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Craniocervical Junction Measurements and Analyses on Age and Gender Differences Using Magnetic Resonance Imaging

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Abstract

Objective: The purpose of this research was verifying the mean values and ranges of powers ratio (PR), atlanto-dental interval (ADI), basion-dens interval (BDI), and basion-axial interval (BAI) which are critical measurements to evaluate atlantooccipital and atlantoaxial dissociations which indicate instability of the injuries in these critical regions.

Methods: After exclusions, 184 female, 87 male, a total of 271 patients' (the mean age was 48.44 ± 14.99) cervical magnetic resonance images were re-assessed regarding the craniocervical measurements. The mean values and SDs of all parameters were presented. All data distribution results of each ratio and interval measurements were presented with boxplot graphics. Each parameter was analyzed regarding gender differences and age.

Results: The mean values of PR, ADI, BDI, and BAI were 0.76 ± 0.07, 1.14 ± 0.61, 5.12 ± 1.74, and 7.41 ± 2.20 respectively. Female and male groups indicated a significant difference regarding ADI and BDI measurements. A significant and negative correlation with ADI and BDI was found regarding age.

Conclusion: Besides the mean values and ranges of the 4 critically important parameters, males had higher ADI and BDI values than females, and age showed a negative significant correlation regarding ADI and BDI measurements according to the results of this investigation. More studies and data from larger series need to be added to the literature to create accurate and valuable meta-analyses that will reveal the normal ranges of these critical values and the effect of age and gender on these parameters.

Keywords: Cervical, Craniocervical junction, Interval, Magnetic Resonance Imaging, Measurement

INTRODUCTION

Atlantooccipital dislocation is a serious injury and primarily an outcome of ligamentous disruption between the occiput and the upper cervical spine, often without accompanying bony fractures. This feature of these critical injuries renders this area likely to underestimate the injuries in this location.[1] Before interpreting the radiological images, one must be aware of specific details about the anatomical features of the craniocervical junction.

The biomechanical considerations and the risk of upper segment spinal injury made the researchers develop criteria in the assessment of the diagnostic approach for the radiology and instability of these injuries. Considering the spinal injury classifications, there are 2 important relationships in this region to consider for instability. These are atlantooccipital and atlantoaxial dislocations where clinicians and surgeons should indicate how to manage the proper approach to the patient. Powers ratio (PR), atlanto-dental interval (ADI), basion-dens interval (BDI), and basion-axial interval (BAI) come to the forefront to indicate these relationships in the literature.

Computerized tomography (CT) scan delineates the anatomic borders better by proper visualization of the bony cortex and this imaging technique is the modality of choice for craniocervical junction injuries.[2] On the other hand, magnetic resonance (MR) imaging reveals the integrity of the soft tissues, ligaments, and spinal cord better than CT. After the physical examination and the initial CT assessment, MR imaging is very useful to reveal any ligamentous or spinal injury after trauma, in clinically indicated patients. Even MR is considered in specific clinical situations, these intervals measured from specific landmarks of the craniocervical junction can also be observed in the field of view of MR images. The MR imaging assessment should be made in awareness of the craniocervical junction injuries and the critical intervals should also be measured during the interpretations where necessary to diagnose or consider an associated instability.

In this study, the researchers aimed to reveal the normative mean values of these critical intervals in patients without any cervical trauma, using MR images. The relationships between these intervals and age and any possible significant difference between genders were also attempted to be verified by proper statistical methods.

MATERIAL METHODS

Patients

This study was carried out in compliance with the basic principles outlined in the Declaration of Helsinki form (revised in 2013) and approved by the institutional ethics committee (Erzincan Binali Yıldırım University, Ethics Committee of Non-Interventional Research, Date: July 24, 2025- Numb: 464431). The requirement for the informed consent from each patient who participated in this study has been waived by the same ethics committee due to the retrospective nature of the study. The investigation was conducted as a retrospective, cross-sectional study and all patients who underwent lumbar MR imaging between June 1and June 30, 2025, were scanned. The study planned to find out the mean normative values of skeletally mature patients who had no cervical trauma; therefore, patients under 18 years old (n=7) and those with cervical trauma or fracture (n=23) were excluded. Considering the biomechanical alterations, 7 patients with scoliosis or kyphosis, 8 patients with spondylolisthesis, and 1 operated patient were excluded from the study. Hence, the lumbar MR images of 271 patients were included in the statistics without any possible biomechanical alterations that might influence the study results (Figure 1). All patients were measured by a radiology specialist with 8 years of experience, and the measurement results were recorded with 2 decimals after the comma. A picture archiving and communication system (Akgün PACS Viewer v7.5, Akgün Software, Ankara, Türkiye) was used to perform measurements on MR images in standard digital imaging communications in medicine formats.

