The Egyptian Journal of Hospital Medicine (October 2022) Vol. 89, Page 4226- 4234

Imaging of Normal Craniocervical Junction at Different Ages

Mohamed S. Abd Al-wahab, Nihal M. Batouty, Jehan A. Mazro
Department of Radiodiagnosis, Faculties of Medicine, Mansoura University, Mansoura, Egypt
***Corresponding author:** Mohamed S. Abd Al-wahab, **Mobile:** (+20)1067408482, **E-Mail:** dr_moh_92@yahoo.com

ABSTRACT

Background: Evaluation of craniovertebral junction (CVJ) diseases involves the use of a wide range of parameters and craniometric measures. As a result, figuring out the range of typical craniometric readings is critical.

Objective: The aim of the current work was to determine the morphometric reference values of the bony structures in the CVJ by computed tomography (CT) and magnetic resonance imaging (MRI) in normal people who have no history of congenital or acquired abnormalities of craniocervical junction (CCJ)

Patients and methods: In the Radiology Department, Mansoura University, 60 people participated in this study (30 by CT and 30 by MRI) at different ages with no history of CCJ abnormalities. These individuals were divided into three age groups. Retrospective analysis was performed on the MDCT and MRI scans. A total of 14 midsagittal parameters and 2 coronal parameters were investigated. The data were analysed statistically.

Results: C.T. for PAI, BAI, BDI, OPFD, and OPFB: there were statistically significant differences among the three age groups tested. The ADI was statistically substantially higher in the group of people under the age of 18, then in the group of people between the ages of 18 and 60, and finally in the group of people older than 60. All other parameters, on the other hand, showed no statistically significant differences. MRI for PAI, BAI, and BDI: the three groups investigated showed statistically significant differences.

Conclusion: We found that some parameters show statistically significant differences between different age groups which are consistent with previous studies and that there is no significant differences between this study in Egyptian people and previous studies in western population with respect to several parameters in CVJ osteometry so that researchers studying pathology in this region will find the normal reference ranges valuable.

Keywords: Craniovertebral junction, CT, MRI, Mansoura University.

INTRODUCTION

From an imaginary line produced from an imaginary line drawn from the midpoint of that distance from dorsum sellae to foramen magnum's anterior edge to the C2-3 interspace level, the cranocervical junction is formed. At the cervicomedullary junction, there are the occipital bone and clivus, as well as the foramen magnum and upper cervical vertebrae that serve as both an axis and an atlas, as well as ligaments that connect these parts together [1].

Conventional tomography, non-contrast 3D CT with reconstruction pictures and conventional magnetic resonance imaging (MRI) are all imaging modalities that can be used to evaluate the craniocervical junction [2].

CVJ anomalies such as basilar invagination, atlantoaxial dislocation, and platybasia can be evaluated using a variety of craniometric measures. Since the usual reference range for craniometric measurements must be established [3].

Radiological evaluation of the craniocervical junction encompass essential anatomical landmarks and craniometric measurements to be aware of. The measurements including Chamberlain line, ADI, BDI, BAI, clivus angle, Welcher basal angle, atlantooccipital joint axis angle, and the relationship of the odontoid to the cranial base make up the Powers ratio (including McGregor and McRae lines) [4].

The aim of the current work was to determine the anatomical landmarks and parameters of the CVJ by CT and MRI, as well as the morphometric reference values of the bony structures in the CVJ in healthy individuals without a history of congenital or acquired abnormalities of craniocervical junction (CCJ)

PATIENTS AND METHODS

This Retrospective study included a total of 60 individuals (30 by CT and 30 by MRI) with normal craniocervical junction, referred to Radiology Department, Mansoura University Hospitals. This study was conducted between 2020 and 2022.

The included 60 individuals were 28 male and 32 female, aged between 2– 87, and were divided into three age groups: < 18, 18-60 and > 60 years.

Ethical Consideration:

This study was ethically approved by Mansoura University's Research Ethics Committee. The study protocol conformed to the Helsinki Declaration, the ethical norm of the World Medical Association for human testing.

Inclusion criteria:

- Patients referred to radiology department (different age groups) with no history of congenital or acquired abnormalities of craniocervical junction.
- Any age.
- Both sexes.

Exclusion criteria:

- Patients with history of craniocervical abnormalities

Received: 26/4/2022
Accepted: 23/6/2022

- Contraindications to MRI scans in general (A pacemaker patient or someone with a metallic foreign object in their eye, poor health and claustrophobia among patients).
- Patients for whom a CT scan was not appropriate (those who were pregnant or in poor health, as well as those who have a movement issue that couldn't be controlled)

TECHNIQUES AND METHODS

. Computed tomography:

(1) Patients underwent CT with 128 multi- detector CT scanner. With no contrast media, the scanning technique included 12-mm collimation with 1-mm slice thickness, 24-cm FOV, 120-kVp, 300-mA output, 512x512 matrix with 0.9-1 pitch for image capture.

(2) Axial pictures were reconstructed at a resolution of one millimetre. Reconstructions of the upper cervical vertebrae and the base of the occiput bone in the sagittal and coronal planes were obtained from the 1 mm axial reconstruction, which was converted to 3-mm thickness every 3 mm.

• Magnetic resonance image:

(1) Sagittally and anteroposteriorly, MRI were performed on a 1.5T Philips machine using the following protocols: a T1W SE and T2-weighted turbo spin echo (T2W TSE).

(2) A coronal T1W SE with a short tau inversion recovery (STIR). In flexion and extension whenever necessary, the T2W TSE.

