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Evaluation of the Normal Craniocervical Junction Craniometry in 137 Asymptomatic Patients

Evaluación de la Craneometría de la Unión Craneocervical Normal en 137 Pacientes Asintomáticos

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SUMMARY: To our best knowledge, most of the craniometric studies on the normal craniocervical junction (CCJ), are still poorly studied and based on measurements taken from plain radiographs. In this study, the authors conducted a craniometric evaluation of the CCJ in a population without known CCJ abnormalities. The purpose of the study was to assess the normal CCJ craniometry based on measures obtained from CT scans. The authors examined 137 consecutive CCJ CT scans obtained in patients evaluated at their hospital for treatment of non-CCJ conditions between 2018 and 2019. Twelve craniometrical dimensions were conducted, including the relation of the odontoid with the cranial base, the atlantodental interval (ADI), the clivus length, and the clivus-canal angle (CCA).

KEY WORDS: CT scan; Craniocervical junction; Craniometry; Normal, Relationship.

INTRODUCTION

The Craniocervical junction (CCJ) is a complex transitional zone. It comprises a complex balance between the different elements of the cranium and the spine. Some authors suggest that the CCJ should be distinct anatomically and radiologically from the cranium and, particularly, the cervical spine (Offiah & Day, 2017). Besides housing the spinal cord and the lower cranial nerves, it is approximated by major vasculature supplying the brain and the spinal cord. Accordingly, anatomical and radiological assessment of this complex junction is paramount to understanding and treating different pathologies affecting this region (Batista *et al*., 2015).

The normal craniometric relationships of the CCJ are meaningful but poorly studied yet. They are also based on measurements taken from plain radiographs where bone structures are superimposed, McRae & Barnum (1953). Moreover, most of what we know about these relationships are based on studies performed on patients with congenital malformations and/or basilar invagination (Botelho & Ferreira, 2013).

Accurate measurements of the normal CCJ craniometry relationships based on normal CT studies can be helpful in the diagnosis and management of pathologies that might affect this region. For instance, basilar invagination is a radiological diagnosis. Diagnosis is made when the tip of the odontoid process is located above the Chamberlain's line (Smoker, 1994). However, the authors have not agreed on one diagnostic criterion, a 2 mm and a 5 mm of the tip measured above the line have been proposed for diagnosing this condition (Goel, 2009).

Considering the above, we performed a craniometric evaluation of the CCJ, based on 3D CT parameters of the CCJ in 137 asymptomatic individuals.

MATERIAL AND METHOD

We obtained formal ethics approval from the institutional Board Review committee to evaluate the CT

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scans of 137 adult patients (64 M and 73 F). Scans were taken between November 2018 and December 2019. We included patients with a history of trauma only if the scan was normal and if the patient had not undergone further spinal imaging. We also included patients who underwent CT scans to assess cervical radiculopathy or myelopathy.

We excluded patients if:

*The scans were done as an investigation for CCJ malformation.
* There was a history suggestive of CCJ injury or pathological conditions.
* They were known to have a facial or spinal abnormality.
* The scans were not sufficient for the proposed measurements.

CT scan measurements. Measurements were performed by two researchers (A consultant neurosurgeon and a senior neurosurgery resident) on a dedication workstation and performed measurements using an electrical caliber. The studies were obtained on a 16 row multidetector CT (MDCT) scanner (Philips brilliance). The dose protocol used consisted of 102 kVp and 25-75 MAs. Images obtained were reconstructed into 1-mm-thick CT images and analyzed on a preset bone window setting: width of 2500 HU and length of 350 HU.

We obtained the following measurements:

1) Chamberlain line (Riew *et al*., 2001): A line from the back of the hard palate in the midsagittal plane to the opisthion. The length was measured and recorded (Fig. 1.A).
2) The distance from the tip of the odontoid to the Chamberlain line. A perpendicular line was drawn from the tip of the odontoid to the Chamberlain line in the midsagittal plane. The length was measured and recorded, as well as whether the odontoid tip was above or below the Chamberlain line (Kaneko *et al*., 1965; Kwong et el., 2011) (Fig. 1.B).
3) The Atlanto-dental interval (ADI). A line was drawn from the posterior cortex of the anterior arc of the atlas in the midsagittal plane to the anterior cortex of the odontoid process. The length was measured and recorded (Batista *et al*., 2015) (Fig. 2.A).
4) McRae line. The length of the line from the basion and the opisthion in the midsagittal plane was measured and recorded (Mcrae & Barnum, 1953) (Fig. 1.A).

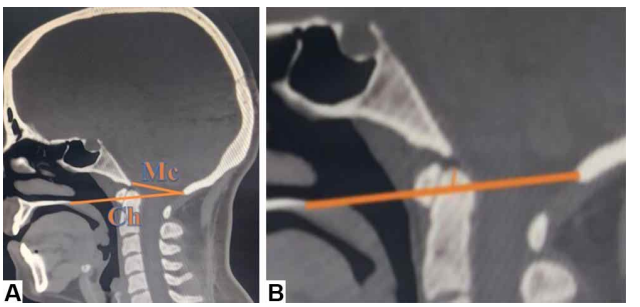

Fig. 1. A) McRae line (Mc) : extends from basion to opisthion. Chamberlain line (Ch): extends from hard palate to opisthion. B) distance from odontoid tip to Chamberlain line.

