194cms. The mean PR was 0.699±0.083. The distance from the tip of the odontoid to McRae's line, mean was 0.412±0.161cms. Mean Redlund Johnell distance was 3.484±0.438cms and Modified Ranawat distance was 2.688±0.215cms.

1.4. Conclusion: The multiplanner reconstruction of CT image is useful for evaluation of Craniovertebral junction. MDCT is valuable to access the bony CVJ.

2. Introduction

The craniocervical (CCJ) is an osteoligament complex between the atlas and axis, which provides both structural stability and movement1.

The craniocervical (craniovertebral) junction represents the complex transitional zone between the cranium and the spine and comprises a complex balance of different elements: it should be considered anatomically and radiologically a distinct entity from both the cranium and, in particular, the cervical spine. It is composed of bony structures articulated with synovial joints, intrinsic ligaments and membranes and muscles. It provides housing the spinal cord and multiple cranial nerves, it is also consists a critical vasculature supplying both the brain and the cervical spinal cord parenchyma. As a result, injury to the craniocervical junction carries the potential for devastating morbidity and mortality. The craniocervical junction not only house, protect and support structures within it but also provide significant mobility.

There should be adequate knowledge of anatomy of CVJ for the management of various pathologies of CVJ including basilar invagination BI and Atlanto-axial dislocation AAD. There is very minimal researches done in craniometric relationship and measurement of the craniocervical junction in Nepelase population. This study performed a craniometric evaluation of the CVJ in 153 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.

The craniocervical junction can be evaluated by X-ray, CT and MRI. X-ray of the skull with the cervical spine was the imaging modality used for the assessment of basilar impression. But now, CVJ can be visualized much better using modern imaging modalities including computed tomography (CT) and magnetic resonance imaging (MRI) which offer a three-dimensional visualization of this region with a relatively complex anatomy. CT scan can provide good spatial resolution combined with speed and ability to perform high-quality multiplanar imaging (MPR). It provides details of the bony anatomy which are superior to that of plain X-ray and MRI studies. CT is a reliable diagnostic modality for the accurate assessment of the classical lines and angles, transverse and anteroposterior (AP) diameters of the foramen magnum and spinal canal. CT is a reliable diagnostic modality for the accurate assessment of the classical lines and angles, transverse and anteroposterior (AP) diameters of the foramen magnum and spinal canal. The skull-base lines namely Basion Axial interval(BAI), Dens height (DH), Basion Dens interval (BDI), Right Atlanto occipital interval(RAOI), Left Atlanto occipital interval(LAOI), Anterior Atlantodental interval (AADI), Posterior Atlantodental interval (PADI), Power Ratio(PR), McRae's lines (MR), Modified Ranawat distance (mRWD), and Redlund-Johnell distance (RLD), are the standard reference measurements used for the evaluation of basilar invagination, in defining anatomy of the CVJ, in pre- and post-operative assessment and follow-up of any CVJ pathology.

Our aim of the study is to provide an up-to-date overview of morphometric measurement of the skull baseline in the normal Nepalese population. This study will provide the "normal" baseline values for the Nepalese population.

Very few studies of CVJ are conducted so far in Nepal so this study was carried out to arrive at a reference value for different measurements and angles.

CVJ injuries of all types from trauma head injuries and road traffic accidents are increasing in number in Nepalese population but no definite reference value available.

This study will help to access CVJ pathologies like Basilar Invagination, platybasia dislocation and fracture in c1, c2, rheumatoid arthiritis, ostio arthiritis, cervical spondylosis.

Since this CVJ area is over crowded with many structures and inaccessible during clinical evaluation. It is important to study by crossectional imaging technology like MDCT. This data and results can be useful for radiologist, neueosergeons and spine sergeons (orthopedics). This study is important for occupational disease related with CV junction as well as sports injuries Methods

This was a quantitative, cross-sectional study conducted in the Department of Radiology and Imaging, Tribhuvan University and Teaching Hospital (TUTH) for the period of 4 months. Purposive sampling technique was used in sampling of the subjects. All the subjects who visited for CT scan of c-spine, Neck, carotid angiography without pathological findings related to spine were included in the study. Measurement was performed on sagittal and coronal sections.