(3) Repetition time (TR) of 598 milliseconds and echo time (TE) of 27 milliseconds were typical parameters for the T1W SE sequence. The TR of 4,100 milliseconds is used for the T2W TSE sequence, and the echo time (TE) was used for STIR sequence. The inversion time (TI) is 150 milliseconds for the STIR sequence. (4) The slices were 3 mm thick and the interslice gap was 0.3 mm.

On the basis of craniometric descriptions, 14 midsagittal plane characteristics and 2 coronal plane parameters were examined in relation to the CVJ.

A-Measurements in the midsagittal plane of a variety of parameters:

(1) Location of odontoid process along the McGregor line (OP-MG) in relation to distance from McGregor line.

(2) Between the odontoid process and the Chamberlain line (OP-C) and the location of the odontoid process as defined by the Chamberlain line.

(3) Between the McRae Line (OP-MR) and the odontoid process's location according to the McRae Line (OP-MR).

(4) Length of the McRae line (LMR).

(5) Clivus canal angle (CCA).

(6) Basion axial interval (BAI**)** and localization of the basion according to the axial line.

(7) Welcher basal angle (WBA).

(8) Atlantodental interval (ADI).

(9) Posterior atlantodental interval (PAI).

(10) Basion dental interval (BDI).

(11) Craniocervical Tilt (CCT).

(12) Powers ratio (PR).

(13) Length of the Redlund-Johnell line (LRJ).

(14) Length of the Modified Ranawat line (LMRa).

B-The coronal plane measurements of parameters:

(1) Distance from Fischgold digastric line to odontoid process (OP-FD).

(2) Anatomical relationship between the odontoid process and the Fischgold bimastoid line.

After a CT scan was performed using a scanning methodology, 14 midsagittal and 2 coronal plane characteristics were evaluated.

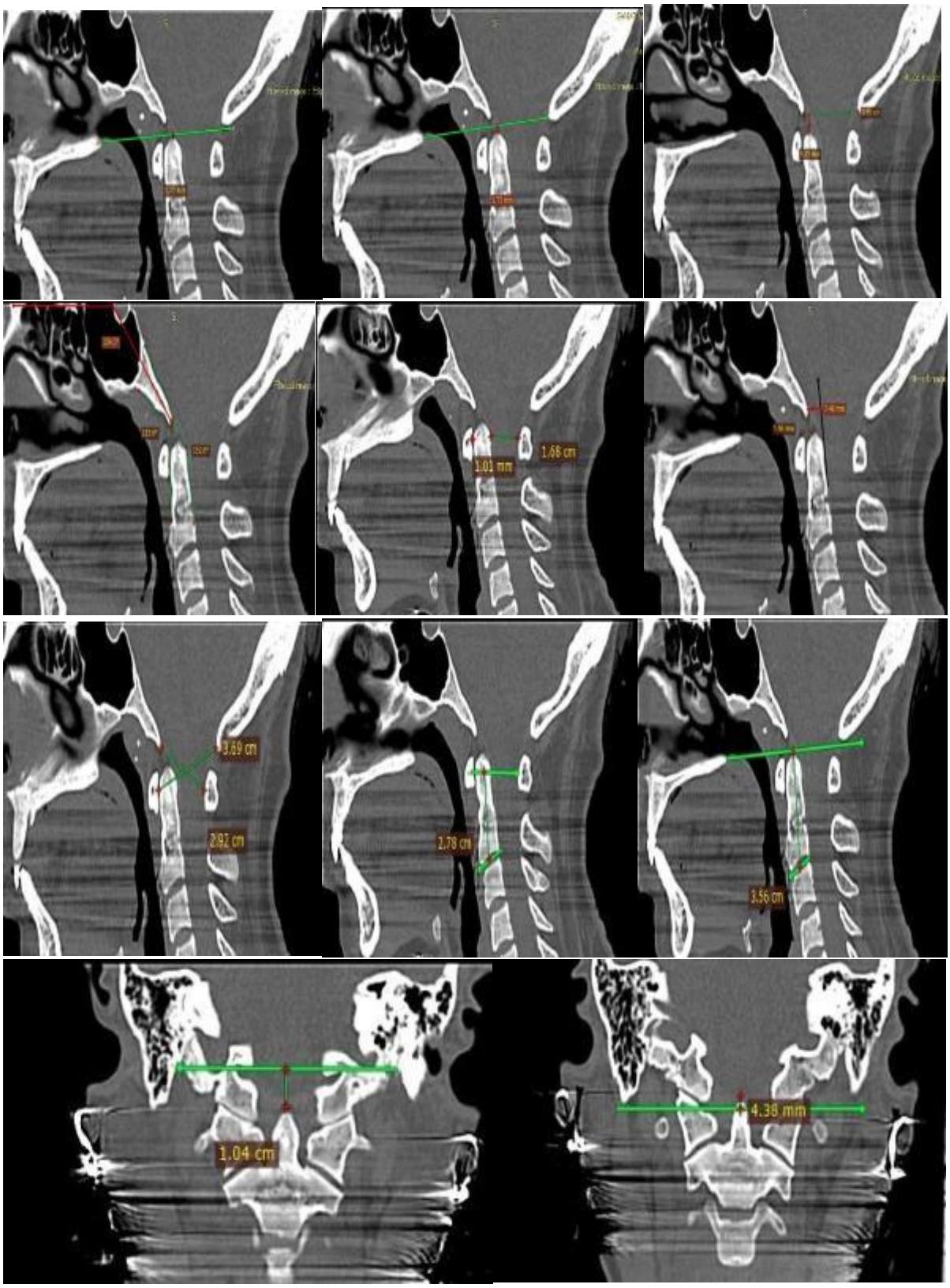

Fig. (1): CVJ midsagittal and coronal plane measurements. **(a)** OP-MG, **(b)** OP-C , **(C)** LMR, OP-MR, **(d)** CCT, WBA, CCA, **(e)** PAI **, ADI, (f)** BDI, **BAI, (g)** PR, **(h)** LMRa, **(i)** LRJ, (j) OP-FD, (k) OP-BM
MRI was performed using a scanning procedure, and 14 midsagittal characteristics were examined.

