

It is the lateral head tilt, not head rotation, causing an asymmetry of the odontoid-lateral mass interspace

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Abstract

Objective Asymmetry in odontoid-lateral mass interspace in trauma patients is a common finding that regularly leads to additional diagnostic work-up, since its dignity is not entirely clear. There is little evidence in the literature that atlantoaxial asymmetry is associated with C1–C2 instability or (sub) luxation. Asymmetry in odontoid-lateral mass interspace seems to occur occasionally in healthy individuals and patients suffering a cervical spine injury. Congenital abnormalities in odontoid-lateral mass asymmetry may mimic an atlantoaxial asymmetry. The center of C1–C2 rotation is based in the peg of dens axis; therefore, a C1–C2 rotational influence seems unlikely. So far, no study examined the influence of C0–C1–C2 tilt to an asymmetry in odontoid-lateral mass interspace.

Subjects and methods In order to determine if rotation or tilt influences the lateral atlantodental interval (LADI) and to estimate physiologic values, we examined 300 CT scans of the cervical spine.

Results The mean LADI was 3.57 mm and the mean odontoid-lateral mass asymmetry was 1.0 mm. Head position during CT examination was found to be rotated in 39 % of the cases in more than 5°. Subsequent mean C0/C2 rotation was 4.6°. There was no significant correlation between atlantoaxial asymmetry and head rotation ($p = 0.437$). The average tilt of C0–C1–C2 was found to be 2°. We found a significant correlation between tilt of C0–C1–C2 and asymmetry in odontoid-lateral mass interspace ($p = 0.000$).

Conclusion We conclude that an atlantoaxial asymmetry revealed in CT scans of the cervical spine occurs occasionally. Since head tilt correlates with an atlantoaxial asymmetry, it is crucial to perform cervical spine CT scans in a precise straight head position.

Keywords Asymmetry · Atlantoaxial · LADI · Odontoid-lateral mass interspace · Head rotation, head tilt · Cervical spine injury

Introduction

When examining CT scans of the upper cervical spine, some considerations need to be made. The anatomic shape of the C0–C1–C2 complex is unique. Head rotation is initiated and has the highest range of motion in this area [1–3]. The odontoid apex is controlled anteriorly and laterally in a bony guidance of the atlas. Anterior posterior movement in the atlantoaxial joint is stabilized by strong transverse ligaments and the joint capsule. Laterally, the bony arch of the atlas controls the odontoid position [3]. Excessive rotation is prevented by the alar ligaments running from the apex of odontoid to the lateral occipital processes. Normal range of rotation is about 40° [4].

Additionally, the space of vertebral artery and sometimes the medullary canal narrows in C0–C1–C2 movement [5]. Normally, this may not cause neurogenous symptoms because the vessels are in some range mobile and the spinal canal has the widest diameter in C1 and C2. [6–16]. In cases of congenital abnormalities, the space for vertebral arteries or the spinal cord may be affected. [6, 17].

It is believed that atlantodental interval asymmetry arises as a result of pathologic atlantoaxial rotation [22]. Furthermore, Atlas fractures occur in 2–13 % of all cervical spine