5) Redlund-Johnell method. In the midsagittal plane, marking the midpoint of the base of C2 was obtained. Then, the minimum distance between that point and the McGreger line was measured and recorded (Redlund-Johnell & Pettersson, 1984). McGreger line was defined and a line connecting the posterior hard palate to the lowest point on the midsagittal occipital curve (McGreger, 1948) (Fig. 2.B).
6) Modified Ranawat method. In the midsagittal plane, a line from the center of the anterior arc to the center of the posterior arc of C1 was obtained. The distance from the midpoint of C2 base till the before mentioned line was measured (Kwong *et al*., 2011) (Fig. 2.C).
7) The greatest anteroposterior (AP) and latero-lateral (LL) diameters of the foramen magnum (FM) were measured and recorded (Chethan *et al*., 2012) (Figs. 3A.B).

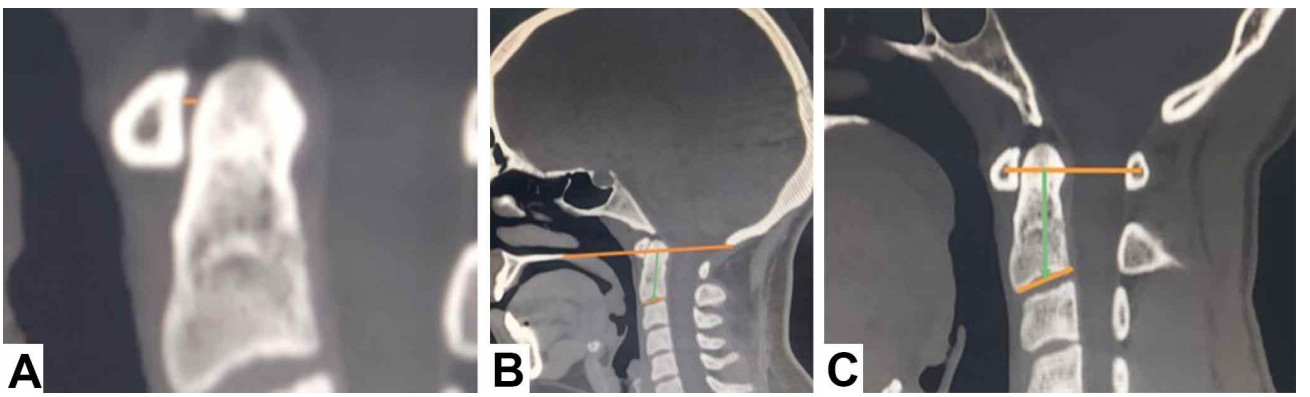

Fig. 2. A) Atlanto-dental Interval. B) Redlund-Johnell method.C) Modified Ranawat method.

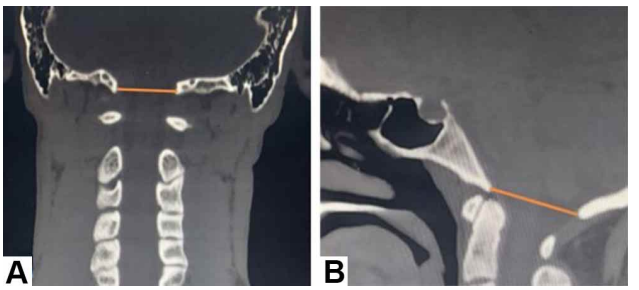

Fig. 3. The greatest diameters of the foramen magnum A) Anterio-posterior.B) Laterio-lateral..

8) The height of the C-1 lateral masses (right and left) on sagittal plane. A line drawn from the midpoint of the superior articular surface of C1 lateral mass to the midpoint of its inferior articular surface on both sides was measured and recorded (De Carvalho *et al*., 2009) (Fig. 4.A).
9) The height of the right and left occipital condyles (OC) on sagittal plane. A line drawn from the midpoint of the superior articular surface of the occipital condyle to the midpoint of its inferior articular surface of both sides was measured and recorded (Batista *et al*., 2015) (Fig. 4.B).
10) The clivus length. A line was drawn in the midsagittal plane between the top of the dorsum sellae and the basion. The distance was measured and recorded (Dufton *et al*., 2011) (Fig. 5.A).

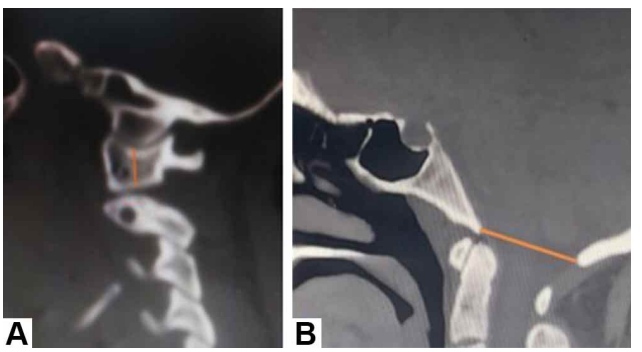

Fig. 4. A) height of C1 lateral mass. B) height of occipital condyle.