Magnetic Resonance Imaging

All cervical MR images were acquired using a 1.5 tesla MR machine (Magnetom Aera, Siemens Healthcare, Erlangen, Germany). T1-weighted sagittal plane spin echo (TR [Time of repetition]: 663 ms, TE [Time of Echo]: 11 ms, FOV [Field of View]: 240 mm, Slice thickness: 3 mm, Voxel size: 0.9 × 0.9 × 3 mm; T2-weighted sagittal plane turbo spin echo (TR: 3800 ms, TE: 91 ms, FOV: 220 mm, Slice thickness: 3 mm, Voxel size: 0.7 × 0.7 × 3 mm) and T2-weighted axial plane turbo spin echo (TR: 780 ms, TE: 22 ms, FOV: 180 mm, Slice thickness: 3 mm, Voxel size: 0.4 × 0.4 × 3 mm) sequences were included in the imaging protocol. All patients were in a supine position, and all images were obtained using a neck coil with 20 channels.

Craniocervical Measurements

The T1-weighted midsagittal planes were used to measure PR, ADI, BDI, and BAI. To initiate, the interval between the basion point of the skull and the midpoint of the anterior cortex of the posterior arch of atlas (C1 vertebra) was measured. Then, the distance between the opistion point of the skull to the posterior cortex of the anterior arch of the atlas was indicated. The ratio of the first measured distance to the second interval has given the PR.[3] Atlanto-dental interval was measured as the line between the posterior edge of the anterior arch of atlas and the foremost part of the dens of axis. The distance between the most inferior edge of basion and the uppermost aspect of the dens axis was measured as BDI.[4] Basion-axial interval represented the distance between a line drawn tangentially to the posterior cortical surface of C2 and the basion[5] (Figure 2).

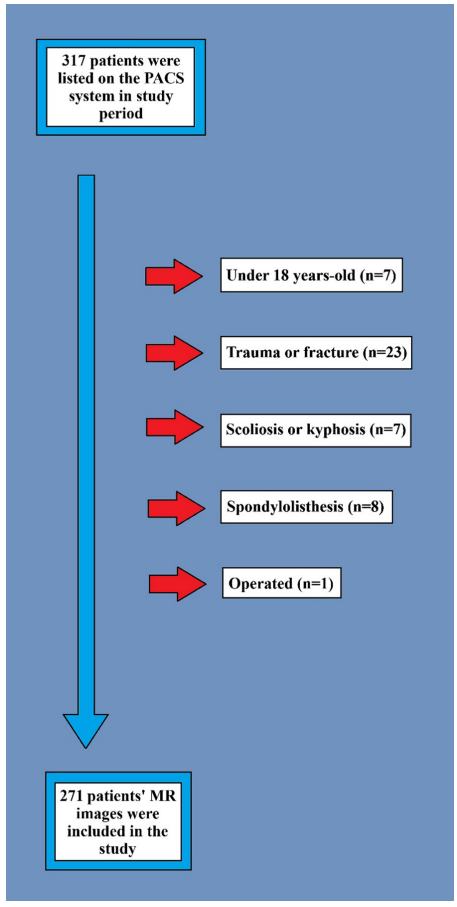

Figure 1. The workflow of the study (PACS: Picture Archiving and Communications System, MR: Magnetic Resonance).

Statistical Analysis

The statistical results of the study were performed by using IBM SPSS Statistics for Windows version 22.0 (IBM SPSS Corp.; Armonk, NY, USA). The Kolmogorov–Smirnov test was performed to determine the data distribution properties; additionally, boxplot graphics were used to represent the data distribution of the measurement results of each parameter for the total study population, females and males. The Mann–Whitney *U* tests were used to compare the results of female and male groups. The correlation between age and measurement results of each parameter, Spearman's Rho tests were carried out. The *P*-values of < .05 were considered to indicate statistical significance.