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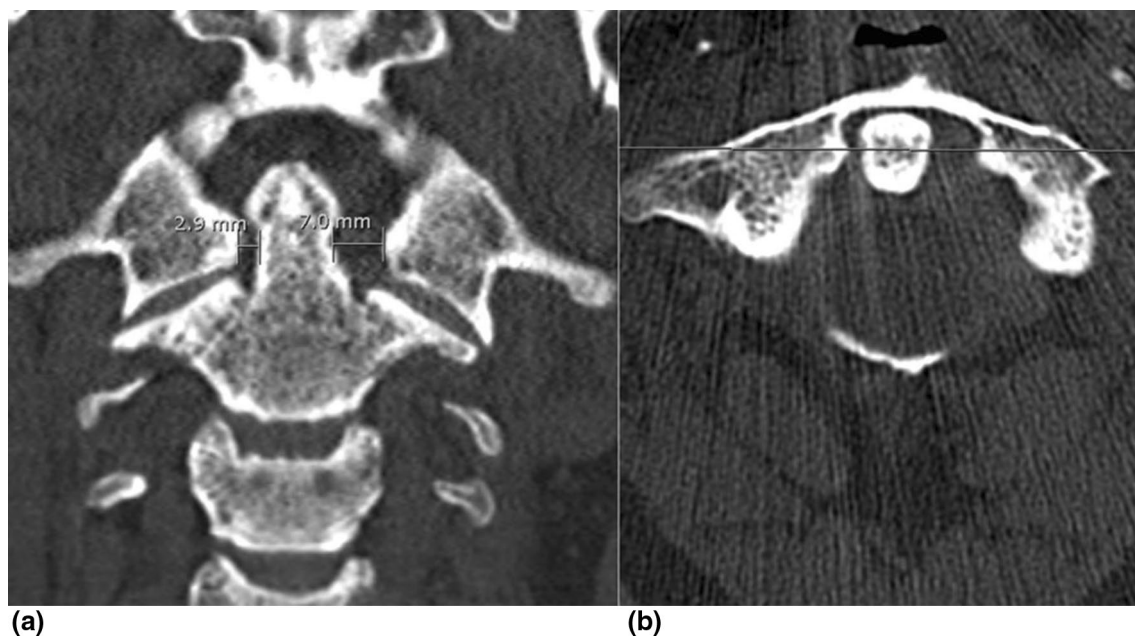


Fig. 1 Example for LADI measurement displaying a typical LADI asymmetry of 4.1 mm; **a** measurement in coronal CT reconstruction, **b** scout in axial CT reconstruction

fractures, whereas axis fractures up to 20 % [1–3, 25–28]. There is evidence that odontoid-lateral mass interspace asymmetry may yield as a sign for spinal injuries such as luxation and instability [14–16, 19, 20]. It is important to distinguish the atlantodental interval (ADI) in the right plane. While in lateral X-rays or sagittal CT reconstructions, increased ADI is accepted as a clear pathologic sign [29–31], in open-mouth X-ray anterior posteriorly or in coronal CT reconstructions clinical relevance of increased ADI, specifically lateral ADI (LADI) remains unclear [31]. To our knowledge, the correlation between LADI asymmetry and lateral head tilt is not investigated so far. Therefore, altered radiological findings and their clinical relevance are important to understand.

To determine the correlation and the clinical relevance between head rotation, lateral head tilt, and atlantoaxial asymmetry, we analyzed 300 consecutive cervical CT scans of patients without cervical spine fractures in a single institution. Physiologic values of lateral atlantodental interval (LADI) were to be identified. The hypothesis is that C0–C1–C2 rotation does not cause asymmetry in odontoid-lateral mass interspace but lateral head tilt does.

Materials and methods

The institutional review board approved this retrospective study waiving the need for patient consent.

We retrospectively reviewed 300 consecutive cervical CT scans from our adult trauma patient population without cervical spine injuries. Multiplanar CT reconstructions (axial and coronal) in 1.5 mm slices were evaluated. CT imaging was performed by the department of radiology (Siemens Somatom Definition Dual Source). For each subject, the LADI of the left and right sides, the rotation of the occiput, atlas vertebra and axis vertebra, and the tilt of occiput and axis vertebra were measured.

LADI distances were measured in coronal reconstructions, and the left/right differences were calculated (Fig. 1).

Angles of rotation of the occiput, of atlas and axis vertebrae, were measured in axial reconstructions in correlation to a vertical reference line (perpendicular to CT table), and the differences of angles between C0, C1, and C2 were calculated (Fig. 2). The lateral head tilt was measured in coronal CT reconstructions. For C0 lateral tilt, a line between the most caudal points of the occipital condyles was drawn and the angle to a reference line (parallel to CT table) was calculated. C2 lateral tilt was measured by determination of the angle between the horizontal centerline of axis vertebrae and a reference line (parallel to CT table). The differences of angles were calculated, respectively (Fig. 3).

Data were collected and the statistical analyses were performed by an institutional statistician using SPSS software (version 20). Correlation was tested by linear regression. A p value <0.05 was considered statistically significant.

