

Clinical Significance of Articulating Facet Displacement of Lateral Atlantoaxial Joint on 3D CT in Diagnosing Atlantoaxial Subluxation

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Background/Purpose: To improve the recognition of articulating facet displacement of lateral atlantoaxial joint (AFDLAJ), and to evaluate the significance of AFDLAJ in diagnosing atlantoaxial subluxation.

Methods: The three-dimensional computed tomography (3D CT) imaging findings of 54 patients with atlantoaxial subluxation were retrospectively analyzed, and the imaging features of AFDLAJ were discussed. All the patients were examined in neutral position, and 25 in an additional rotary position. 3D images of the atlantoaxial joints were obtained by surface shade display and volume rendering. The diagnostic results of 3D CT, routine CT and X-ray were compared.

Results: All the 54 patients with atlantoaxial subluxation were correctly diagnosed by 3D CT with no suspicious or missed diagnoses, including 38 cases of rotatory subluxation, 11 of anterior subluxation and five of posterior subluxation. AFDLAJ was found in all the 54 patients in neutral position, with the extent of subluxation between 2.0 mm and 9.0 mm. Among the 25 cases in rotary position, rotational fixation was found in 10 cases and rotational asymmetry in 15. The diagnostic accuracy of 3D CT was higher than that of X-ray or routine CT.

Conclusion: Once AFDLAJ appears in neutral position and rotational fixation or asymmetry in rotary position, atlantoaxial subluxation can be ascertained, as well as the type and extent of subluxation, and fake subluxation due to the head's rotation or normal lateralized odontoid can be excluded. AFDLAJ is a vital direct sign in diagnosing atlantoaxial subluxation. [*J Formos Med Assoc* 2007;106(10):840–846]

Key Words: atlantoaxial joint, computed tomography, computer-assisted, image processing, subluxation, X-ray

Conventional X-ray (X-ray), routine computed tomography (RCT) and magnetic resonance imaging (MRI) are common imaging examinations for atlantoaxial subluxation, whose major signs are widened atlantodental interval (ADI) and lateralized odontoid (LO). However, suspicious or missed diagnoses are likely with these examination methods.^{1–5} Recent studies reported that another sign of dislocation—articulating facet displacement of lateral atlantoaxial joint (AFDLAJ)—can be demonstrated with three-dimensional CT (3D

CT), and the diagnostic accuracy can be improved if AFDLAJ is shown.^{3,6,7} In this article, we report the results of a clinical study on AFDLAJ and evaluate its application.

Methods

Between June 1998 and March 2006 in our hospital, there were 54 patients with atlantoaxial subluxation that was verified by surgery (operating

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from the front or lateral, the surgeon could directly see the AFDLAJ; from the back, the structural relaxation and distortion of joint capsules and the change in relationship between the posterior arch of C1 and the spinous process of C2 could be seen) or clinical evidence (clinical symptoms, physical signs of atlantoaxial subluxation, imaging findings). There were 26 males and 28 females, with a mean age of 29.4 years (range, 6–63 years). Thirty-four cases were caused by trauma, while the other 20 had no history of trauma. The duration of cervicodynia and/or movement limitation ranged from 1 day to 5 years.

Examination method

All 54 patients were examined by 3D CT in neutral position, and 25 in an additional rotary position; 15 were re-examined in neutral and rotary positions after treatment. In neutral position, the patient lay in supine position with the sagittal plane of the head and Reid's line perpendicular to the horizontal, and then a topogram of the cervix in lateral view was made. The atlantoaxial joint was scanned with the scanning plane perpendicular to the articular facet of the atlantodens joint, with the scanning range inclusive of the atlas (C1) and axis (C2). In rotary position, the patient turned his/her head to the right and then left as far as possible and stayed fixed in that position. The atlantoaxial joint was again scanned with the same parameters as those in neutral position. Of the 54 cases, 41 were further examined by RCT and 13 by X-ray.

The examination equipment and scanning parameters used in 39 cases were a spiral CT scanner (Somatom Plus 4; Siemens, Erlangen, Germany) and workstation with 3D imaging software (SUN Magic View 1000), scanning with a beam collimation of 5 mm or 2 mm, increment of 2.4 mm or 0.9 mm, pitch of 1.5, 120 kVp, 110 mA, and 1.0 sec/rot. Multidetector row spiral CT (MDCT) scanner (LightSpeed 16 and LightSpeed VCT; GE Healthcare, USA), Advantage Workstation 4.2, and 3D imaging software were used in 15 cases, scanning with a beam collimation of 1.25 mm, increment of 0.6 mm, pitch of 1.375, 120 kVp, 110 mA, and 0.8 sec/rot.