Patients of both genders above age 18 years referred for CT scan of C- spine, Neck and Cerebral Angiography without pathological findings were included in the study. All measurements of distances and angles were done by electronic callipers in the CT console (Syngo via). In this study, different measurement were taken in sagittal MPR of CT of c-spine, Neck and Carotid angiography. The measured line and distance are;

Basion axial interval (BAI) is measured according to the method described by Haris et al as the distance between the basion and the rostral extension of the posterior cortical margin of the body of the axis.It is the distance between the basion and the posterior axial line PAL which is drawn along the posterior cortex id the body of the axis and extended cranially. It was measured in midsagittal plane.

Dens height (DH) is the distance from midway between the base of C2 end plate to the tip of the odontoid process.

Basion dens interval (BDI) is obtained by measuring the distance from the inferior most portion of the clivus to the closest point of the tip of the odontoid in the midsagittal plane.

Atlanto-occipital interval (AOI) is calculated by drawing the line perpendicular to the articular surfaces of the occipital condyle and the lateral mass of the C1 in sagittal plane.

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 (Figure 1A).

Power Ratio (PR) is calculated by the ratio of distance between the tip of the basion to the spinolaminar line of the atlas by the distance from the tip of the opisthion to the midpoint of the posterior aspect of the anterior arch of the C1.

McRae line (MR): It is a line drawn across the foramen magnum from the basion to the opisthion.

Redlund-Johnell method (RLJD): The perpendicular distance between the McGregor line and the midpoint of the caudal margin of the second cervical vertebra body is measured (Figure 1C).[5]

Modified Ranawat distance (mRWD) is the perpendicular distance midway between the base of C2 end plate and a line from the center of anterior arch of C1 to the center of the posterior arch.[53]

CT scan was performed on 128 slice MDCT scanner (Seimens Somatom Defination As+, TUTH Biomedical equipment no: 1001915) and data collection and measurement was done in Syngo Via workstation with resolution of 3 megapixel.

Statistical analysis was carried out with the help of SPSS version 26 (IBM, Version: 1.0.0.1406, Window OS, Free trial license) and Microsoft Excel version 2013 (64 bit OS). The quantitative value of BAI, DH, BDI, RAOI, LAOI, AADI, PADI, PR, MR, RLJD, mRWD were analyzed using Shapiro Wilk test for normal distribution. Data were presented as mean, range and SD for all variables. Patient's age, gender, BAI, DH, BDI, RAOI, LAOI, AADI, PADI, PR, MR, RLJD, mRWD were recorded. The tested quantitative data was analyzed using independent t-test, Mann-Whitney Test, Pearson's correlation and Spearman correlation.

3. Results

The data was collected from 153 subjects found to be normal in 87 males and 66 females with the age from 18 to 92 years old.