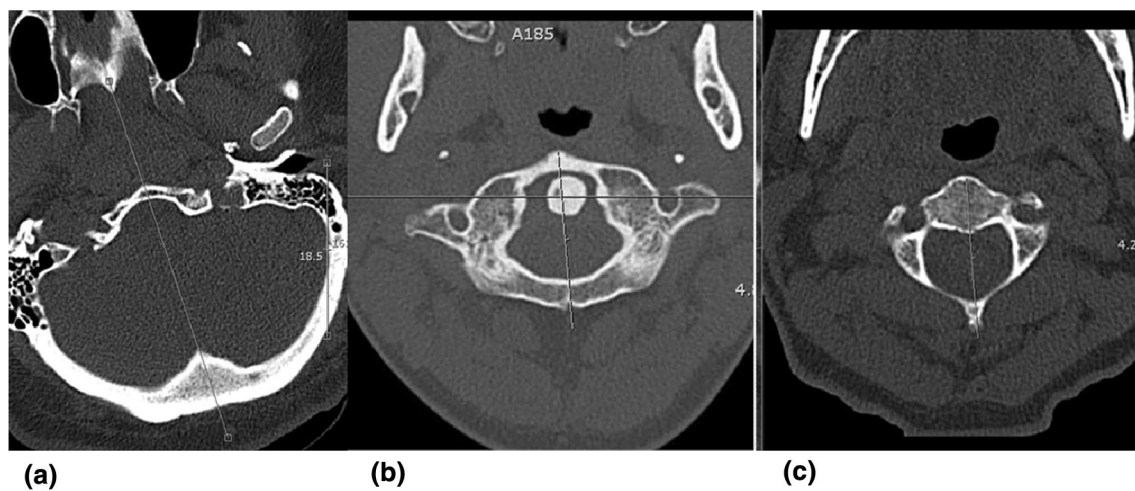


Fig. 2 Example for head rotation measurement of C0, C1, and C2 vertebrae, **a** measurement of rotation head centerline (C0) to table, **b** measurement of rotation atlas centerline (C1) to table, **c** measurement of rotation axis centerline (C2) to table

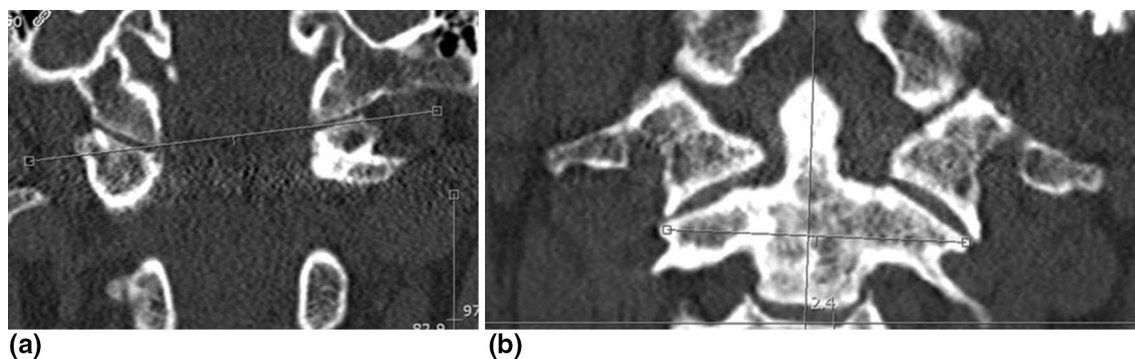


Fig. 3 Example for lateral head tilt measurement of C0 and C2 vertebrae, **a** measurement of occipital tilt, *line* between the most caudal points of the occipital condyles, **b** measurement of axis vertebra tilt, *horizontal centerline* of axis vertebrae

Table 1 LADI

	LADI left	LADI right	LADI left/right	LADI asymmetry
Total mean (mm) 95 % confidence interval	3.63 (3.51–3.74)	3.51 (3.39–3.64)	3.57 (3.58–3.87)	0.96 (0.87–1.05)
Male mean (mm) 95 % confidence interval	3.75 (3.61–3.89)	3.70 (3.54–3.86)	3.72 (3.58–3.87)	0.96 (0.84–1.08)
Female mean (mm) 95 % confidence interval	3.42 (3.23–3.61)	3.18 (3.00–3.37)	3.30 (3.11–3.49)	0.96 (0.81–1.10)

Results

CT records of 300 consecutive uninjured patients were analyzed. The patient age ranged between 16 and 98 years, mean age was 52 years, and 63 % of the patients were male.

