

# Evaluation of Cranio-Cervical Junction on Multidetector Computed Tomography

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## ABSTRACT

**Background and purpose:** 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 aimed to derive a range of various measurements in craniovertebral junction area.

**Materials and methods:** This retrospective cross-sectional study was performed at the Department of Radiology and Imaging, Tribhuvan University Teaching Hospital, Maharajgunj, Kathmandu, Nepal. Data were collected over the period of January to April 2021 with total of 153 patients who underwent CT scan of C- spine, Neck and Carotid angiography without having any pathological findings related to craniocervical junction. The measurement was done at mid sagittal section in MPR. Various parameters like patient's age, gender, Basion-Axial interval (BAI), Dens Height (DH), Basion Dens interval (BDI), Right and Left Atlanto-axial interval (RLAOI), Anterior and Posterior Atlantodental interval (A/PADI), Power Ratio (PR), McRae line (MR), Redlund-Jonhel Distance (RLD) and modified Ranawat line (mRWD) were measured.

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

**Conclusion:** 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.

**Keywords:** CT Scan, Craniocervical junction (CVJ), Distance

## INTRODUCTION

The craniocervical junction (CCJ) is an osteoligament complex between the atlas and axis vertebrae and should be considered anatomically and radiologically as a distinct entity from both the cranium and the

cervical spine<sup>1</sup>. It is composed of bony structures articulated with synovial joints, intrinsic ligaments and membranes and muscles. It provides housing of the spinal cord and multiple cranial nerves, it also consists a critical vasculature supplying

both the brain and the cervical spinal cord parenchyma<sup>1</sup>. The injury to the craniocervical junction can result in morbidity and mortality. The craniocervical junction not only house, protect and support structures within it but also provide significant mobility<sup>2</sup>.

The craniocervical junction can be evaluated by X-ray, CT and MRI<sup>3</sup>. 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<sup>4</sup>. CT scan can provide good spatial resolution combined with speed and ability to perform high-quality multiplanar imaging (MPR)<sup>4</sup>. The details of the anatomy relating to bones by CT are superior to that plain X-ray and MRI studies<sup>3</sup>. CT is the preferred imaging modality for the accurate assessment of the classical lines and angles, transverse and anteroposterior (AP) diameters of the foramen magnum and spinal canal<sup>(3,4)</sup>. 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 and craniocervical instability, in defining anatomy of the CVJ, in pre- and post-operative assessment and follow-up of any CVJ pathology<sup>(3,4)</sup>.

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 are very minimal researches done in craniometric relationship and measurement of the craniocervical

junction in Nepalese population. This study performed craniometrical evaluation of the CVJ in 153 Nepalese populations without known CVJ anomalies based on measurements obtained from CT scans to establish the normal range of their measurements in the Nepalese population. 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.

## **MATERIALS & METHODS**

This was a quantitative, cross-sectional study conducted at 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 MPR.

Patients of both genders above age 18 years referred for CT scan of C- spine, Neck and Carotid angiography without pathological findings were included in the study. Patient with a CVJ malformation, congenital anomaly, Chiari Malformations, Basilar Invagination, rheumatoid arthritis, spondyloarthropathies or upper cervical spine trauma were excluded.

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

### **Method of measurement:**

In this study, different measurements were taken in sagittal MPR of CT of c-spine, Neck and Carotid angiography. The measured line and distance are measured according to the method described by Haris et al<sup>5</sup>.

**Basion axial interval (BAI)** is measured 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 of 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.

**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.

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.

### STATISTICAL ANALYSIS

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 was 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 wherever applicable.

### RESULT

The data was collected from 153 subjects. Among them, 87 (57.9%) were males and 66 (43.1%) were females with the age from 18 to 92 years old.

Table-1: Mean, SD and range (minimum, maximum) of total sample

	Mean	SD	Minimum	Maximum
Age	48.61	18.690	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	0.10	0.23
LAOI	0.139	0.024	0.10	0.23
AADI	0.149	0.043	0.00	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