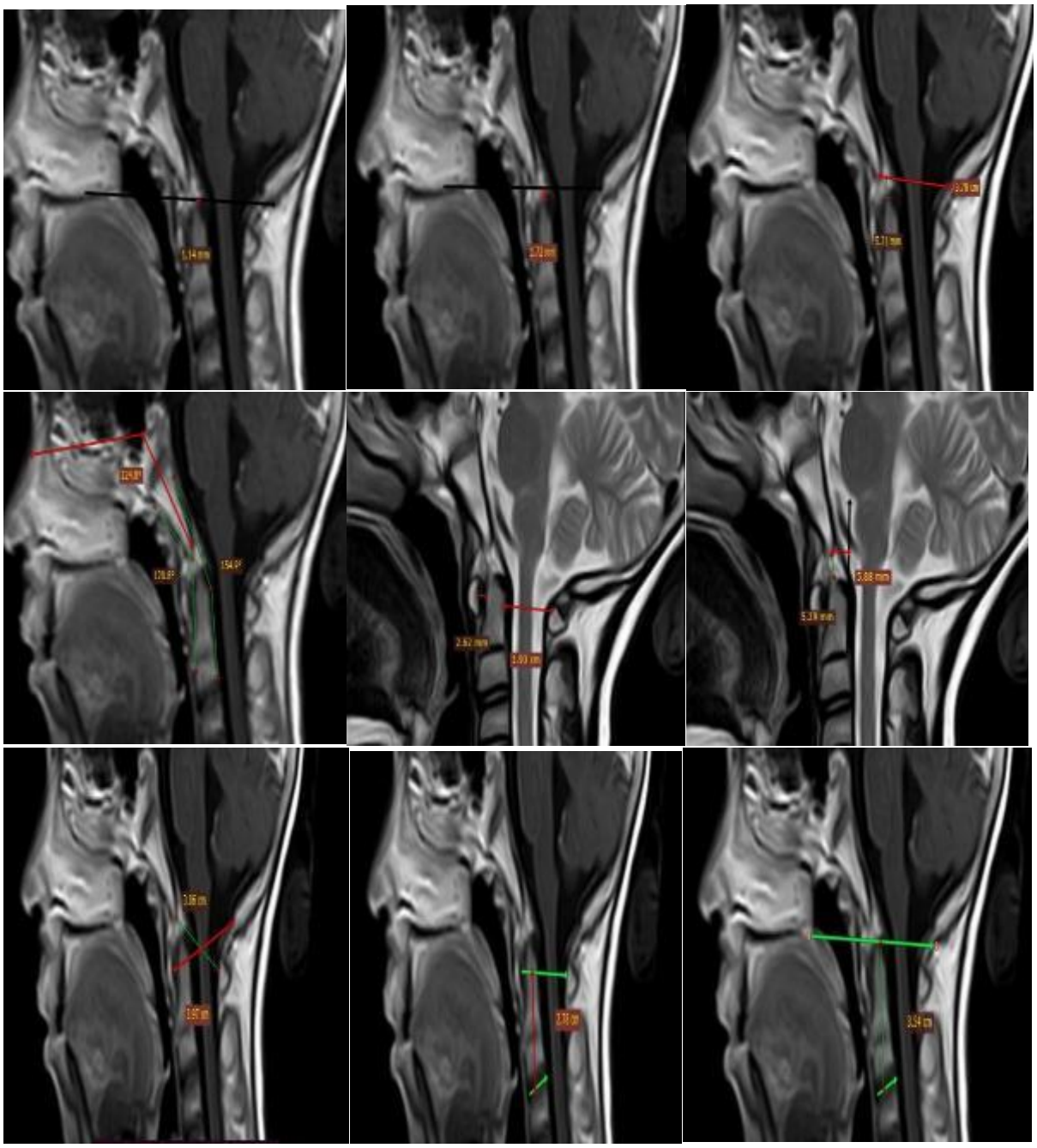

Fig. (2): CVJ midsagittal and coronal plane measurements. **(a)** OP-MG, **(b)** OP-C , **(C)** LMR, OP-MR, **(d)** CCT, WBA, CCA, **(e)** PAI **, ADI, (f)** BDI, **BAI, (g):** PR, **(h)** LMRa, **(i)** LRJ.

Statistical analysis

IBM SPSS Corp. was used to examine the data given into the computer. Windows version 22.0 of IBM SPSS Statistics. IBM Corp. is based in Armonk, New York. Number and percentage were used to describe qualitative data. For parametric data, the Kolmogorov-Smirnov test was used to verify normality before describing the mean and standard deviation. One Way ANOVA test was used to compare more than 2 independent groups with Post Hoc Tukey test to detect pair-wise comparison. P value < 0.05 was considered significant.