11) The Clivus-Canal angle (CCA). An angle formed by a line extending from the inferior one-third of the clivus and a line extending from the infereo-dorsal portion of the C-2 body to the supereo-dorsal part of the dens (Botelho & Ferreira, 2013) (Fig. 5.B).
12) The Basal angle. An angle formed by an intersection of the line from the nasion to the dorsum sellae and a line from the dorsum sellae to the basion was measured and recorded (Koenigsberg *et al*., 2005; Botelho & Ferreira, 2013) (Fig. 5.C).

Results of all these measurements are presented in detail with descriptive statistics. The mean, median, range, and standard deviation for each variable were calculated. The normal range was defined as the values within 2 standard deviations of the mean (± 2 SD), representing approximately 95 % of patients in a normal distribution. The values of both genders were compared using the independent sample t test. We divided our sample into four age groups: 5-18 years (n=8), 19- 44 (n=58), 45-64 (n=58), and 65-84 (n=13). The results were considered statistically significant when the P value was less than 0.05.

RESULTS

The craniometric measurements were obtained in 137 asymptomatic patients with an average age of 43 years (SD 18.74, Median 47 years, and range 5–84 years). Most patients were in the 19-44 and 45-64 age groups (n=58, 42 % for each group). Eight patients (6 %) were below 18 years, and thirteen (10 %) were above 65. Slightly more than half of the patients were females (n=73), representing (53.2 %).

Chamberlain line. Was found to be, on average, 79.6 mm in length (Table I). There was no significant difference between males and female (average 82.6 and 76 mm,

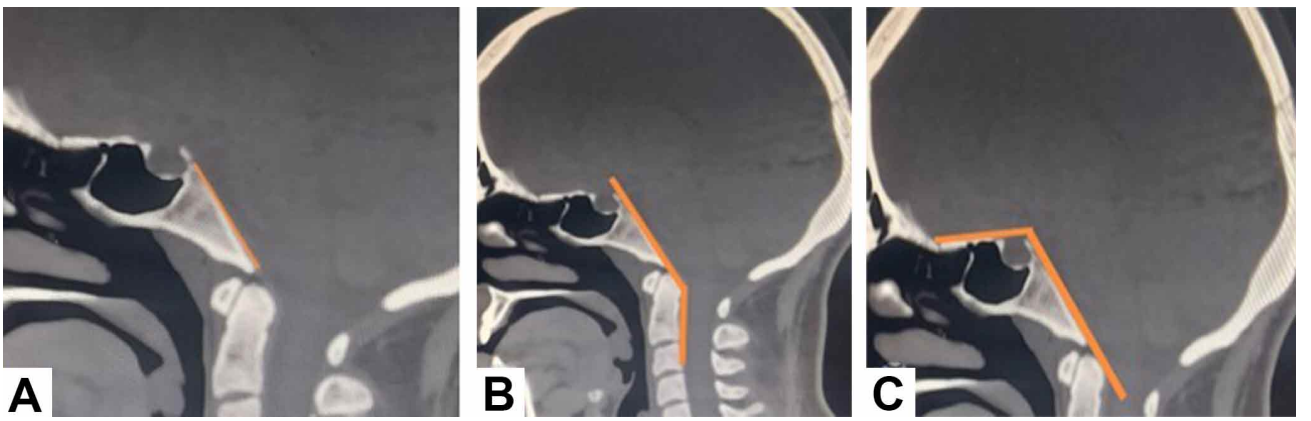

Fig. 5. A) clivus length. B) Clivus-canal angle. C) Basal angle.

respectively) (Table II).

McRae line. The average length of McRae's line was 35.5 mm (Table I). There was no significant difference between males and females (average 36.82 and 34.26 mm, respectively) (Table II).

The Atlanto-dental interval (ADI). The mean ADI was 1.45 mm. Normal ranges are 0.47 – 2.42 mm. None of the 137 patients had an ADI of more than 2.8 mm. Males have significantly higher values than females (P value 0.04) (Table II). The fourth age group (65-84 years) has the smallest ADI, while the first (5-18 years) has the highest.

Distance from the tip of the odontoid to the Chamberlain line (Above or below): Of our study population. the odontoid tip was above CL in 14 % of our patients (n=29), 84 % have their tip below (n=101), and 2 % (n=7) at the same level (Table I).

In patients who's the odontoid tip was above CL, the average was 2.6 mm. Only one patient has a distance of more than 6.6 mm (Table I), which is proposed to be the cutoff point for the diagnosis of Basilar Invagination (Smoker, 1994; Goel, 2009). In patients who's the odontoid tip was below CL, the average was 3.48 mm. the highest value was 8.5 mm below the line. The normal range is 8.5 mm below and 4.47 above the line (Table I).

Redlund-Johnell method. The average is 35.5 mm, with a normal range of (25.9 – 45.1) mm. The average is higher in males than in females (Table II).

Modified Ranawat method. The average is 26.9 mm. There is a statistically significant difference between males and females (28.5 and 25.5, respectively) (P value 0.039) (Table II).

The anteroposterior (AP) and Latereo-lateral (LL) diameters of the foramen magnum (FM). The average latero-lateral diameter is 30.3 mm, with a normal range of 24.8 and 38.8 mm. The average AP diameter is 36 mm. Males have significantly wider LL diameter than females (P value= 0.019) (Table II).