RESULTS

One hundred eighty-four females, 87 males, totally 271 patients' cervical MR images were re-assessed regarding PR, ADI, BDI, and BAI measurements. The mean age of the study population was 48.44 ±

MAIN POINTS

- This research was based on 4 critical craniocervical measurements and reveals the normative values using magnetic resonance images.
- The mean values of Powers ratio, atlanto-dental interval (ADI), basion-dens interval (BDI), and basion-axial interval were 0.76 ± 0.07, 1.14 ± 0.61 mm, 5.12 ± 1.74 mm, and 7.41 ± 2.20 mm, respectively, in this study.
- Males had higher ADI and BDI values than females according to the results of this investigation.
- Age showed a significant negative correlation regarding ADI and BDI measurements in this current research.

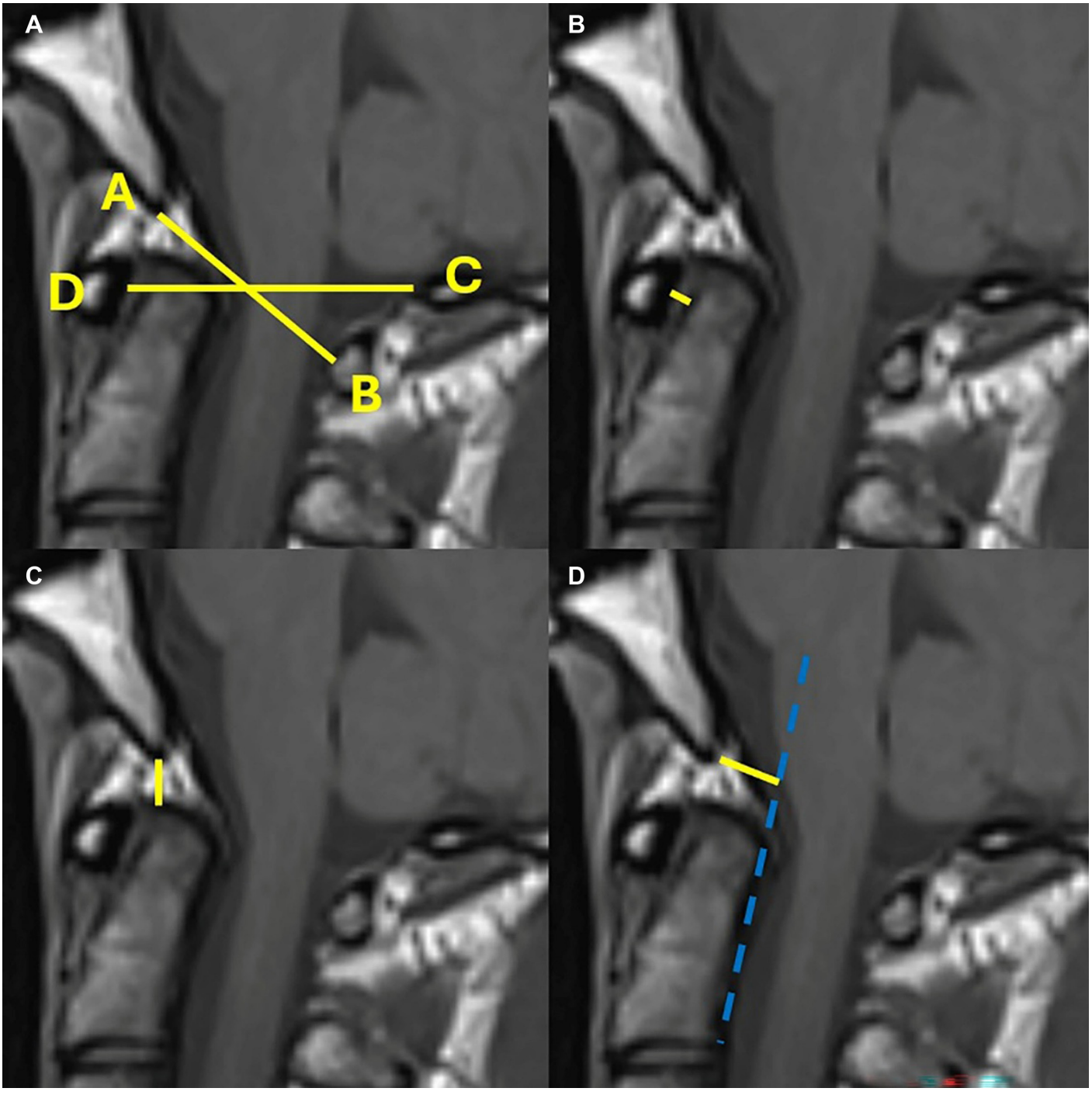

Figure 2. The distance between basion and the midpoint of the anterior cortex of the posterior arch of atlas is represented by the AB interval. The distance between the opistion to the posterior cortex of the anterior arch of the atlas is shown as the CD interval. The AB/CD ratio indicates the Powers ratio (A). The distance between the posterior edge of the anterior arch of atlas and the foremost part of the dens of axis is the atlanto-dental interval (B). The distance between the most inferior edge of basion and the uppermost aspect of the dens axis was measured as the basion-dens interval. A line drawn tangentially to the posterior cortical surface of C2 and the distance from basion to this line represented the basion-axial interval (D).

14.99. The female group was significantly older than the male group in the study population ($P = .002$) (Table 1).

The data distribution was analyzed by the Kolmogorov–Smirnov test and normal data distribution could not be reached regarding the ADI measurements. Hence, a non-parametric test (Mann–Whitney *U*) was considered to compare the results between the female and the male groups for ADI measurements. The data distribution results were shown by boxplot analyses (Figure 3).

Powers ratio and BAI indicated no significant difference between female and male groups. However, higher ADI ($P = .001$) and BDI

Table 1. Demographic Data of the Study Population

Gender (n)		Number		Percentage	
Females		184		67.9	
Males		87		32.1	
Total		271		–	
Age	**Mean**	**SD**	**Min**	**Max**	***P***
Females	50.31	15.19	18	84	**.002**
Males	44.47	13.83	18	76	
Total	48.44	14.99	18	84	–

The bold numbers indicate the significant difference.

(P = .017) values were obtained for males, compared with the female group (Table 2).