The mean LADI was 3.6 mm (ranging from 1.2 to 8.3 mm). In male patients, mean LADI was found to be 3.7 mm and in female was 3.3 mm.

The mean odontoid-lateral mass asymmetry was 1.0 mm (Table 1).

We found that the head of the evaluated trauma patients during CT examination was in 39 % of the cases rotated more than 5° to one side (16 % to the left; 23 % to the right). The mean head rotation in relation to the CT table was 5.0°. Subsequent mean rotation between C0 and C2 was 4.6° (Table 2). There was no significant correlation

Table 2 Rotation

	Head to CT table rotation	C0–C1 rotation	C1–C2 rotation	C0–C2 rotation
Total rotation (mm) 95 % con- fidence interval	5.0 (4.5–5.5)	2.1 (1.9–2.4)	4.4 (4.0–4.8)	4.6 (3.39–3.64)

Table 3 Tilt

	Tilt of C0/C2
Total tilt (°) 95 % confidence interval	2.1 (1.9–2.3)
Male mean tilt (°) 95 % confidence interval	2.0 (1.8–2.3)
Female mean tilt (°) 95 % confidence interval	2.2 (1.8–2.6)

Table 4 Statistical correlation depending on variable LADI

	Std. error	Beta	<i>t</i>	Sig.
Difference tilt	0.024	0.354	6.530	0.000
Difference rotation	0.013	0.045	0.770	0.437

p values less than 0.05 are considered significant

between LADI asymmetry and head rotation ($p = 0.437$; Tables 2 and 4).

The average tilt of C0 to C2 was found to be 2.1° (ranging from 0° to 9.5° , Table 3). We could find a significant correlation between a tilt of C0–C2 and an asymmetry in odontoid-lateral mass interspace ($p < 0.001$; Table 4). Furthermore, 1° of lateral tilt leads to 0.35 mm of LADI asymmetry.

Linear regression analysis showed that tilt to be an independent factor to influence LADI asymmetry.

Discussion

In this study, we found that LADI asymmetry is not depending on rotation but on lateral head tilt. This is in contrast to the findings of some authors who found that there might be a dependency of head rotation and asymmetry in odontoid-lateral mass interspace [10, 12, 19]. One possible explanation is that in none of the studies lateral head tilt was analyzed.

Till today, biomechanics of upper cervical spine is not completely understood. The center of rotation between C1 and C2 is proven to be situated in the odontoid peg, probably in the middle to posterior third [5, 18]. These findings suggest a mainly symmetric rotation in the upper cervical spine and therefore an unlikely cause of asymmetry in odontoid-lateral mass interspace, at least in a physiologic range. Movement of C0–C1–C2 is probably more complex

because the osseous and ligamentous guidance allows a three-dimensional motion.

Many studies examined the atlantoaxial joint. Formerly plain radiographs in open-mouth technique anterior posteriorly and laterally were used to examine the upper cervical spine. The literature reveals dissension about the clinical significance of radiological alterations in X-rays [5, 10–15, 19–21].

Older studies suggest that fractures as well as dislocations and subluxations could be found in plain X-rays [14–16]. In more recent studies, modern tools such as CT and MRI were used for diagnostics and in order to understand biomechanics of the upper cervical spine. Most of them stated that some asymmetry in odontoid-lateral mass interspace is physiological and without pathological relevance. [8, 10, 13].

Normal values of lateral atlantodental interval (LADI) and LADI asymmetry remain uncertain.