The height of C-1 lateral masses (Right and left). All participants have the same average height of C-1 lateral masses on both sides (11 mm). Males have higher heights and a broader range than females (P value < 0.005) (Tables I and II).

Occipital condyle (OC) height (Right and left). The average right and left occipital condyle heights are similar (10.6 and 10.5 mm, respectively. Males have higher measurements than females (P value < 0.05) (Table II).

Clivus length. Our sample's average values of clivus length lie within the normal range. It ranges between (28.7 – 48.5) mms (Table I). Males have significantly higher values than females (P value = 0.023) (Table II).

Clivus canal angle (CCA). The normal range of this angle is between 139° and 178° (Table I). There was no significant difference between males and females.

Basal angle (BA). The normal range of the basal angle in our sample was (100°-144°). It was (104°-134°) and (99°-151°) for females and males, respectively. Notably, the females' numbers are more closely related than males. (Table II).

Table I. General description of craniocervical measurements performed in 137 individuals using 3D CT reconstruction.

Measurement	Average	median	SD	Range	Normal range*
Chamberlain line	79.62	79	5.35	(68.9 – 92.7)	(68.55 – 89.96)
McRae line	35.46	35.70	3.03	(27.9 – 44.7)	(29.4 – 41.52)
The atlantodental interval (ADI) (mm)	1.45	1.4	0.49	(0.0 – 2.8)	(0.47 – 2.42)
Distance from the tip of the odontoid to Chamberlain line	- 2.02 (below)	-2.10 (below)	3.24	(- 8.5 to 11.1)	(-8.50 – 4.47)
Redlund-Johnell method	35.48	35.9	4.8	(18.7 – 47.9)	(25.88 – 45.08)
Modified Ranawat method	26.92	26.60	3.57	(16.0 – 39.3)	(19.77 – 34.06)
The anteroposterior diameters FM	36.04	35.9	2.84	(29.2 – 45.5)	(30.35 – 41.72)
The latero-lateral diameters of FM	30.32	30	2.76	(22.8 – 39.3)	(24.8 – 35.84)
C1 LM ht. (right)	11.01	10.7	1.66	(6.5 – 19.7)	(7.69 – 14.33)
C1 LM ht. (left)	11.02	10.9	1.87	(7.0 – 18.3)	(7.46 – 14.59)
OC ht. (right)	10.67	10.25	1.89	(7.2 - 22)	(6.89 – 14.4)
OC ht. (left)	10.56	10.4	1.61	(7 – 17.7)	(7.33 – 13.79)
Clivus length (mm)	38.63	37.9	4.94	(18.1 - 51.2)	(28.75 – 48.5)
CCA	158.57°	158.75°	9.9	(131.5° - 191.6°)	(138.7°-178.5°)
Basal angles	122.27°	122.08°	11	(102.6° - 191.5°)	(100.2°-144.2°)

*Values within 2 standard deviations (± 2 SD) of the average

Table II. Comparison of craniocervical measurements between males and females.

	Mean	Median	Range	Normal range*	*P value* Sex difference
Chamberlain line	79.62	97	68.9-92.7	68.55-89.96	
Female	76.68	76	68.9-86.8	68.09-85.26	0.54
Male	82.2	82.6	71.1-92.7	72.36-92.05	
McRae line	35.46	35.7	27.9-44.7	29.4-41.52	
Female	34.26	34.4	27.9-40.3	28.73-39.8	0.54
Male	36.82	37.05	29.5-44.7	31.34-42.3	
ADI	1.45	1.4	0-2.8	0.47-2.42	
Female	1.34	1.35	0.5-2.30	0.53-2.15	0.04#
Male	1.57	1.6	0-2.8	0.48-2.66	
Distance from tip of odontoid process to Chamberlain line (mm)	-2.02	-2.1	8.5 below to 11.1 above	8.5 below to 4.47 above	
Female	-1.45	-1.6	6.9 below to 11.1 above	7.87 below to 4.96 above	0.74
Male	-2.66	-3	8.5 below to 6.3 above	9.02 below to 3.71 above	
Redlund-Johnell method	35.48	35.9	18.7-47.9	25.88-45.08	
Female	33.35	33.5	18.7-45.3	25.14-41.55	0.71
Male	37.85	37.9	23.6-47.9	29.02-46.67	
Modified Rawat method	26.92	26.6	16-39.9	19.77-34.06	
Female	25.52	25.5	17-39.3	19.69-31.34	0.039#
Male	28.49	28.45	16-38.1	21.27-35.71	
Anteroposterior diameter of FM (mm)	36.04	35.9	29.2-45.5	30.35-41.72	
Female	35.05	35.2	29.2-41.1	30.15-39.95	0.32
Male	37.15	37.7	29.7-45.5	31.43-42.86	
Latero-lateral diameter of FM (mm)	30.32	30	22.8-39.3	24.8-38.84	
Female	29.11	29.1	22.8-32.9	25.07-33.15	0.019#
Male	31.72	31.4	26.1-39.3	26-37.43	
Height of C-1 lateral mass, right (mm)	11.01	10.7	6.5-19.7	7.69-14.33	
Female	10.67	10.6	8-12.8	8.77-12.58	0.0001#
Male	11.38	10.9	6.5-19.7	7.09-15.66	
Height of C-1 lateral mass, left (mm)	11.02	10.9	7-18.3	7.46-14.59	
Female	10.58	10.5	7.3-14.8	8.28-12.88	0.001#
Male	11.51	11.25	7-18.3	7.11-15.9	
Occipital condyle height, right (mm)	10.67	10.25	7.2-22	6.89-14.4	
Female	9.97	9.85	7.2-14.4	7.69-12.25	0.0001#
Male	11.45	11	7.3-22	6.99-15.92	
Occipital condyle height, left (mm)	10.56	10.4	7-17.7	7.33-13.79	
Female	9.91	9.75	7.4-12.8	7.8-12.02	0.002#
Male	11.29	10.95	7-17.7	7.65-14.93	
Clivus length	38.63	37.9	18.1-51.2	28.75-48.5	
Female	36.33	36.1	24.8-46.5	29.36-43.29	0.023#
Male	41.21	42.1	18.1-51.2	31.05-51.37	
CCA	158.6	158.75	131.5-191.6	138.7-178.5	
Female	158	158.9	131.49-175.4	139.29-176.5	0.67
Male	159.3	158.75	132.54-191.58	138.08-180.58	
Basal angle	122.3	122.08	102.6-191.5	100.2-144.2	
Female	119.5	120.55	102.61-132.79	104.55-134.52	0.16
Male	125.2	124.3	106.74-191.52	98.68-151.67	

