Cross-sectional Study

ANNALS OF MEDICINE & SURGERY

OPEN

Three-dimensional computed tomography analysis of the atlanto-dental interval in a healthy Karachi population: a single-center retrospective cross-sectional study

Anum Sultan, FCPS[a], Sanobar Bhugio, MD[a], Omer A. Shaikh, MBBS[b], Faizan S. Swaleh, MBBS[a], Komal Subhash, MBBS[c], Yameena N. Khan, MBBS[b], Ali Mala, MBBS[b], Md. Al Hasibuzzaman, MBBS, MPHIL[d,*]

Background: The atlantoaxial joint has a complex anatomical configuration and has a wide range of mobility. Traumatic, inflammatory, and neoplastic joint pathologies frequently affect this joint. The aim of this retrospective cross-sectional study was to evaluate the atlanto-dental intervals (ADI) in patients who underwent computed tomography (CT) scans of the neck and cervical spine in at a Tertiary Care Hospital in Karachi, Pakistan.

Methods: This was a retrospective cross-sectional study conducted at a tertiary care hospital in Karachi between 1 January 2021 and 31 December 2021, following approval from the hospital ethical review committee. Patients above the age of 15 who underwent CT scans were included, while individuals with a history of cervical trauma, infection, rheumatoid arthritis, or congenital anomalies, as well as those younger than 15 years old, were excluded. CT scans were performed using a multidetector scanner utilizing a standardized protocol. Sagittal and coronal images were reconstructed. ADI measurements, including anterior ADI (AADI), posterior ADI (PADI), and lateral ADI (LADI) on both sides, were determined using appropriate bone window settings. A radiologist with a minimum of 3 years of experience analyzed the CT scans.

Results: The mean age of the patients was 49.3 ± 17.7 years (age range: 16–85 years). The mean AADI was 1.4 ± 0.4 mm, with a range of 0.0–2.1 mm. The mean PADI was 19.1 ± 1.9 mm, with a range of 13.8–24.6 mm. The mean left LADI measurement was 3.3 ± 1.2 mm with a range of 1.2–10.0 mm, and the mean right LADI measurement was 3.2 ± 1.1 mm with a range of 1.2–6.3 mm.

Conclusion: Our study examined the ADI in patients who underwent CT scans of the neck and cervical spine in Karachi. The findings provide valuable insights into the relationship between ADI measurements, age, and sex. These results contribute to our understanding of the anatomical variations in this region, which may aid in the diagnosis and management of cervical spine disorders.

Keywords: AADI, cervical spine, CT scan, LADI, PADI

Introduction

The atlantoaxial joint is the bi-axial pivot joint between the atlas (C1) and axis (C2) cervical vertebral bodies that allows for a wide range of mobility at the cranio-cervical junction. This is attributed to the complex anatomical shape and articulation of the C1 and C2 vertebral bodies. The atlantoaxial joint comprises one medial and two lateral atlanto-dental constructing parts[1–3]. The dens of the C2 vertebral body is bounded at its anterior and lateral aspects by the atlas vertebra. It is stabilized by the transverse ligament posteriorly, which restraints the atlas up to 3 mm and limits its anteroposterior movement. Lateral rotation of the dens is limited by alar ligaments, which extend from the apex of the dens up to the lateral occipital condyles[2,3].

HIGHLIGHTS

- The atlantoaxial joint has a complicated anatomical structure and a large range of motion. This joint is commonly affected by inflammatory, traumatic, and neoplastic joint diseases, which may cause widening of the anterior and lateral atlantoaxial distance further causing it to be highly prone to instability.
- The present research aimed to investigate the relationship between the normal atlanta-dental interval (ADI) and its correlation with age and sex in an asymptomatic Pakistani population.
- The results of the study determined a significant correlation between age and ADI. While no significant relation could be identified with sex.
- The normal values of ADI were established in the Pakistani population for future reference.

[a]Department of Radiology, [b]Department of Medicine, Ziauddin University, [c]Department of Medicine, Southcity Hospital, Karachi, Pakistan and [d]Institute of Nutrition and Food Science, University of Dhaka, Dhaka, Bangladesh

Sponsorships or competing interests that may be relevant to content are disclosed at the end of this article.

*Corresponding author. Address: Institute of Nutrition and Food Science, University of Dhaka, Suhrawardi Udyan Rd, Dhaka 1000, Bangladesh. Tel.: +880 172 320 22 17; fax: +880 296 672 22. E-mail: al.hasibuzzaman.hasib@gmail.com (M.A. Hasibuzzaman).