Some authors postulate LADI asymmetry to serve as a sign for atlantoaxial instability [19, 22]. Since the atlantoaxial joint is one of the most active parts in the human body, it is responsible for the most part of neck rotation [1, 2]. This mobility makes it prone to injuries, e.g., sometimes fixed (sub) luxation or instabilities [3]. The atlantoaxial movement ranges from physiologic head rotation to pathologic atlantoaxial rotatory displacement. The higher energy a trauma causes and the more rotation occurs, the more likely the C0–C1–C2 complex injures. Soft tissues, ligaments, and joint capsule might tear and potential fractures may be found. When the alar ligaments are disrupted, non-physiological C0–C1–C2 movement is possible. In these conditions, subluxation or total luxation in the facet joints leads to torticollis and sometimes fixed head rotations [21, 23, 24].

In the past, the phenomenon of atlantoaxial asymmetry was found first in plain anterior posterior open-mouth radiographs. It was believed that LADI asymmetry and the lateral overriding of the C1–C2 joint on one side are signs for atlantoaxial rotatory subluxation or fixation [14–16]. Ajmal et al. stated, that an atlantoaxial asymmetry in the open-mouth view may be a sign of cervical injury, although it has a low sensitivity and specificity for true subluxation or instability and recommend a further CT evaluation [19].

To rule out atlantoaxial asymmetry as pathologic finding, studies with radiographs from cadaveric cervical spines were taken in different head rotations. The found atlantoaxial asymmetries, even in neutrally positioned necks, indicated a low prognostic value for instability [12]. This agrees with our data.

A variety of anatomical diversities in the upper cervical spine seems to be physiological [7, 13, 17]. LADI differs widely among the population. We found a range of LADI from 1.2 to 8.3 mm. In our patient cohort, mean LADI asymmetry was almost 1 mm. This is consistent with the

recently published literature, where the range of asymmetry in odontoid-lateral mass interspace in a healthy population was found to lie between 0 and 3.7 mm with a mean asymmetry of less than 1 mm [8].

Furthermore, a congenital odontoid-lateral mass asymmetry may mimic an atlantoaxial asymmetry and has an incidence of about 1 % [13]. Therefore, we agree with the majority of recent literature that an asymmetry in odontoid-lateral mass interspace in properly open-mouth X-rays and axial CT scans appears to be incidental [7–13]. Nevertheless, in patients with cervical spine injuries an occult fracture may be present, if they show symptomatic findings and radiologic signs of LADI asymmetry. We experienced a situation with a patient who presented with a congenital posterior atlas arch defect and an atlas ring fracture after cervical spine trauma. Because of LADI asymmetry in open-mouth X-ray, we further examined the cervical spine with CT scans and diagnosed the unstable fracture [32].

To our knowledge, lateral tilt has not been investigated to correlate with LADI asymmetry so far. In our analysis, we found the occurrence of asymmetry in odontoid-lateral mass interspace depending on lateral head tilt. It seems as odontoid-lateral mass interspace widens on the side, where the head is tilted to. Since the correlation is significant among 300 CT scans, we emphasize to position patients with an absolute upright position during CT diagnostic.

C0–C1–C2 motion is very complex in three dimensions. We studied the correlation between LADI asymmetry and head position in each single plane. Statistical analysis showed head tilt to be an independent factor for LADI asymmetry. It therefore has an influence on LADI asymmetry in a straight head rotation and in combination with head rotation. In many cases, the head was not only tilted but also rotated. Other phenomena may additionally influence LADI asymmetry.

Conclusion

Lateral head tilt correlates with an asymmetry in odontoid-lateral mass interval. In trauma patients susceptible for cervical spine lesions with a suspect LADI asymmetry, we recommend to exclude a lateral head tilt during diagnostic. LADI asymmetry in combination with present clinical symptoms and elimination of lateral head tilt may require further diagnostic work-up.

Compliance with ethical standards

Conflict of interest Dr. Sebastian Guenkel, Dr. Max Joseph Scheyerer, PD. Dr. Georg Osterhoff, Prof. Dr. Guido A Wanner, Prof. Dr. Hans-Peter Simmen, and Prof. Dr. Clement ML Werner declare that they have no conflict of interest.

Ethical standards By compliance with ethical requirements, the approval was waived by the institutional ethical committee.

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