The correlation between age and PR, ADI, BDI, and BAI measurements was analyzed by Spearman's Rho tests. Age showed no significant correlation regarding PR and BAI measurements. There was a negative and moderate correlation between age and ADI, while BDI measurement results indicated a negative and very low correlation with age. According to the analyses with different gender groups, ADI revealed a negative moderate correlation for females and a negative low-level correlation for the male group regarding age (Table 3).

DISCUSSION

The study results of the current study indicated the mean values of PR, ADI, BDI, and BAI as 0.76 ± 0.07, 1.14 ± 0.61, 5.12 ± 1.74, and 7.41 ± 2.20 respectively. Female and male groups indicated a significant difference regarding ADI and BDI. Age showed a significant and negative correlation with ADI and BDI in the study population.

After the traumatic collisions or any suspicion of vertebral injuries to the head and neck region, CT is mostly considered in many health centers to investigate the abnormalities in the craniocervical junction. However, due to the superiority of MR imaging in the evaluation of the integrity of ligamentous structures in this specific location, this imaging modality is now more widely used than in the past. Before the interpretation of the cervical MR imaging, the doctors should know adequate information about patient history and be aware of the normal anatomic alignment of the osseous structures in this region. The normative values of the intervals between the critical anatomic reference points are a crucial part of the interpretation, along with the integrities of the bony and the ligamentous structures. Therefore one should be aware of the normative values of these critical intervals before the MR evaluations as well as for CT interpretations.

The upper segment cervical spinal injuries account for 56%-73% among all cervical traumas. Atlantooccipital dislocation is a serious injury associated with high mortality rates.[6] In postmortem studies, evidence of atlantooccipital dislocations has been reported in 20%-31% of deaths due to spinal injuries of the cervical region.[7] X-rays and CT scans are the most used imaging modalities for the initial screening of craniocervical junction traumas. The radiological criteria for craniocervical junction traumas have still been optimized. Harris et al's[8] method included BAI and BDI combined, was reported to be reliable in the guidelines published in 2013.[9] The PR was originally described to determine the anterior atlantooccipital injuries.[10] The normal value of the PR is less than 0.90, and this ratio is sensitive to distraction or posterior dislocation type atlantooccipital injuries.[1] On the other hand, an abnormally widened ADI is an indirect indicator of injury to the transverse atlantal ligament.[11]