RESULTS

This study included a total of 60 individuals (30 by CT and 30 by MRI) with normal craniocervical junction at different ages, these individuals were divided into three age groups. A comparison of the morphometric values was done between the three age groups**.**

Table (1) reveals comparison of CT findings distribution according to age categories of the studied cases. There were statistically significant differences among the three studied groups as regards PAI, BAI, BDI, OB-FD and OB-FB.

There were highly statistically significant difference in ADI being significantly increased in <18 group followed by age (18-60) and lastly cases with age >60. However, there were no statistically significant differences regarding all other parameters.

Table (1): Comparison of CT findings distribution according to age categories of the studied cases:

CT	Age/years			Test of significance
	<18	18-60	>60	
OP-MR	5.12±0.79	4.82±0.618	4.93±0.91	F=0.391 P=0.680
LMR	3.48±0.20	3.45±0.14	3.57±0.13	F=1.56 P=0.228
CCA	153.54±6.86	156.92±6.15	160.31±5.56	F=2.38 P=0.111
WBA	129.56±3.23	129.49±5.52	130.99±1.89	F=0.349 P=0.708
CCT	120.28±7.21	123.44±6.41	125.71±5.48	F=1.46 P=0.250
ADI	2.44 ± 0.38^{AB}	1.71 ± 0.43^{A}	1.52 ± 0.45^{B}	F=10.87 P<0.001*
PAI	1.87 ± 0.07^{A}	1.83 ± 0.13^{B}	2.02 ± 0.16^{AB}	F=5.62 P=0.009*
BAI	6.64 ± 1.38^{A}	5.02 ± 1.17^{A}	6.04±1.22	F=4.69 P=0.018*
BDI	5.61 ± 0.92^{A}	4.41±1.04A	5.29±1.08	F=4.12 P=0.027*
PR	0.706±0.042	0.738±0.065	0.749±0.028	F=1.49 P=0.243
LAMRa	2.92±0.13	2.86±0.26	2.68±0.44	F=1.45 P=0.252
LRJ	3.66±0.34	3.69±0.28	3.89±0.28	F=1.47 P=0.247
OP-DIGASTRIC	7.21 ± 2.67^{A}	8.44±2.01	10.53 ± 3.15^{A}	F=3.59 P=0.042*
OP-BIMASTOID	4.72 ± 1.35^{A}	5.04 ± 2.03^{B}	7.27 ± 2.37^{AB}	F=4.20 P=0.026*

F:One Way ANOVA test , similar superscripted letters denote significant difference between studied groups.

Table (2) demonstrates comparison of MRI findings distribution according to age categories of the studied cases. There were statistically significant differences among the three studied groups as regards PAI, BAI, BDI. There were highly statistically significant difference in ADI being significantly increased in <18 group followed by age (18-60) and lastly cases with age >60. However, there were no statistically significant differences regarding all other parameters.

Table (2): Comparison of MRI findings distribution according to age categories of the studied cases:

MRI	Age/years			Test of significance
	<18	18-60	>60	
OP-MR	5.58±0.97	6.17±0.491	5.49±0.78	F=3.22 P=0.06
LMR	3.41±0.45	3.60±0.24	3.66±0.216	F=1.37 P=0.272
CCA	153.48±8.02	152.23±7.89	152.28±7.04	F=0.069 P=0.933
WBA	127.17±3.81	124.3±5.26	123.43±4.92	F=1.18 P=0.324
CCT	120.30±8.96	118.80±6.47	115.91±5.89	F=0.727 P=0.493
ADI	2.46 ± 0.508^{A}	2.78 ± 0.34^{B}	1.68 ± 0.158^{AB}	F=12.97 P<0.001*
PAI	1.86 ± 0.17^{AB}	2.05 ± 0.14^{A}	2.07 ± 0.18^{B}	F=4.31 P=0.024*
BAI	4.43 ± 1.36^{AB}	6.17 ± 0.878^{A}	5.75 ± 0.89^{B}	F=7.23 P=0.003*
BDI	5.81 ± 1.06^{A}	6.62 ± 0.75^{AB}	5.65 ± 0.85^{B}	F=4.21 P=0.026*
PR	0.731±0.09	0.728±0.047	0.731±0.035	F=0.013 P=0.987
LAMRa	2.82±0.18	2.98±0.19	2.99±0.16	F=2.19 P=0.132
LRJ	3.64±0.14	3.83±0.20	3.84±0.18	F=2.65 P=0.09

F: One Way ANOVA test , similar superscripted letters denote significant difference between studied groups *statistically significant