3.1. Distribution of patients with gender:

Table 1

3.2. Mean, SD, and range of total sample:

Table 2-4

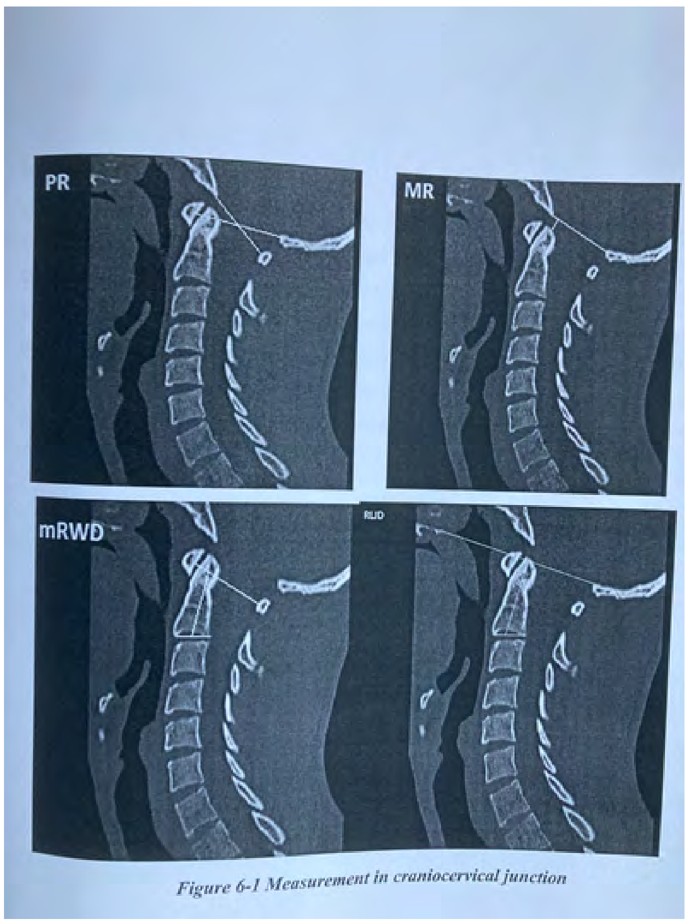

Figure 1: Measurement in craniocervical Junction

Table 1: Distribution of sample size according to gender

Gender	Frequency	Percent
Male	87	57.90%
Female	66	43.10%
Total	153	100%

Table 2: Mean, SD and range (minimum, maximum) of total sample

	Mean	SD	Minimum	Maximum
Age	48.61	18.69	18	92
BAI	0.561	0.226	0.09	1.13
DH	3.476	0.263	2.67	4.22
BDI	0.474	0.167	0.08	0.97
RAOI	0.139	0.024	0.1	0.23
LAOI	0.139	0.024	0.1	0.23
AADI	0.149	0.043	0	0.35
PADI	1.766	0.193	1.24	2.44
PR	0.699	0.083	0.43	0.89
MR	0.412	0.161	0.06	0.87
RLJD	3.483	0.438	1.69	4.62
mRWD	2.688	0.215	2.21	3.24

Table 3: Distribution of Range, Mean and SD with respect to male and female

	GENDER			
	Male		Female	
	Mean ± SD	Range	Mean ± SD	Range
BAI(cm)	0.499±0.210	1.030-0.090	0.642±0.220	1.130-0.240
DH(cm)	3.560±0.235	4.200-2.670	3.366±0.257	4.220-2.720
BDI(cm)	0.484±0.172	0.970-0.080	0.459±0.158	0.780-0.120
RAOI(cm)	0.144±0.022	0.190-0.100	0.130±0.023	0.230-0.100
LAOI(cm)	0.143±0.023	0.200-0.100	0.132±0.023	0.230-0.100
AADI(cm)	0.151±0.045	0.350-0.000	0.146±0.038	0.270-0.080
PADI(cm)	1.845±0.174	2.440-1.450	1.662±0.167	2.150-1.240
PR(cm)	0.685±0.081	0.890-0.430	0.716±0.081	0.880-0.520
MR(cm)	0.433±0.179	0.870-0.060	0.385±0.128	0.670-0.090
RLJD(cm)	3.611±0.402	4.620-2.640	3.315±0.428	4.260-1.690
mRWD(cm)	2.771±.192	3.240-2.240	2.577±0.191	2.980 -2.210

Table 4: Distribution of Mean, SD and Frequency with Age groups and parameters.

Age Group	N		BAI	DH	BDI	RAOI	LAOI	AADI	PADI	PR	MR	RLJD	MRWD
<27	24	Mean	0.6	3.39	0.53	0.13	0.13	0.17	1.74	0.69	0.45	3.55	2.7
		SD	0.21	0.291	0.13	0.026	0.025	0.041	0.185	0.087	0.107	0.419	0.232
28-37	26	Mean	0.526	3.422	0.503	0.136	0.138	0.148	1.744	0.69	0.428	3.467	2.65
		SD	0.228	0.234	0.153	0.022	0.024	0.036	0.155	0.095	0.181	0.568	0.184
38-47	27	Mean	0.593	3.482	0.42	0.132	0.134	0.15	1.77	0.7	0.369	3.44	2.7
		SD	0.233	0.228	0.115	0.017	0.018	0.048	0.183	0.084	0.148	0.501	0.269
48-57	25	Mean	0.56	3.549	0.482	0.142	0.139	0.147	1.797	0.687	0.437	3.583	2.75
		SD	0.252	0.174	0.15	0.021	0.022	0.028	0.179	0.062	0.114	0.255	0.118
58-67	21	Mean	0.53	3.48	0.485	0.129	0.133	0.141	1.754	0.719	0.431	3.41	2.657
		SD	0.241	0.236	0.23	0.019	0.019	0.032	0.201	0.081	0.214	0.425	0.251
68-77	21	Mean	0.53	3.48	0.485	0.129	0.133	0.141	1.754	0.71	0.431	3.41	2.65
		SD	0.241	0.236	0.23	0.019	0.019	0.032	0.201	0.081	0.214	0.425	0.251
78-87	8	Mean	0.509	3.464	0.479	0.141	0.138	0.132	1.79	0.694	0.423	3.43	2.657
		SD	0.169	0.37	0.159	0.021	0.025	0.04	0.191	0.074	0.153	0.44	0.209
>88	1	Mean	0.67	3.81	0.32	0.15	0.15	0.18	1.43	0.71	0.2	3.67	2.64
		SD	0	0	0	0	0	0	0	0	0	0	0