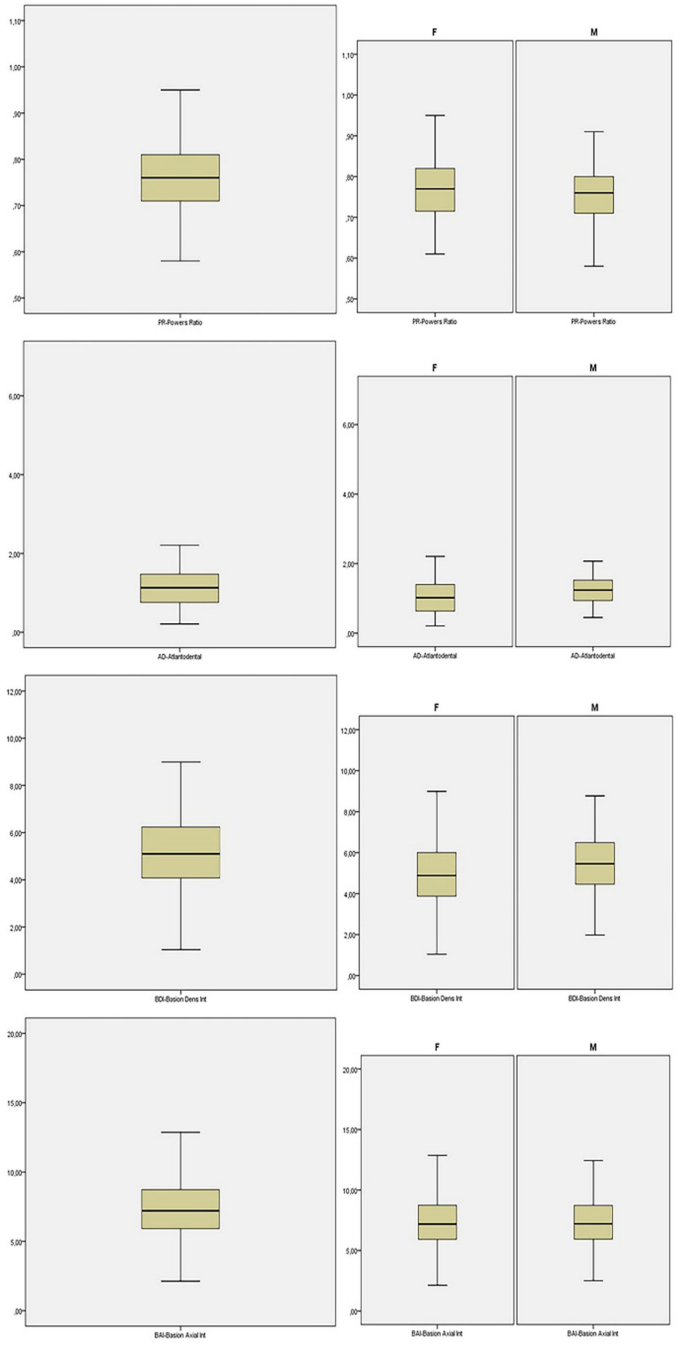

Figure 3. Boxplot graphics showing the data distribution for the total study population, females and males regarding the analysis of each parameter, Powers ratio, atlanto-dental interval (ADI), basion-dens interval (BDI), and BAI. Normal data distribution could not be reached regarding the ADI measurements (second row in the figure). Males had significantly higher ADI and BDI values than females in the study population of the research.

In a study by Martinez-del-Campo et al,[6] the patients with atlantooccipital dissociation (n=22) were compared with the control group (n=59) and performed the craniocervical measurements on CT images. The mean values of PR, BDI, and BAI were 0.71, 6.53, and 5.41, respectively, for the control group. Another study used CT images and was conducted on 200 patients examined for cervical spine injury, without osseous or soft tissue abnormality on initial CT

Table 2. The Comparison Between Females and Males Regarding Powers Ratio, Atlanto-Dental Interval, Basion-Dens Interval, and Basion-Axial Interval

	Mean	SD	*P*
PR			
Females	0.76	0.07	.397
Males	0.75	0.07	
Total	0.76	0.07	–
ADI (mm)			
Females	1.07	0.55	**.001**
Males	1.30	0.70	
Total	1.14	0.61	–
BDI (mm)			
Females	4.95	1.73	**.017**
Males	5.49	1.73	
Total	5.12	1.74	–
BAI (mm)			
Females	7.38	2.11	.794
Males	7.46	2.40	
Total	7.41	2.20	–