*Values within 2 standard deviations (± 2 SD) of the average; # significant difference p value <0.05

DISCUSSION

Our study shows the relationships of the normal CCJ morphometry based on CT scan measurements performed in asymptomatic 137 patients. The normal ranges as presented, are crucial for improving the diagnostic standards of different CCJ congenital malformations or acquired diseases.

Table III. Comparison of craniocervical measurements between different age groups.

	Mean	Median	SD	Range	Normal range
Chamberlain line					
(5 - 18)	74.60	73.65	3.46	(70.9 - 80.9)	(67.8 - 81.4)
(19-44)	81.60	81.65	4.85	(69.3 - 92.7)	(79.1 - 91.1)
(45-64)	78.00	77.10	5.15	(68.9 - 92.4)	(67.8 - 88.2)
(65-84)	77.10	75.30	5.23	(69.3 - 88.6)	(66.7 - 87.5)
McRae line					
(5 - 18)	34.60	34.60	2.20	(32.1 - 38.6)	(30.2 - 39)
(19-44)	36.60	36.80	2.50	(30.7 - 44.7)	(31.6 - 41.6)
(45-64)	34.60	34.80	3.10	(27.9 - 40)	(28.4 - 40.8)
(65-84)	34.60	33.90	3.40	(29.4 - 40.6)	(27.8 - 41.4)
Atlantodental Interval (ADI)					
(5 - 18)	1.90	1.80	0.53	(1 - 2.8)	(0.84 - 2.96)
(19-44)	1.50	1.55	0.39	(0.7 - 2.6)	(0.72 - 2.28)
(45-64)	1.30	1.30	0.43	(0.5 - 2.3)	(0.44 - 2.16)
(65-84)	0.90	1.00	0.66	(0 - 2.3)	(0.35 - 2.22)
Distance from tip of odontoid process to Chamberlain line (mm)					
(5 - 18)	-2.30	-1.70	3.30	6.5 below to 1.5 above	9 below to 4.3 above
(19-44)	-2.50	-2.95	3.00	8.5 below to 6.5 above	8.5 below to 3.5 above
(45-64)	-1.90	-2.10	2.80	7 below to 6.3 above	7.5 below to 3.7 above
(65-84)	-0.23	-1.40	4.60	6.8 below to 11.1 above	9.4 below to 9 above
Redlund-Johnell method					
(5 - 18)	32.20	34.20	5.80	(23.6 - 39)	(20.6 - 43.8)
(19-44)	36.30	36.20	4.70	(25.3 - 47.9)	(26.9 - 45.7)
(45-64)	35.50	36.20	4.10	(26.2 - 45.4)	(27.3 - 43.7)
(65-84)	33.80	34.90	5.80	(18.7 - 41.8)	(22.2 - 45.4)
Modified Rawat method					
(5 - 18)	22.30	23.00	3.70	(16 - 27.7)	(14.8 - 29.6)
(19-44)	27.30	26.70	2.80	(21.7 - 33.3)	(21.7 - 32.9)
(45-64)	27.00	26.30	3.60	(21.8 - 39.3)	(19.7 - 34.1)
(65-84)	27.40	27.40	4.30	(17 - 35.4)	(18.8 - 36)
Anteroposterior diameter of FM					
(5 - 18)	35.00	35.20	2.30	(32.2 - 38.8)	(30.4 - 39.6)
(19-44)	37.10	37.00	2.50	(31.1 - 45.5)	(32.1 - 42.1)
(45-64)	35.40	35.40	2.70	(29.2 - 40.4)	(30 - 40.8)
(65-84)	34.60	34.70	3.20	(29.4 - 40.6)	(28.2 - 41)
Latero-lateral diameter of FM (mm)					
(5 - 18)	29.50	29.60	1.50	(27 - 32)	(26.5 - 32.5)
(19-44)	30.80	30.50	2.80	(25.2 - 39.3)	(25.2 - 26.4)
(45-64)	29.70	29.10	2.50	(22.8 - 35.7)	(25.7 - 34.7)
(65-84)	30.80	30.00	3.40	(24.7 - 38.5)	(24 - 37.6)
Height of C-1 lateral mass, right (mm)					
(5 - 18)	9.50	10.20	1.70	(6.5 - 11.6)	(6.1 - 12.9)
(19-44)	11.10	10.90	1.40	(8.7 - 17.8)	(8.9 - 13.9)
(45-64)	10.90	10.60	1.40	(8 - 17.1)	(8.1 - 13.7)
(65-84)	11.70	10.90	2.50	(9.1 - 19.7)	(6.7 - 16.7)
Height of C-1 lateral mass, left (mm)					
(5 - 18)	9.40	9.90	1.20	(7 - 10.7)	(7 - 11.8)
(19-44)	11.20	11.00	1.60	(8 - 18.3)	(8 - 14.4)
(45-64)	11.00	10.80	1.80	(7.3 - 17.8)	(7.4 - 14.6)
(65-84)	11.20	11.20	2.00	(8.4 - 16.9)	(7.2 - 15.2)
Occipital condyle height, right (mm)					
(5 - 18)	8.80	9.20	1.00	(7.3 - 10.2)	(6.8 - 10.8)
(19-44)	10.60	10.20	1.40	(8.4 - 15.3)	(7.8 - 13.4)
(45-64)	10.90	10.50	2.10	(7.2 - 22)	(6.7 - 15.1)
(65-84)	10.60	10.20	2.40	(7.7 - 17.4)	(5.8 - 15.4)