The measurement of craniocervical junction in computed tomography revealed mean Basion axial interval was  $0.561 \pm 0.226$  cm with minimum interval of 0.09 cms and maximum interval of 1.13 cms. Mean DH was  $3.477 \pm 0.263$  cm with minimum height of 2.67 cm and maximum height of 4.22 cm. Mean BDI was  $0.474 \pm 0.167$ cm with minimum interval of 0.08 cm and maximum interval of 0.97 cm .Mean RAOI was  $0.139 \pm 0.233$  cm with minimum interval of 0.1 cm and maximum interval of 0.23 cm. Mean LAOI was  $0.139 \pm 0.238$ cms with the range of 0.1 cm to 0.23 cm. While measuring the AADI, mean AADI was  $0.149 \pm 0.422$  cm with the range of of 0.00

cm to 0.35cm. Mean PADI was  $1.767 \pm 0.194$  cms with minimum measurement of 1.24 c and maximum of 2.44 cm. Mean PR was  $0.699 \pm 0.083$  cm with the minimum of 0.43 and the maximum of 0.89 cm. While measuring the distance from the tip of the odontoid to McRae’s line, mean were  $0.412 \pm 0.161$ cms while the minimum distance was 0.06cms and maximum distance of 0.87cms. Mean RLJD was calculated to be  $3.484 \pm 0.438$  cms with minimum distance of 1.69 cms to maximum distance of 4.62 cms. Similarly, mean of mRWD was found to be  $2.688 \pm 0.215$ cm with minimum distance of 2.21 cms to maximum distance of 3.24cms. (Table-1).

**Table-2: Distribution of Range, Mean and SD with respect to male and female**

	Male		Female	
	Mean $\pm$ SD	Range	Mean $\pm$ SD	Range
BAI (cm)	$0.499 \pm 0.210$	1.030 -0.090	$0.642 \pm 0.220$	1.130-0.24
DH(cm)	$3.560 \pm 0.235$	4.200-2.670	$3.366 \pm 0.257$	4.220-2.72
BDI(cm)	$0.484 \pm 0.172$	0.970-0.080	$0.459 \pm 0.158$	0.780-0.12
RAOI(cm)	$0.144 \pm 0.022$	0.190-0.100	$0.130 \pm 0.023$	0.230-0.10
LAOI(cm)	$0.143 \pm 0.023$	0.200-0.100	$0.132 \pm 0.023$	0.230-0.10
AADI(cm)	$0.151 \pm 0.045$	0.350-0.000	$0.146 \pm 0.038$	0.270-0.08
PADI(cm)	$1.845 \pm 0.174$	2.440-1.450	$1.662 \pm 0.167$	2.150-1.24
PR(cm)	$0.685 \pm 0.081$	0.890-0.430	$0.716 \pm 0.081$	0.880-0.52
MR(cm)	$0.433 \pm 0.179$	0.870-0.060	$0.385 \pm 0.128$	0.670-0.09
RLJD(cm)	$3.611 \pm 0.402$	4.620-2.640	$3.315 \pm 0.428$	4.26-1.69
mRWD(cm)	$2.771 \pm 0.192$	3.240-2.240	$2.577 \pm 0.191$	2.980 -2.21

The mean value of BAI of females was found to be  $0.642 \pm 0.220$  cm with maximum 1.13 cm and minimum 0.24 cm. The mean value of DH of females was found to be  $3.366 \pm 0.257$  cm with maximum 4.22 cm and minimum 2.72 cm. The mean value of BDI of females was found to be  $0.459 \pm 0.159$  cm with maximum 0.78 cm and minimum 0.12cm. The mean value of RAOI of females was  $0.131 \pm 0.0278$  cm with maximum 0.23 cm and minimum 0.10 cm. The mean value of LAOI of females was  $0.133 \pm 0.0231$  cm with maximum 0.1 cm and minimum 0.23 cm. The mean value of AADI of females was found to be  $0.146 \pm 0.0384$  cm with maximum 0.27 cm and minimum 0.08 cm [Table-2]. The mean value of PADI of females was  $1.663 \pm 0.168$ cm with maximum 2.15 cm and minimum 1.24 cm. The mean value of PR of females was found to be  $0.716 \pm 0.0806$  cm with maximum 0.88 cm and minimum 0.52

cm. The mean value of MR of females was found to be  $0.385 \pm 0.128$ cm with maximum 0.67 cm and minimum 0.09 cm. The mean values of RLJD of females were found to be  $3.316 \pm 0.428$ cm with maximum 4.26 cm and minimum 1.69 cm. The mean value of mRWD of females was  $2.578 \pm 0.192$  cm with maximum 2.98 cm and minimum 2.21 cm.