Annals of Medicine & Surgery (2023) 85:5410–5413

Received 16 April 2023; Accepted 6 September 2023

Published online 13 September 2023

http://dx.doi.org/10.1097/MS9.0000000000001316

Due to the extensive range of movement of the head, the atlantoaxial joint is highly prone to instability[4]. Trauma, arthropathies, and neoplastic lesions frequently affect the atlantoaxial joint[5]. The most common cause of atlantoaxial instability (AAI) is trauma leading to the disruption of the transverse odontoid ligament. Over the past few decades, there have been an increasing prevalence of connective tissue, inflammatory, and hereditary disorders such as rheumatoid arthritis, systemic lupus erythematosus, Ehlers-Danlos syndrome, ankylosing spondylitis, mucopolysaccharidoses, which also contribute to AAI[6].

The instability at the atlantoaxial joint can be ascertained by measuring the atlanto-dental distance, which was defined by Hinck and Hopkins in 1960[7]. Measurements of the anterior atlanto-dental interval (AADI), posterior atlanto-dental interval (PADI), and lateral atlanto-dental interval (LADI) are frequently used to detect atlantoaxial dislocation secondary to trauma[8,9]. Diameters of AADI and PADI are of diagnostic significance in patients having neurological symptoms in rheumatoid arthritis[7]. This is due to the subluxation of the AADI due to erosion of the apical, transverse, and alar ligaments, as well as the dens of the C2 vertebra in extreme cases. This results in a narrowing of the spinal canal with reduced PADI causing compression over the spinal cord, nerves, and intraspinal arteries[5].

Computed tomography (CT) scan has superseded the radiographs in the evaluation of the atlantoaxial joint and provides the greater resolution to delineate the anatomic relationships as well as definitive bony landmarks for atlanto-dental interval (ADI) measurement[5]. Moreover, three-dimensional CT has a higher resolution in diagnosing atlantoaxial facet dislocation[10].

Considering that there are a wide spectrum of diseases and associated therapeutic implications, a comprehensive discussion on the subject is mandatory. Our objective is to evaluate the reference ranges for the AADI, PADI, and LADI in asymptomatic adult patients of the Pakistani population on multidetector computed tomography and to analyze the relationships of these measurements with age and sex.

Methods

Our study is a retrospective cross-sectional study conducted at Karachi from 1st January 2021 to 31st December 2021 after obtaining approval from the hospital ethical review committee. All the patients above the age of 15 who underwent CT scans of the neck and cervical spine were included in this study. Patients younger than the age of 15, having a history of cervical trauma, infection, rheumatoid arthritis, and patients with congenital anomalies were excluded from the study. All examinations were performed on a multidetector Asteion 16 (Toshiba, Japan). The CT protocol included scanning from the base of the skull to the lung apices. Axial slices were obtained with a slice thickness of 2 mm, the pitch of 2, at 120 kvp, 250 mAs, and a medium field of view. The sagittal and coronal images were reconstructed. CT scans were analyzed by a radiologist having at least 3 years of experience. The AADI, PADI, and LADI on either side were measured using appropriate bone windows settings which were taken as follows:

AADI: horizontal distance between the anterior arch of the atlas and the odontoid process of the axis on a midsagittal CT image[11].

PADI: distance between the posterior surface of the dens and the anterior margin of the posterior arch of the atlas on a midsagittal CT image[11].

LADI: distance between the lateral mass of the C1 vertebra at its mid part and dens measured in the coronal plane on both right and left sides[11].

Data was recorded and analyzed using IBM SPSS Statistics for Windows, Version 25.0 (IBM Corp.). The division of patients according to their ages and sex was established. Frequency and percentage for age and sex, and means and SD for AADI, PADI, as well as LADI on the right and left sides were calculated. The correlation of AADI, PADI, and right and left LADI with age and sex was also determined. The Pearson correlation coefficient was used to calculate the relationship between age and ADIs, and the independent samples *t*-test was used to compare ADIs in males and females. A *P*-value of less than 0.05 was considered significant. Our study has been reported in line with the STROCCS criteria[12].