	Mean	Median	SD	Range	Normal range
Occipital condyle height, left (mm)					
(5 - 18)	8.90	9.30	1.20	(7 - 10.1)	(6.5 - 11.3)
(19-44)	10.70	10.60	1.60	(7.4 - 14.8)	(7.5 - 13.9)
(45-64)	10.60	10.30	1.60	(8 - 17.7)	(7.4 - 13.8)
(65-84)	10.40	10.40	1.20	(8.6 - 13.5)	(8 - 12.8)
Clivus length					
(5 - 18)	31.80	32.50	8.60	(18.1 - 45.7)	(14.6 - 49)
(19-44)	39.50	38.80	3.90	(30 - 49.4)	(31.7 - 47.3)
(45-64)	38.40	37.00	4.00	(30.6 - 46.4)	(30 - 46.4)
(65-84)	39.50	37.00	5.80	(32.2 - 51.2)	(27.9 - 51.1)
CCA					
(5 - 18)	150.70	153.60	10.50	(131.4 - 161.8)	(129.7 - 171.7)
(19-44)	156.90	156.80	9.70	(132.5 - 177.2)	(137.5 - 176.3)
(45-64)	160.40	160.00	7.40	(141.4 - 170.09)	(145.6 - 175.2)
(65-84)	162.10	158.80	15.10	(143.8 - 191.5)	(131.9 - 192.3)
Basal angle					
(5 - 18)	120.80	121.20	5.60	(109.27 - 126.45)	(109.6 - 132)
(19-44)	123.50	122.20	9.30	(108.3 - 151.77)	(104.9 - 142.1)
(45-64)	122.00	122.00	14.00	(102.61 - 191.52)	(94 - 150)
(65-84)	117.40	118.40	8.90	(106.61 - 131.66)	(99.6 - 135.2)

Rojas *et al*. (2007) evaluated normal anatomical relationships of the CCJ on CT scans. They reported that 95 % of their 200 patients had an ADI less than 2 mm, less than the documented value of 3 mm formerly reported in studies from the 1960s as the normal upper limit (Hinck & Hopkins, 1960). Batista *et al*. (2015) reported that none of their 100 patients had an ADI of more than 2 mm. They recommend that the normal upper superior limit of ADI in sagittal CT scan reconstruction should be 2 mm. In our series, none of our 137 patients had an ADI of more than 2.6 mm. None of the 137 patients had an ADI of more than 2.8 mm. Males have significantly higher values than females (P value 0.04) (Table II). The fourth age group (65-84 years) has the smallest ADI, while the first (5-18 years) has the highest (Table III). Our findings correlate with Liu *et al*. (2015), who found that ADI linearly decreases with increasing age. It is our view that the standard upper superior limit of ADI in sagittal CT scan reconstruction should be 3 mm.

In our study population, the mean distance from the odontoid tip to the proposed CL was -2.36 (below the line). The range was from 8.5 mm below to 6.3 mm above the line. 19 % of the total patients had their odontoid tip above the line, 75 % below, and 6 % at the same level. Based on a normal distribution, the normally accepted range (± 2 SD from the mean) of this measurement in our study population was from 5.36 mm below to 3.16 mm above the CL. Notably, some patients had the tip of the odontoid 2 mm or 5 mm above the CL, both values that are considered diagnostic criteria for basilar invagination (Goel, 2009). These values correlate with the normal values proposed by different authors for the normal population (2mm, 5mm or 6.6 mm) (Smoker, 1994; Goel, 2009). Based on our results, we could extrapolate that, due to anatomical variations, some asymptomatic individuals would have the diagnosis of basilar invagination (up to 2 % of the patients in our series).