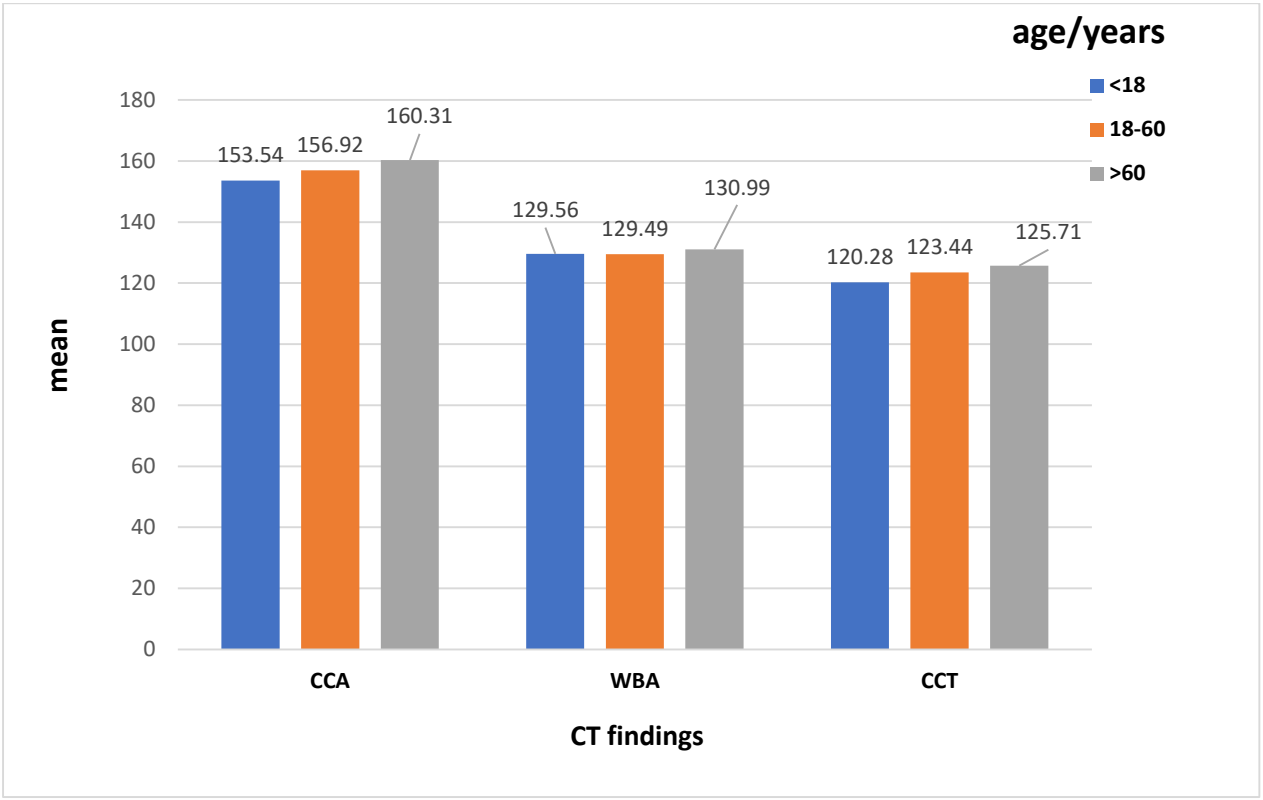

Figure (3a): Comparison of CT findings distribution according to age categories of the studied cases.

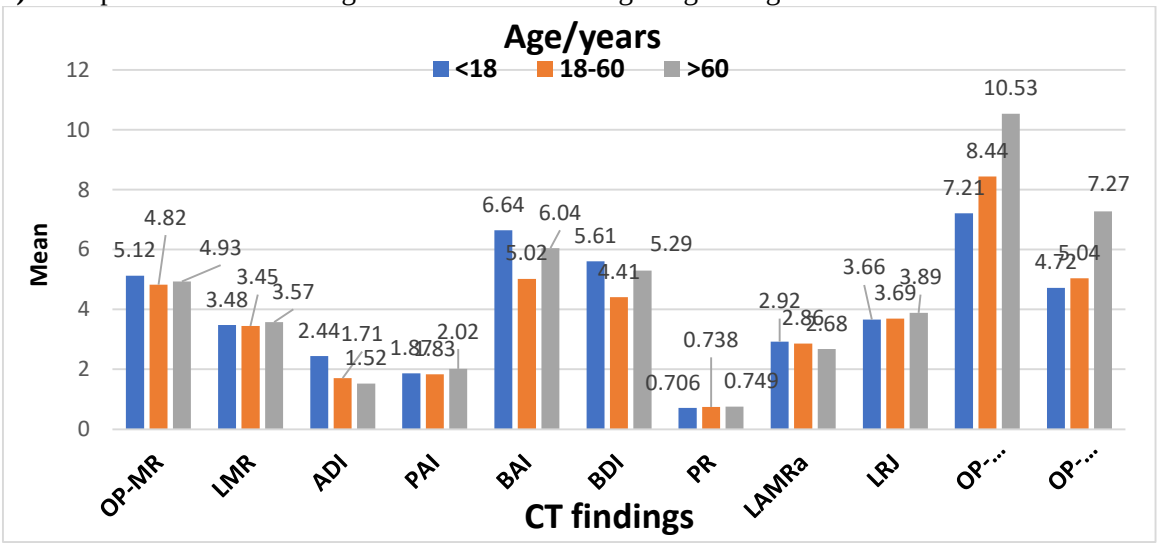

Figure (3b): Comparison of CT findings distribution according to age categories of the studied cases.