The mean value of BAI in males was  $0.499 \pm 0.211$ cm with maximum 1.03 cm and minimum 0.09 cm. The mean value of DH of males was found to be  $3.561 \pm 0.235$  cm with maximum 4.20 cm and minimum 2.67 cm. The mean value of BDI of males was  $0.485 \pm 0.174$  cm with maximum 0.97 cm and minimum 0.08 cm. The mean values of RAOI of males were found to be  $0.145 \pm 0.023$  cm with maximum 0.19 cm and minimum 0.1 cm. The mean value of LAOI of males was found to be  $0.144 \pm 0.0235$ cm with maximum 0.20 cm and

minimum 0.1 cm. The mean value of AADI of males was  $0.151 \pm 0.045$  cm with maximum 0.35 cm and minimum 0.00 cm. The mean value of PADI of males was found to be  $1.846 \pm 0.174$  cm with maximum 2.44 cm and minimum 1.45 cm. The mean value of PR of males was  $0.686 \pm 0.082$  cm with maximum 0.89 cm and minimum 0.43 cm. The mean value of MR of males was found to be  $0.433 \pm 0.179$  cm with maximum 0.87 cm and minimum 0.06 cm. The mean values of RLJD of males were found to be  $3.612 \pm 0.403$  cm with maximum 4.62 cm and minimum 2.64 cm. The mean value of mRWD of males was  $2.772 \pm 0.193$  cm with maximum 3.24 cm and minimum 2.24 cm. (Table-2)

Statistically significant difference was found between BAI, DH, RAOI, LAOI, PADI, RLJD, mRWD in gender ( $p < 0.05$ ) and no statistically significant difference were observed between BDI, AADI, PR, MR in gender. ( $p > 0.05$ ). There was negligible negative correlation between age and BAI ( $r = -0.053$ ) which is statistically insignificant at  $p < 0.05$  ( $p = 0.512$ ). There is negligible positive correlation between age and DH ( $r = -0.173$ ) which is statistically significant at  $p < 0.05$  ( $p = 0.032$ ). The correlation between age and BDI ( $r = -0.188$ ,  $p = 0.20$ ), between age and RAOI ( $r = 0.095$ ,  $p = 0.243$ ), between age and LAOI ( $r = 0.09$ ,  $p = 0.260$ ), age and PADI ( $r = 0.034$ ,  $p = 0.42$ ), between age and PR ( $r = 0.066$ ,  $p = 0.421$ ), between age and MR ( $r = -0.135$ ,  $p = 0.096$ ), age and RLJD ( $r = -0.073$ ,  $p = 0.369$ ) and between age and mRWD ( $r = -0.06$ ,  $p = 0.464$ ) were statistically insignificant at  $p < 0.05$ . There is negligible negative correlation between age and AADI ( $r = -0.264$ ) which is statistically significant at  $p < 0.05$  ( $p = 0.001$ )

## DISCUSSION

Our study was done to provide comprehensive overview of morphometric measurement of the CVJ in the normal Nepalese population. Štulík et al performed the study and they found mean DH of 3.59 cm in male and 3.342 cm in female.<sup>[6]</sup> In our

study, we found the mean DH of  $3.476 \pm 0.263$  cms with minimum of 2.67 cms and maximum height of DH as 4.22 cms. Our study shows the mean height of DH was 3.56 cms in male and 3.366 cms in female which shows that, DH is greater in male than in female. We found our data consistent with study by Stulik et al.<sup>[6]</sup> The study done by Rojas et al shows that mean BAI of 0.34 cm in CT.<sup>[7]</sup> In our study, BAI was measured as 0.561 cm. Our study shows the mean BAI of 0.499 cm in male and 0.642 cm in female. We found that the mean Basion Axial Interval was greater in female than male. The normal upper limit of BDI was reported as 1.2 cm in the literature<sup>[5,8]</sup>. Gonzalez et al. published the mean BDI as 0.47 cm with maximum of 0.9 cm<sup>[9]</sup>. Rojas et al. showed the maximum as 0.91 cm in 200 patients with the age of 20-40 years with CT, and up to 0.85 cm for  $>95\%$ <sup>[7]</sup>. In our study, we found that the mean 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 mean BDI of 0.484 cm in male and 0.459 cm in female. Average BAI interval was found greater in male than in female.

Power ratio was shown as  $< 0.9$  for more than 95 % of normal population.<sup>[10]</sup> In our study, power ratio was 0.699 with maximum of 0.88 and minimum of 0.52. Our data was found consistent with it. The normal values for AOI in 95 % of the adults were reported as 0.1 cm in average (0.06-0.14 cm) with CT<sup>[7]</sup>. In our study, the mean value of RAOI and LAOI measured with CT was found 0.139 cm in both with range of 0.10-0.23 cm (Table 7-1).