The clivus canal angle (CCA) is depicted by the junction of a line lengthening along the clivus crossing and a line along the upper cervical spine. Measures based on plain radiographs typically vary from 150° to 180°, and measures less than 150° have been reported to be associated with ventral spinal cord compression (Smoker, 1994). However, in our current examination, the mean CCA in normal subjects was 158° (normal range 139°–179°, Table I), and one fifth of our sample had an angle less than 150°. These values are similar to ranges obtained by Botelho & Ferreira (2013), based on MRI of 33 patients (range 129°–179°). Batista *et al*. (2015) reported that the mean CCA angle measured on CT scans of 100 asymptomatic patients was 153.6° +/- 7.6° (range 132.3°-173.9°). Therefore, the range of CCA values obtained from CT and MRI scans of asymptomatic patients seems to be substantially larger than the published values based on plain radiographs (Smoker, 1994).

The basal angle (BA) measured in our present study is formed by a junction of a line starting from nasion to dorsum sellae and a line from dorsum sellae to basion (Koenigsberg *et al*., 2005) . Our mean Basal angle was 121.44° (SD 8.5°, median 121.88°, range (102.6°–151.7°). Koenigsberg *et al*. (2005) assessed the normal Basal angle

of 200 adults using MRI; they obtained a mean value of 129° ± 6°. Botelho and Ferreira (2013), noted that the BA ranged from 107° to 132° in their study population of 33 asymptomatic patients. They suggested that the diagnosis of Platybasia (flattening of the skull base) is when the BA is beyond 133°. Batsita *et al*. (2015) noted that the literature described smaller BA values when it is measured using the top of the dorsum sellae instead of the center of the sella. They concluded that using the tuberculum sellae or the center of the sella turcica rather than the dorsum sellae would result in greater BA values than measures perpetrated using the top of the dorsum sellae (Smoker, 1994; Batista *et al*., 2015).

Regarding the clivus length (CL), estimated from the top of the dorsum sellae to the basion, the mean distance obtained in our examination was 39 mm (SD 5 mm, median 38 mm, range 18.1 – 51.2 mm). Our estimated values are similar to the normal range obtained by Heiss *et al*. (2012) (mean 43.2 ± 3.5 mm).

Saralaya *et al*. (2012) conducted an anatomical analysis of 140 occipital condyles (OC) from 70 cadavers. The average height was 10.2 mm. Interestingly, our measures were very similar to the natural measures in dry skulls — we obtained a mean height of 10.6 mm for the right OC and 10.5 mm for the left. On contrary, the mean height of the C-1 lateral masses in a study of 32 cadavers was 13.68 ± 1.38 mm (Batista *et al*., 2015), higher values than ours (the mean height of C-1 lateral masses in our study were similar for both sides; 11 ± 1.6 mm), suggesting that sagittal CT measurement of the atlas lateral mass height resulted in an undervalue.

The lack of intra- and inter-reliability limits our study assessment for the presented CCJ measurements. Further studies addressing the reliability of CT scan dimensions of the standard CCJ craniometry are crucial. Further, CCJ craniometry may be affected by many other elements, such as patient ethnicity, sex, age, and height. Our study did not address these issues, but they should be considered in future research in this field. Eventually, we acknowledge that the detailed landmarks obtained with CT reconstructions should enhance the reproducibility of CCJ craniometry compared with dimensions conveyed with simple plain radiographs.

CONCLUSION

We reported our results on average craniometrical values obtained from modern 3D reconstructions in 137 asymptomatic people. These data can be helpful in assessing abnormalities of the CCJ compared to standard parameters, potentially improving the diagnostic standards of most abnormalities. When evaluating CCJ malformations, surgeons should consider the standard ranges established on CT scans rather than those obtained from plain radiographs.

AL-DWAIRY, S.; FATAFTAH, J.; AL-MOUSA, A.; EJJO, M. Z.; ALBAKRI, K. & MOHAMMAD, A. Evaluación de la craneometría de la unión craneocervical normal en 137 pacientes asintomáticos. *Int. J. Morphol., 41(1)*:216-224, 2022.

RESUMEN: Hasta donde sabemos, aun son escasos y pocos los estudios craneométricos respecto a la unión craneocervical normal (UCCN) y estos se basan en mediciones tomadas de radiografías simples. En este estudio, realizamos una evaluación craneométrica de la UCCN en una población sin anomalías conocidas. El propósito del estudio fue evaluar la craneometría UCCN normal en función de las medidas obtenidas de las tomografías computarizadas. Los autores examinaron 137 tomografías computarizadas UCCN consecutivas obtenidas en pacientes evaluados en su hospital para el tratamiento de condiciones no UCCN entre los años 2018 y 2019. Se realizaron doce dimensiones craneométricas, incluida la relación del proceso odontoides con la base del cráneo, el intervalo atlantodental (ADI), la longitud del clivus y el ángulo clivus-canal (CCA).