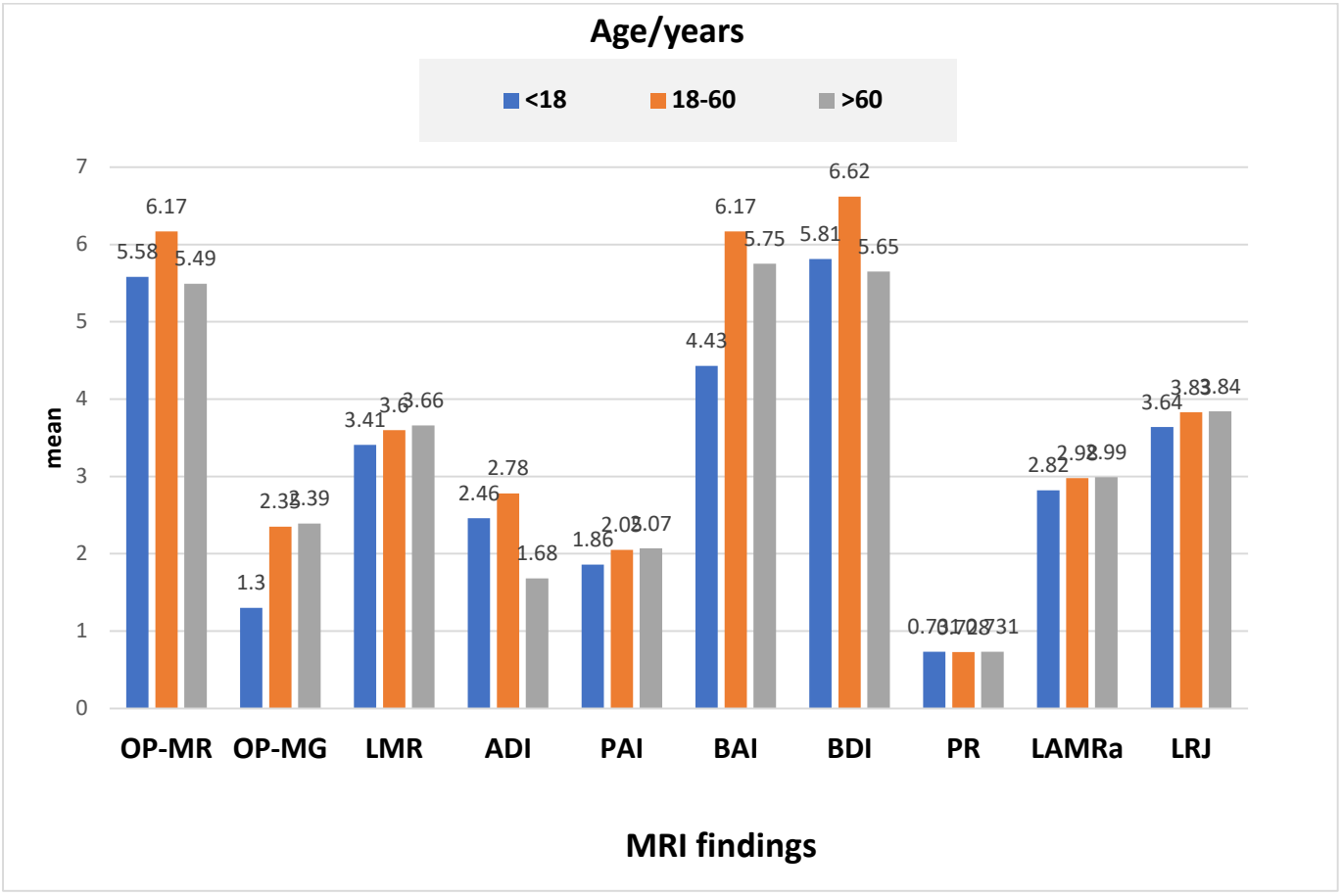

Figure (4a): Comparison of MRI findings distribution according to age categories of the studied cases