4. Discussion

It is recommended to measure from the sections of midline to accurately assess the contour of the posterior cortex, since BAI gives the erroneous results in the different sections of axis [41]. In their study, Rojas et al. measured the BAI as 3.4 cm in average with CT [41]. In our study, BAI was measured as 0.561cm. Our study shows the average BAI of 0.499 cm in male and 0.642 cm in female. We found that the average BAI interval was greater in female than male.

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. [57] Subluxation in the lower joints of cervical spine usually accompanies the instability in C1–C2. In our study, we found the average DH of 3.476cms±0.263 with minimum of 2.67cms and maximum height of DH as 4.22cms. Our study shows the average height of DH was 3.56cms in male and 3.366cms in female which suggest that normally DH is greater in male than in female.

The normal upper limit of BDI was reported as 12 mm in the literature [58, 59]. Gonzalez et al. published the average as 4.7 mm and the maximum as 9 mm [60]. Rojas et al. showed the maximum as 9.1 mm in 200 patients with the age of 20-40 years with CT, and up to 8.5 mm for >95% [41]. Balioglu et al. in their study found the median value of BDI as 4.9 mm and the maximum as 7.5 mm in the adolescent patients with congenital spine anomalies. In our study, we found that the average value of BDI as 0.474 cm and the maximum of 0.97 cm. We found our results consistent with the normal values reported in the literature. Additionally, in our study we found the average BDI of 0.484 cm in male and average of 0.459 cm in female. Average BAI interval was found greater in male than in female.

Power ratio was shown as <0.9 mm for more than 95 % of normal population [61]. Balioglu et al., in their study found the power ratio as 0.76. In our study, we found the power ratio in our patients as 0.699 which is compatible with the normal values in the literature.

The normal values for AOI in 95 % of the adults were reported as 1 mm in average (0.6-1.4 mm) with CT [41]. Balioglu et al., in their study found the median value of AOI measured with CT was found as 1.2 mm (0-2.8 mm). In our study, the average value of RAOI and LAOI measured with CT was found as 0.139cm in both with range of 0.10-0.23 cm.

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 [62], and AADI > 8 mm is an indication for surgical treatment. [63] Ranabhat et al in their study they found that the 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. In our study, AADI was calculated to be 0.149±0.043cms with minimum distance of 0.00cm to maximum distance of 0.23cms.

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. [63] Ranabhat et al in their study they found that the 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. In our study, PADI was calculated to be 1.766±0.193cms with minimum distance of 1.24cm to maximum distance of 2.44cms.

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. [64] 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. [65] 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. [52] 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. [57]

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.[64, 66] However, different thresholds, such as 2 or 5 mm above the line, have been proposed for diagnosis of this condition.[67,66] 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. [68] 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. [69, 70]

The McRae line is a line drawn on a lateral radiograph of the skull or on a sagittal cut from a CT or MRI scan that connects the posterior (opisthion) and anterior (basion) aspects of the foramen magnum [71]. The tip of the dens (or odontoid process) should be ~5 mm below this line. If it is above this line it is concerning for a possible basilar invagination. The MR line in our study shows an average of 0.412 cms with a maximum of 0.87 cms.

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.[64, 65] 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. [72] 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. [53] In our study, modified RW distance was calculated to be 2.688±0.215cms with minimum distance of 2.21cm to maximum distance of 3 cm. 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. [52] In our study, Redlund Johnell distance was calculated to be 3.483±0.438cms with minimum distance of 2.21cms to maximum distance of 4 cm.

Data were distributed to age groups and the mean and SD of each age groups were found. As there was only one individual in the age group higher than 88 years, the SD was 0 (the value of SD will only be greater than 0, if there are variables greater than 1).

5. Conclusion

We generated our results on normal craniometrical values obtained from Computed tomography in 153 asymptomatic Nepalese individuals. The multiplanner reconstruction of the CT image is very useful for evaluation of Craniovertebral junction. These data will be important for Neurosurgeon and Spine surgeon (Orthopedics) for clinical purpose when evaluating CVJ malformation. MDCT is very valuable to access the bony CVJ.

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