PALABRAS CLAVE: TAC; Unión craneocervical; Craneometría; Normal; Relación.

REFERENCES

Batista, U. C.; Joaquim, A. F.; Fernandes, Y. B.; Mathias, R. N.; Ghizoni, E. & Tedeschi, H. Computed tomography evaluation of the normal craniocervical junction craniometry in 100 asymptomatic patients. *Neurosurg. Focus, 38(4)*:E5, 2015.

Botelho, R. V. & Ferreira, E. D. Z. Angular craniometry in craniocervical junction malformation. *Neurosurg. Rev., 36(4)*:603-10, 2013.

Chethan, P.; Prakash, K. G.; Murlimanju, B. V.; Prashanth, K. U.; Prabhu, L. V.; Saralaya, V. V.; Krishnamurthy, A.; Somesh, M. S. & Kumar, C. G. Morphological analysis and morphometry of the foramen magnum: an anatomical investigation. *Turk. Neurosurg., 22(4)*:416-9, 2012.

De Carvalho, M. F.; Rocha, R. T.; Silva Monteiro, J. T.; Pereira, C. U.; Leite, R. F. & Aparecido Defino, H. L. Tomographic study of the atlas concerning screw fixation on lateral mass. *Acta Ortop. Bras., 17(3)*:136-8, 2009.

Dufton, J. A.; Habeeb, S. Y.; Heran, M. K.; Mikulis, D. J. & Islam, O. Posterior fossa measurements in patients with and without Chiari I malformation. *Can. J. Neurol. ScI., 38(3)*:452-5, 2011.

Goel, A. Basilar invagination, Chiari malformation, syringomyelia: a review. *Neurol. India, 57(3)*:235-46, 2009.

Heiss, J. D.; Suffredini, G.; Bakhtian, K. D.; Sarntinoranont, M. & Oldfield, E. H. Normalization of hindbrain morphology after decompression of Chiari malformation Type I. *J. Neurosurg., 117(5)*:942-6, 2012.

Hinck, V. C. & Hopkins, C. E. Measurement of the atlanto-dental interval in the adult. *Am. J. Roentgenol. Radium Ther. Nucl. Med., 84*:945-51, 1960.

Kaneko, H.; Kimura, K.; Kamei, T. & Noro, H, Kawabuchi J, Ushio A, *et al*. Basilar impression. *Nihon Jibiinkoka Gakkai Kaiho, 68*:231-43, 1965.

Koenigsberg, R. A.; Vakil, N.; Hong, T. A.; Htaik, T.; Faerber, E.; Maiorano, T.; Dua, M.; Faro, S. & Gonzales, C. Evaluation of platybasia with MR imaging. *AJNR Am. J. Neuroradiol., 26(1)*:89-92, 2005.

Kwong, Y.; Rao, N. & Latief, K. Craniometric measurements in the assessment of craniovertebral settling: are they still relevant in the age of cross-sectional imaging? *AJR Am. J. Roentgenol., 196(4)*:W421-5, 2011.

Liu, K.; Xie, F.; Wang, D.; Guo, L.; Qi, Y.; Tian, J.; Zhao, B. & Chhabra, A. Reference ranges for atlantodental interval in adults and its variation with age and gender in a large series of subjects on multidetector computed tomography. *Acta Radiol., 56(4)*:465-70, 2015.

McGreger, M. The significance of certain measurements of the skull in the diagnosis of basilar impression. *Br. J. Radiol., 21(244)*:171-81, 1948.

McRae, D. L. & Barnum, A. S. Occipitalization of the atlas. *Am. J. Roentgenol. Radium Ther. Nucl. Med., 70(1)*:23-46, 1953.

Offiah, C. E. & Day, E. The craniocervical junction: embryology, anatomy, biomechanics and imaging in blunt trauma. *Insights Imaging, 8(1)*:29-47, 2017.

Redlund-Johnell, I. & Pettersson, H. Radiographic measurements of the cranio-vertebral region. Designed for evaluation of abnormalities in rheumatoid arthritis. *Acta Radiol. Diagn. (Stockh.), 25(1)*:23-8, 1984.

Riew, K. D.; Hilibrand, A. S.; Palumbo, M. A.; Sethi, N. & Bohlman, H. H. Diagnosing basilar invagination in the rheumatoid patient. The reliability of radiographic criteria. *J. Bone Joint Surg. Am., 83(2)*:194-200, 2001.

Rojas, C. A.; Bertozzi, J. C.; Martinez, C. R. & Whitlow, J. Reassessment of the craniocervical junction: normal values on CT. *AJNR Am. J. Neuroradiol., 28(9)*:1819-23, 2007.

Saralaya, V. V.; Murlimanju, B. V.; Vaderav, R.; Tonse, M.; Prameela, M. D. & Jiji, P. J. Occipital condyle morphometry and incidence of condylus tertius: phylogenetic and clinical significance. *Clin. Ter., 163(6)*:479-82, 2012.

Smoker, W. R. Craniovertebral junction: normal anatomy, craniometry, and congenital anomalies. *Radiographics, 14(2)*:255-77, 1994.

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