Results

A total of 103 patients were included in this study. There were 67 (65.0%) males and 36 (35.0%) females. The mean age of patients was 49.3 ± 17.7 years (age range: 16–85 years). The measurement of AADI ranges from 0.0–2.1 mm with an overall mean of 1.4 ± 0.4 mm. The mean AADI in males was 1.4 ± 0.3 mm and in females, it was 1.3 ± 0.4 mm. The PADI ranges from 13.8–24.6 mm with an overall mean of 19.1 ± 1.9 mm. In males, the mean PADI was 19.2 ± 1.8 mm while in females, it was 19.0 ± 2.1 mm. The right LADI ranges from 1.2–6.3 mm with an overall mean of 3.2 ± 1.1 mm. The mean right LADI in males and females was 3.2 ± 1.1 mm and 3.1 ± 1.0 mm, respectively. Left LADI ranges from 1.2–10.0 mm with an overall mean of 3.3 ± 1.2 mm. In males, the mean left LADI was 3.5 ± 1.4 mm while in females it was 3.0 ± 0.9 mm. There is a significant statistical correlation of AADI with age ($P = 0.000$). No statistical significance was noted between PADI, right LADI, and left LADI, and the age of the patient. There was no statistical difference between AADI, PADI, and right LADI when comparing males and females. However, there is a statistically significant difference between left LADI in males and females ($P = 0.03$). The measurement ranges, means, and SD of the ADIs are given in Table 1. Figure 1 shows AADI, PADI, and right and left LADI.

Table 1

Measurement range of AADI, PADI, and right and left LADI, their overall mean, SD, and sex stratified mean, SD, and *P*-values

	Range (mm)	Overall Mean + SD (mm)	Males Mean + SD (mm)	Females Mean + SD (mm)	*P*
AADI	0.0–2.1	1.4 + 0.4	1.4 + 0.3	1.3 + 0.4	0.532
PADI	13.8–24.6	19.1 ± 1.9	19.2 + 1.8	19.0 + 2.1	0.483
Right LADI	1.2–6.3	3.2 ± 1.1	3.2 + 1.1	3.1 + 1.0	0.609
Left LADI	1.2–10.0	3.3 ± 1.2	3.5 + 1.4	3.0 + 0.9	0.032

AADI, anterior atlanto-dental interval; LADI, lateral atlanto-dental interval; PADI, posterior atlanto-dental interval.

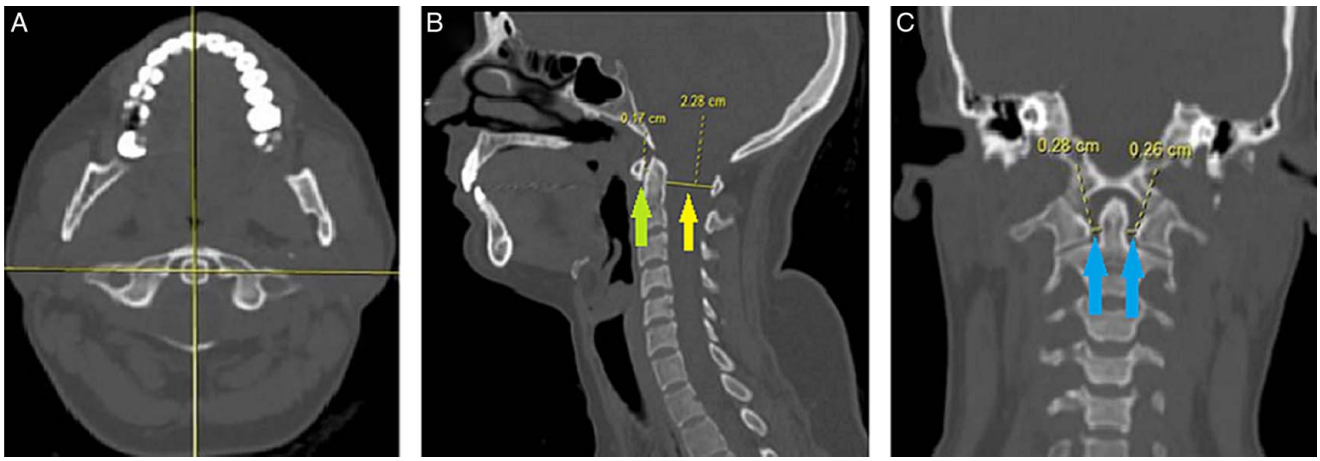

Figure 1. CT scan axial (A), sagittal (B) and coronal (C) bone window images showing AADI (green arrow), PADI (yellow arrow) and right and left LADI (blue arrows). AADI, anterior atlanto-dental interval; CT, computed tomography; LADI, lateral atlanto-dental interval; PADI, posterior atlanto-dental interval.