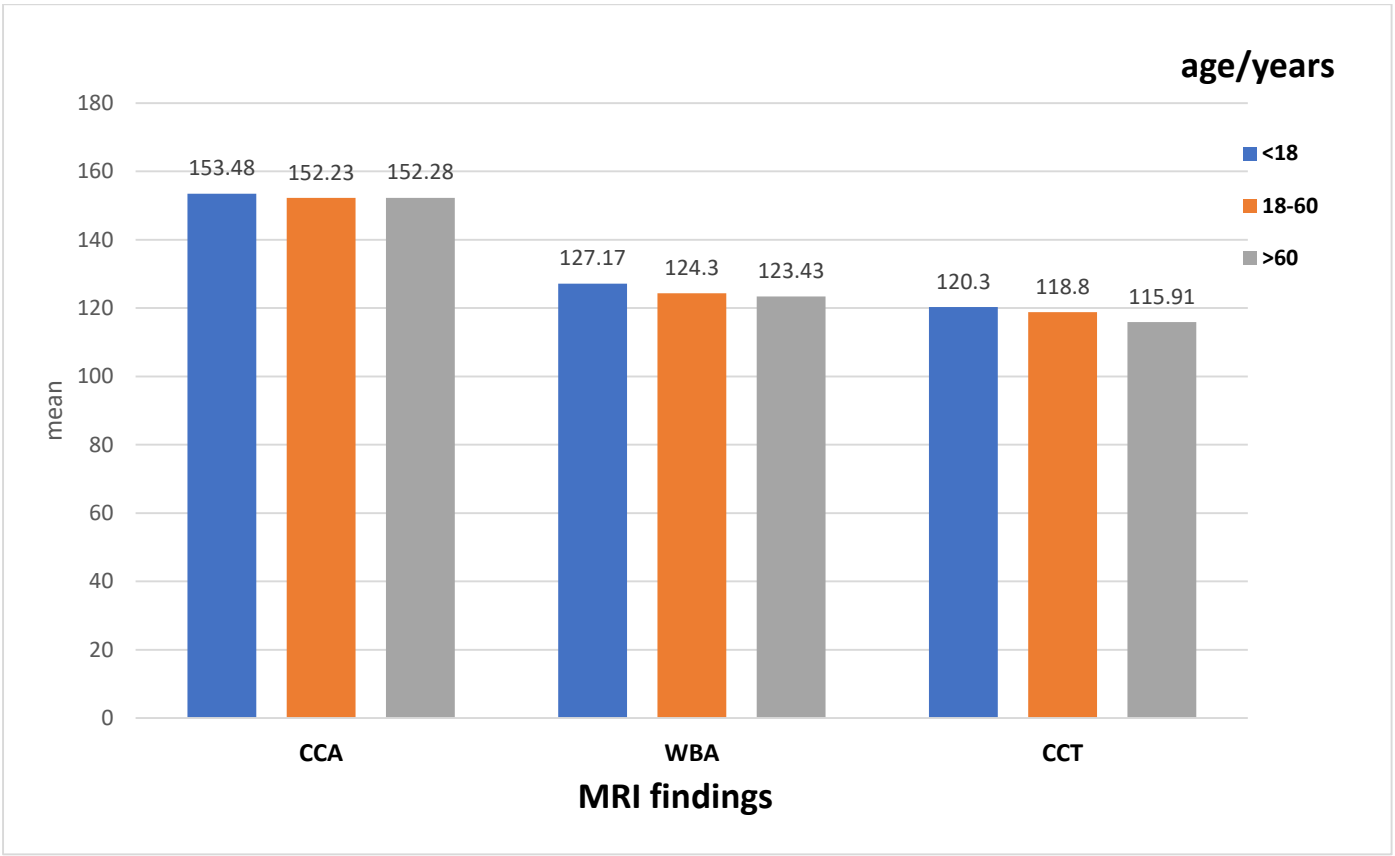

Figure (4b): Comparison of MRI findings distribution according to age categories of the studied cases

DISCUSSION

Individuals who have no anomalies in the craniocervical junction were compared to prior research in terms of morphometric values based on their age in this investigation. These craniometric characteristics were measured and compared to earlier research in great detail.

Odontoid process and McGregor line are separated by a significant distance.

According to McGregor, diseases could result from an OP greater than 4.5 mm above the MG. In the literature, it has been stated that the OP-MG value can reach 6.5 mm in healthy persons.

The OP was only 3.95 mm higher than the MG in this investigation. which is in line with existing research [5].

Distance between odontoid process and Chamberlain line

While McRae found that the OP was higher than the C in a third of healthy people, the current study found that the OP was higher in 36.6% of the participants. That which is placed more than 3mm above the C indicates basilar invagination, according to McRae." [6]. As previously reported, the OP in this study was no more than 3.08 mm above the C.

McRae's line and the odontoid process's distance: A range of 4.60–5.80mm OP-MR was recorded in the control group in prior research [7,8]. When OP-MR was measured by CT, it was found that it had a diameter of 4.93 millimetres, which is in line with previous studies in this area of research. There was no statistically significant difference between the ages of the participants in this study.

Length of the McRae line

Males' LMR was found to be 36.48 mm and females' LMR was found to be 35.97 mm in a study by **Dash *et al.*** [8]**.** The LMR was found to be between 32 and 37.6 mm by CT and 29.5 and 40 mm by MRI in the current investigation, which is in line with previous findings. There was no statistically significant difference between the ages of the participants in this study.

Clivus canal angle

Normal values for CCA in earlier research have been reported as a range of 135° to 175°, with a mean CCA value in the control group of 135° to 159,61° [8,9]. CCA was found to be 140.6-168.4° by CT and 139.1-164.6° by MRI in the current investigation, which is in line with previous findings. The CCA, like many other criteria, is congruent with prior research and the current investigation in healthy people. Ages are not statistically different from one another, according to this study.

Welcher basal angle

According to prior research, this angle should always be lower than 140°. In this study's data, the mean WBA in the control group was recorded in a range of 113.7 to 131.2°. By CT and MRI, WBA was shown to be 118.8-136.3°, which is consistent with prior reports [8,9]. There was no statistically significant difference between the ages of the participants in this study.

Craniocervical tilt

A study by **Chandra *et al.*** [7] reported that the CCT in the control group was 119.8° 9.2°. **Chandra *et al.*** [7] reported a CCT of 123.206.51° by CT and 118.486.92° by MRI, which is consistent with this work. According to the findings, there was no statistically significant age difference among the participants.

Atlantodental interval

Adults with an ADI of 3.5 mm or less are considered to have a normal value [13]. The ADI is the subject of numerous investigations. ADI was found to have an average range of 1.10–2.29 mm in the control group in these research studies [8,9,10].

According to the literature, the ADI measured in this study was between 0.78 and 2.88 mm by CT and between 1.44 and 3.22 millimetres by MRI. An age-related decline in atlantoaxial subluxation or dislocation is found in a study by **Liu *et al.*** [11]**,** hence various age-related reference ranges should be employed. In line with previous research by **Liu *et al.*** [11]**,** this study also found a link between ADI and growing older.

Posterior atlantodental interval

From CT pictures of 42 children, **Vachhrajani *et al.*** [12] found this distance to be 18.3 0.065 mm. The PAI was discovered to be 18.9±0.15 mm by CT and 20.1±0.17 mm by MRI, which is identical to **Vachhrajani *et al.*** [12] An age difference is found to be significant in this study.

Basion axial and basion dental intervals

Measurement of BAI ranged between 3.71-8.14 mm by CT, which was similar to the results reported by **Rojas and colleagues** [13]**,** who determined this distance to be between 2.63 and 8.84 millimetres in this investigation. Age differences were found to be statistically significant in the current investigation.