ADI, atlanto-dental interval; BAI, basion-axial intervals; BDI, basion-dens interval; mm, millimeter; PR, Powers ratio.

scan, and if the patients were discharged from the hospital without a diagnosis of a cervical spine injury. The mean values were 0.8, 1.3 mm, 5.7 mm, and 3.4 mm for PR, ADI, BDI, and BAI, respectively, in their study.[4] A cone-beam CT study indicated 0.72, 1.28 mm, 4.92 mm, and 4.01 mm mean values with regard to the measurements of PR, ADI, BDI, and BAI respectively.[12] Powers ratio, ADI, BDI, and BAI mean values were measured as 0.76, 1.14 mm, 5.12 mm, and 7.41, respectively.

The differences between the measured values in the current research might not be similar or close to some other researchers' studies, especially for the mean value of BAI measurement results. This might be a result of cortical irregularities regarding degenerative changes, and T1 weighted MR images might not reflect these alterations or delineate the cortical borders optimally and exaggerate the interval. On the other hand, these results may originate from the genetic differences between the study populations. Much more data obtained from the studies comparing the CT and MR results would be a lot better to verify this situation.

Table 3. The Correlation (Sperman's Rho) Analysis of Age and Powers Ratio, Atlanto-Dental Interval, Basion-Dens Interval, and Basion-Axial Interval for Total Study Population, Females and Males

		PR	ADI	BDI	BAI
Total (n = 271)					
Age	Correlation Coefficient	0.089	−0.480	−0.161	−0.075
	P	.145	**<.001**	**.008**	.216
Females (n = 184)					
Age	Correlation Coefficient	0.091	−0.531	−0.137	−0.049
	P	.221	**<.001**	.064	.511
Total (n = 87)					
Age	Correlation Coefficient	0.097	−0.233	−0.125	−0.184
	P	.370	**.030**	.248	.089

ADI, atlanto-dental interval; BAI, basion-axial interval; BDI, basion-dens interval; PR: Powers ratio,

This research was based on the 4 critical measurements to assess the craniocervical region, using MR images. Some important aspects should be considered before analyzing the results of this study. To begin with, many research results were discussed and compared with the current study results; however, some of these investigations were carried out with radiological modalities other than MR imaging. Additionally, the researchers performed measurements on T1-weighted sequences of MR imaging to depict the anatomical properties optimally. Computed tomography scan has the capacity to delineate the bony cortex and indicate the anatomical reference points better to measure the intervals. Even though the researchers aimed to underline the awareness of the morphological outcomes of the craniocervical trauma during MR image interpretations, the intervals can be measured on CT images more accurately. The data distributions of this research indicated a significant age difference between the female and the male group. Moreover, ADI results should also be discussed carefully since normal data distribution could not be reached due to the measurement results. Because of the data properties in the study population, these conditions should also be accepted as additional limitations before interpreting the results of the study.

In conclusion, MR imaging is a significant method to assess the ligamentous and spinal parameters of cervical trauma; however, to understand the secondary signal alterations of the traumatic impact one should be aware of the critical intervals to evaluate the craniocervical region better in MR image interpretations. Simple but useful parameters, which were important to make critical decisions, were measured on MR images, and the measurement results were discussed with the ranges in CT examinations to establish the normative values of MR imaging. Further studies are needed to verify these results, and these mean values and the influence of age and gender on these parameters should also be compared with the measurement results of larger series from different populations.

Data Availability Statement: The data that support the findings of this study are available on reasonable request from the corresponding author.

Ethics Committee Approval: This study is approved by the institutional ethics committee of Erzincan Binali Yıldırım University Ethics Committee of Non-Interventional Research, Date: July 24, 2025- Number: 469488).

Informed Consent: The requirement for the informed consent from each patient participating in this study has been waived by the ethics committee regarding the methodology of the research.

Peer-review: Externally peer-reviewed.

Author Contributions: Concept – B.K.; Design – B.K.; Resources – F.Ö.; Materials – F.Ö.; Data Collection and/or Processing – B.K, F.Ö.; Analysis and/or Interpretation – B.K, F.Ö.; Literature Search – F.Ö.; Writing Manuscript – B.K.; Critical Review – F.Ö.

Declaration of Interests: The authors have no conflict of interest to declare.

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