Discussion

It is important to identify cervical instability in clinical practice, for which imaging plays a crucial role. Apart from trauma and congenital etiologies causing AAI, vitamin deficiency, malnutrition especially related to protein deficiency and excessive alcohol consumption can also lead to AAI[13]. In clinical practice, narrowing of the PADI does not necessarily mean that there is a neurological deficit or compromise but there is a great risk of vascular compromise of vital vessels like the vertebral artery in the absence of neurological compromise. If there is no neurological compromise, the joint instability may be reversed[5]. The most reliable tool for the displacement of the atlantoaxial joint is AADI as determined by the study conducted by Coutts in 1934[13]. Concerning the LADI, if it persists even after correction, then this implies rotatory fixation of the atlantoaxial joint[14]. Due to the complexity of the atlantoaxial junction, CT has been widely used for proper assessment as conventional radiography in this regard is insufficient[7]. This study determines the variation of ADI related to age on MDCT, which is highly accurate as we take measurements from cortex to cortex and there are no problems of magnification as encountered in X-rays[5]. To our knowledge, the AADI, PADI, and LADI have not been measured in the Pakistani population.

Previous studies by Chen *et al.*[14] and Omercikoglu *et al.*[15] showed a statistically significant difference in measurements of AADI between males and females. According to Chen *et al.*, AADI was significantly greater in males than in females with a *P*-value of 0.05. Their study showed the 95% CI for AADI was 1.2–2.7 mm in male and 1.1–2.3 mm in females; however, no statistical significance is noted between sex when comparing right and left LADI[14]. Another study by Liu *et al.*[16] mentioned that sex has no effect on the measurements of ADI. Interestingly, while our study shows no statistically significant difference in AADI, PADI, right LADI between males and females in concordance with other published studies, it differs from the available literature by showing a statistically significant difference in left LADI between males and females.

Studies by Liu *et al.*[16] and Osmotherly *et al.*[17] found a negative correlation between ADI and age. According to the results of the study by Osmotherly *et al.*, the AADI tends to decrease from 2.07 to 0.85 mm with increasing age ($P < 0.01$); however, various disorders such as rheumatoid arthritis, trauma, and degeneration also tends to increase the AADI[17]. The results of our study, however, showed that there was a positive correlation between age and AADI. In our study, the mean AADI in males was $1.4 + 0.4$ mm and in females, it was $1.3 + 0.4$ mm.

This may be attributed to the cervical spine degeneration leading to pannus formation with the advancing age of the patient as described by Joyce *et al.*[18]. However, further research for the measurement of AADI in the elderly population is needed as our study includes a small sample of elderly patients.

There was slight asymmetry in measurements of right and left LADI in our study; however, it shows an insignificant *P*-value of 0.81 and 0.09, respectively, between males and females. This asymmetry in right and left LADI may be attributed to normal congenital variation as described by Harty *et al.*[19] who states that 32% of patients has asymmetrical LADI. Studies by Lee *et al.*[20], Ellis GL[21], and Sutherland *et al.*[22] has also described that asymmetry in LADI may present as a normal radiographic finding and is not necessarily indicative of cervical instability if it is unrelated to trauma. However, careful evaluation of LADI is mandatory in post-traumatic patients since it may be the only indicator of cervical injury leading to instability and extensive evaluation of cervical ligaments with an MRI examination is vital in such cases.

Our study had several limitations, which must be acknowledged. Foremost amongst these is our small sample size, which may impact the confidence with which we can report our results. Our patients were also not stratified according to ethnic groups, which prevented us from accurately reporting the variations in ADIs across our diverse patient population. Moreover, our study was conducted at a single center, which also limits the variation in patient population with respect to patient ethnicity and socioeconomic background.

Despite these limitations, our study still provides important insights into the variations in the measurements of the atlantoaxial joint in our patient population, where the patient demographic widely differs from other parts of the world.

Conclusion

There was no significant difference between males and females in the measurements of AADI, PADI, and right LADI; however, our results showed a significant difference between males and females in left LADI. Furthermore, increasing age has a significant correlation with increasing AADI. Further studies need to be conducted in the Pakistani population to establish the veracity of our results.

Ethical approval

Ethical approval was taken from the institutional approval from Ethical review committee dated 12 November March 2022. Reference Code: 4890222SBRAD.

Consent

Written informed consent was obtained from the patient for publication of this case report and accompanying images. A copy of the written consent is available for review by the Editor-in-Chief of this journal on request.

Sources of funding

No source of funding.

Author contribution

A.S. and S.B., and M.A.H.: administration and methodology; A.S., S.B., O.A.S., F.S.S., K.S., Y.N.K., A.M., and M.A.H.: literature search and manuscript preparation; M.A.H.: conceptualization, methodology, and supervision.

Conflicts of interest disclosures

The author(s) declared no potential conflicts of interest concerning the research, authorship, and/or publication of this article.

Research registration unique identifying number (UIN)

1. Name of the registry: not applicable.
2. Unique identifying number or registration ID: not applicable.
3. Hyperlink to your specific registration (must be publicly accessible and will be checked): not applicable.