The control group's mean BDI value has previously been found to range between 4.59 and 7.5 mm in previous research [13,14]. The BDI was determined to be 3.02-7.05 mm by CT and 4.33-7.72 mm by MRI in the present investigation, which is in line with previous findings in the literature. Age differences were found to be statistically significant in the current investigation.

Powers ratio

According to **Rojas *et al.*** [13]**,** the mean PR value from MDCT scans of 200 participants was 0.8 (0.6–1.2).

Received: 26/4/2022
Accepted: 23/6/2022

These new findings, which are consistent with those of **Rojas *et al.* [13],** showed PR values of (0.63-0.85) on CT (0.60.82) on MRI. Age differences were not found to be statistically significant in the current investigation.

Length of the Modified Ranawat line

From CT pictures of 200 people, **Kwong *et al.* [5]** determined that the LMRa was 31.1 mm in men, 28.4 in females, and 29.7 mm in the general population. MRI and CT measurements of LMRa were both determined to be similar to those made by **Kwong *et al.*[5],** at 28.3 mm and 29.5 mm, respectively. There was also a statistically significant age difference in this study, which is consistent with the findings of **Kwong *et al.* [5]**.

Length of the Redlund-Johnell line

For men, the mean LRJ was 39.6 millimetres, for women 35.5 millimetres, and for the general population 37.5 millimetres, as determined by CT imaging of 200 people by **Kwong *et al.*[5].** The LRJ was found to be 37.4 mm by CT and 37.9 mm by MRI in this investigation, which is similar to **Kwong *et al.*[5]** Similar to the findings of **Kwong *et al.* [5]**, a statistically significant difference was detected between ages in the current investigation.

The distances between the odontoid process and the Fischgold digastric and bimastoid lines

To put it another way, according to Tanriserver and coworkers, the Op was situated 8.70–4.12 mm below the FDD. The OP was found by CT to be 8.672.74 mm below the FD, which is in agreement with the current study. Statistically significant differences were found between the ages of the subjects studied. According to **Tanrisever *et al.*[3]**, the OP should be 3–10 mm above the FB.

By CT, the OP was found to be 1.95-9.38 mm above the FB in this investigation. Age differences were found to be statistically significant in the current investigation.

CONCLUSION

We found that some parameters show statistically significant differences between different age groups which are consistent with previous studies.

And that there are no significant differences between this study in Egyptian people and previous studies in western population with respect to several parameters in CVJ osteometry so that researchers studying pathology in this region will find the normal reference ranges valuable.

Conflict of interest: The authors declare no conflict of interest.

Sources of funding: This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Author contribution: Authors contributed equally in the study.

REFERENCES

1. **Talukdar R, Yalawar R, Kumar M (2015):** Imaging in Craniovertebral Junction (CVJ) Abnormalities. IOSR Journal of Dental and Medical Sciences (IOSR-JDMS), 14: 33-49.
2. **Deliganis A, Baxter A, Hanson J *et al.* (2000):** Radiologic spectrum of craniocervical distraction injuries. Radiographics, 20: 237-250.
3. **Tanrisever S, Orhan M, Bahşi İ *et al.* (2020):** Anatomical evaluation of the craniovertebral junction on cone-beam computed tomography images. Surgical and Radiologic Anatomy, 42**,** 797-815.
4. **Tassanawipas A, Mokkhavesa S, Chatchavong S *et al.* (2005):** Magnetic resonance imaging study of the craniocervical junction. J Orthop Surg (Hong Kong), 13:228–231.
5. **Kwong Y, Rao N, Latief K (2011):** Craniometric measurements in the assessment of craniovertebral settling: are they still relevant in the age of cross-sectional imaging? American Journal of Roentgenology, 196: 421-425.
6. **Mcrae D (1953):** Bony abnormalities in the region of the foramen magnum: correlation of the anatomic and neurologic findings. Acta radiologica, 40: 335-354.
7. **Chandra P, Goyal N, Chauhan A *et al.* (2014):** The severity of basilar invagination and atlantoaxial dislocation correlates with sagittal joint inclination, coronal joint inclination, and craniocervical tilt: a description of new indexes for the craniovertebral junction. Operative Neurosurgery, 10: 621-630.
8. **Dash C, Singla R, Agarwal M *et al.* (2018):** Craniovertebral junction evaluation by computed tomography in asymptomatic individuals in the Indian population. Neurology India, 66: 797-802.
9. **Batista U, Joaquim A, Fernandes Y *et al.* (2015):** Computed tomography evaluation of the normal craniocervical junction craniometry in 100 asymptomatic patients. Neurosurgical Focus, 38: 5-9.
10. **Chen Y, Zhuang Z, Qi W *et al.* (2011):** A three-dimensional study of the atlantodental interval in a normal Chinese population using reformatted computed tomography. Surgical and Radiologic Anatomy, 33: 801-806
11. **Liu K, Xie F, Wang D *et al.* (2015):** 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 Radiologica, 56: 465-470.
12. **Vachhrajani S, Sen A, Satyan K *et al.* (2014):** Estimation of normal computed tomography measurements for the upper cervical spine in the pediatric age group. Journal of Neurosurgery: Pediatrics, 14: 425-433.
13. **Rojas C, Bertozzi J, Martinez C *et al.* (2007):** Reassessment of the craniocervical junction: normal values on CT. American Journal of Neuroradiology, 28: 1819-1823.
14. **Chang W, Alexander M, Mirvis S (2009):** Diagnostic determinants of craniocervical distraction injury in adults. American Journal of Roentgenology, 192: 52-58.