When evaluating plain radiographs for cervical instability, several measurements can be made to assess 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. Some authors consider that AADI  $> 0.5$  cm is a sign of clinically significant AAS instability and AADI  $> 0.8$  cm is an indication for

surgical treatment [11]. In the study performed by Ozdogan et al [12], mean ADI was found as 0.147 cm in males and 0.151 cm in females with CT in the study of 50 males and 50 females. Ranabhat et al found that the mean of  $0.183 \pm 0.047$  cm with minimum distance of 0.1 cm to maximum distance of 0.35 cm. [13] In our study, the mean AADI measurement was  $0.149 \pm 0.043$  cm, and similarly mean RAOI in male and female was found to be 0.144 cms and 0.130 respectively. Similarly, LAOI in male and female was found to be 0.143 cms and 0.132 cms respectively (Table-2). We found our data compatible with that of the literature. Posterior atlantodental interval is the interval between the dens and posterior arch of first cervical vertebra. Ranabhat et al found the PADI of  $1.772 \pm 0.021$  cms with minimum distance of 1.41 cm to maximum distance of 2.55 cms. [13] In our study, PADI was calculated to be  $1.766 \pm 0.193$  cms with minimum distance of 1.24 cm to maximum distance of 2.44 cms. Our data was found to be consistent with the study by Ranabhat et al. [13] This might be because of the similar population of both the study i.e. in Nepalese population.

The McRae line is a line that connects the posterior (opisthion) and anterior (basion) aspects of the foramen magnum. [14] The tip of the dens (or odontoid process) should be ~0.5 cm below this line, if it is above this line it is concerning for a possible BI. Chinmaya Dash et al, in their study the mean McRae line measurement was 0.511 cm. [15] Hercules et al shows the mean McRae line of 0.533 cm. [16] The MR line in our study shows an average of 0.412 cm with a maximum of 0.87 cm. Our data was found consistent with that of previous literatures. [15-16] Based on the work by Riew et al. [17] the presence of CS is best evaluated using a combination of the Clark station, Modified/Ranawat criterion, and the Redlund-Johnell criterion. [18,19] When at least one of these measures is positive, the sensitivity for detecting CS is 94% with a negative predictive value of 91%. [17] 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 1.3 cm in women and 1.5 cm in men are assumed to be correct. [19] Ranabhat et al found mean mRWD of 2.443 cms. [13] In our study, modified RWD was calculated to be  $2.688 \pm 0.215$  cms with minimum distance of 2.21 cm to maximum distance of 3 cm. In male, we found mean mRWD as  $2.771 \pm 0.193$  cms and in female it was  $2.578 \pm 0.192$  cms. We found our data consistent to that of other literature.

McGregorline connects the hard palate with the most caudal point of the occipital curve. Redlund-Johnell criterion is the distance between the centre of the lower end plate of C2 to the McGregor's line. The distance of 3.4 cm in men and 2.9 cm or more in women is considered normal. [18] Ranabhat et al measured RLJD of 3.15 cms. In our study, Redlund-Johnell distance was found to be  $3.483 \pm 0.438$  cms. We found our data consistent to that of the study by Ranabhat et al. [13]

Statistically significant difference was found between BAI, DH, RAOI, LAOI, PADI, RLJD, mRWD in gender ( $p < 0.05$ ) and no statistically significant difference were observed between BDI, AADI, PR, MR in gender. ( $p > 0.05$ ). The correlation between age and BAI (age and BDI ( $r = -0.188$ ,  $p = 0.20$ ), between age and RAOI ( $r = 0.095$ ,  $p = 0.243$ ), between age and LAOI ( $r = 0.09$ ,  $p = 0.260$ ), age and PADI ( $r = 0.034$ ,  $p = 0.42$ ), between age and PR ( $r = 0.066$ ,  $p = 0.421$ ), between age and MR ( $r = -0.135$ ,  $p = 0.096$ ), age and RLJD ( $r = -0.073$ ,  $p = 0.369$ ) and between age and mRWD ( $r = -0.06$ ,  $p = 0.464$ ) were statistically insignificant at  $p < 0.05$ . There is weak negative correlation between age and AADI ( $r = -0.264$ ,  $p = 0.001$ ) and between age and DH ( $r = -0.173$ ,  $p = 0.032$ ) which is statistically significant at  $p < 0.05$  ( $p = 0.001$ ).

Knowing the distance between each of the anatomical structure of the craniocervical junction can be necessary for the treatment and follow-up of adolescent cases. As our aim of study was to show the morphometric measurement of normal craniocervical junction. Further, large sample size and multi-centric studies involving the even patients with spinal deformities are recommended to actually differentiate normal from abnormal values.

## CONCLUSION

The study provides an insight on normal craniometrical values obtained from Computed tomography in 153 asymptomatic Nepalese individuals. The multiplanar reconstruction of the CT image is very useful for evaluation of Craniocervical junction. These data will be important for Radiologist, Neurosurgeon and Spine surgeon for clinical management when evaluating CVJ malformation

## Declaration by Authors

**Ethical Approval:** Approved

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