Guarantor

Md. Al Hasibuzzaman.

Data availability statement

Data analyzed in the study is original data from institution and cannot be shared openly to protect study participant privacy.

Provenance and peer review

Not applicable.

References

[1] Forbes J, Das JM. Anatomy, head and neck, atlantoaxial joint. [Updated 2022 Aug 29]. In: StatPearls [Internet]. Treasure Island (FL): StatPearls Publishing; 2023. https://www.ncbi.nlm.nih.gov/books/NBK563271/
[2] Guenkel S, Scheyerer MJ, Osterhoff G, *et al*. It is the lateral head tilt, not head rotation, causing an asymmetry of the odontoid-lateral mass interspace. Eur J Trauma Emerg Surg 2016;42:749–54.
[3] Lopez AJ, Scheer JK, Leibl KE, *et al*. Anatomy and biomechanics of the craniovertebral junction. Neurosurg Focus 2015;38:2.
[4] Goel A. A review of a new clinical entity of 'central atlantoaxial instability': expanding horizons of craniovertebral junction surgery. Neurospine 2019;16:186.
[5] Yoon K, Cha SW, Ryu JA, *et al*. Anterior atlantodental and posterior atlantodental intervals on plain radiography, multidetector CT, and MRI. J Korean Soc Radiol 2015;72:57–64.
[6] Henderson FC, Rosenbaum R, Narayanan M, *et al*. Atlanto-axial rotary instability (Fielding type 1): characteristic clinical and radiological findings, and treatment outcomes following alignment, fusion, and stabilization. Neurosurg Rev 2020;4:1–6.
[7] Hinck VC, Hopkins CE. Measurement of the atlanto-dental interval in the adult. Am J Roentgenol Radium Ther Nucl Med 1960;84: 945–51.
[8] Meyer C, Bredow J, Heising E, *et al*. Rheumatoid arthritis affecting the upper cervical spine: biomechanical assessment of the stabilizing ligaments. Biomed Res Int 2017;2017:6131703.
[9] Eran A, Yousem DM, Izbudak I. Asymmetry of the odontoid lateral mass interval in pediatric trauma CT: do we need to investigate further? AJNR Am J Neuroradiol 2016;1:176–9.
[10] Duan S, Huang X, Lin Q, *et al*. Clinical significance of articulating facet displacement of lateral atlantoaxial joint on 3D CT in diagnosing atlantoaxial subluxation. J Formos Med Assoc 2007;106:840–6.
[11] Gupta PP, Dhok AM, Shaikh ST, *et al*. Computed tomography evaluation of craniovertebral junction in asymptomatic central rural Indian population. J Neurosci Rural Pract 2020;11:442.
[12] Mathew G, Agha R. for the STROCSS Group. STROCSS 2021: strengthening the reporting of cohort, cross-sectional and case-control studies in surgery. Int J Surg 2021;96:106165.
[13] Coutts MB. Atlanto-epistropheal subluxations. Arch Surg 1934;29: 297–311.
[14] Chen Y, Zhuang Z, Qi W, *et al*. A three-dimensional study of the atlantodental interval in a normal Chinese population using reformatted computed tomography. Surg Radiol Anat 2011;1:801.
[15] Omercikoglu S, Altunbas E, Akoglu H, *et al*. Normal values of cervical vertebral measurements according to age and sex in CT. Am J Emerg Med 2017;35:383–90.
[16] Liu K, Xie F, Wang D, *et al*. 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 2015;56:465–70.
[17] Osmotherly PG, Farrell SF, Digby SD, *et al*. The influence of age, sex, and posture on the measurement of atlantodental interval in a normal population. J Manipulative Physiol Ther 2013;36:226–31.
[18] Joyce AA, Williams JN, Shi J, *et al*. Atlanto-axial Pannus in patients with and without rheumatoid arthritis. J Rheumatol 2019;1:1431–7.
[19] Harty JA, Lenehan B, O'Rourke SK. Odontoid lateral mass asymmetry: do we over-investigate? Emerg Med J 2005;22:625–7.
[20] Lee S, Joyce S, Seeger J. Asymmetry of the odontoid-lateral mass interspaces: a radiographic finding of questionable clinical significance. Ann Emerg Med 1986;15:1173–6.
[21] Ellis GL. Imaging of the atlas (C1) and axis (C2). Emergency medicine clinics of North America. Ann Emerg Med 1991;9:719–32.
[22] Sutherland JP Jr, Yaszemski MJ. White 3rd AA.: radiographic appearance of the odontoid lateral mass interspace in the occipitoatlantoaxial complex. Spine 1995;20:2221–5.