Image processing and data management

3D imaging was made with surface shade display and volume rendering,^{3,7} whose reconstructed threshold of bone was between 150 Hu and 3000 Hu. On the 3D images, we measured and judged the following: (1) extent of AFDLAJ in neutral position—the widest displacement of superior articulating facets of the axis or that of inferior articulating facets of the atlas; (2) rotational function of the atlantoaxial joint—whether the head's rotary angle or rotational facet displacement was symmetrical or the same between the left and right rotary position; (3) ADI—the smallest distance from the posterior edge of the atlas to the anterior edge of the dens; (4) LO—whether the distance from the middle axes of the dens to the left and right lateral mass was the same. 3D CT imaging findings were retrospectively analyzed, and the imaging features of AFDLAJ discussed. The diagnostic results of 3D CT, RCT and X-ray were compared.

Diagnostic criterion

According to the normal features and rotational function of the atlantoaxial joint,⁸ the diagnostic criterion of atlantoaxial subluxation is AFDLAJ in neutral position and rotational fixation or rotational asymmetry in rotary position.

Results

All of the 54 patients with atlantoaxial subluxation were correctly diagnosed by 3D CT (26 cases verified by surgery and 28 by clinical evidence); 38 cases had rotatory dislocation (Figures 1–3), 11 had anterior dislocation, and five had posterior dislocation. There was no suspicious or missed diagnosis by 3D CT, but there were by RCT and X-ray. 3D CT changed the original diagnosis of RCT and X-ray (from suspicious or missed diagnosis to positive diagnosis) in 53.7% (29/54) of patients. The details are presented in the Table.

AFDLAJ was found in all 54 patients. The extent of AFDLAJ was between 2.0 mm and 9.0 mm (34 cases were 2.0–5.0 mm, 20 were 5.1–9.0 mm).

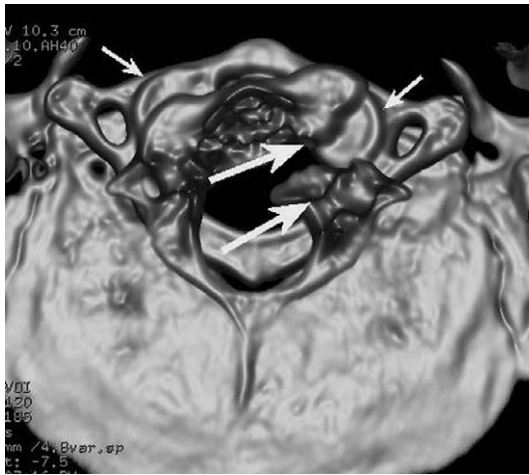


Figure 1. Surface shade display effect of volume rendering imaging of atlantoaxial rotatory subluxation with fracture of the pedicle of the C2 vertebral arch (big white arrows) in neutral position (slice thickness of 5 mm). The axial view from below shows the AFDLAJ and the dislocated joint panel (small white arrows).

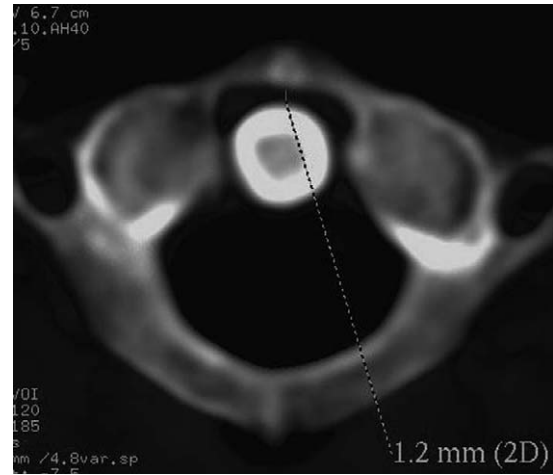


Figure 3. Volume rendering imaging and cutting technique of the same case as in Figure 1 in neutral position. The axial view from below shows that the width of the atlantodental interval is 1.2 mm.

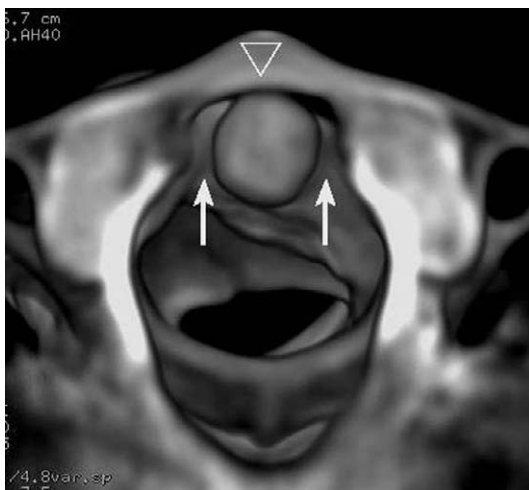


Figure 2. Volume rendering imaging and cutting technique of the same case as in Figure 1 in neutral position. The axial view from above shows no sign of widened atlantodental interval (the triangle) or deviation of the odontoid process (white arrows).

Widened ADI was found in 24 cases, lateralized odontoid in 45, and fracture of C1 or C2 in 10. Among the 25 cases in rotary position, rotational fixation was found in 10 and rotational asymmetry in 15 (Figures 4–8).

Among the 15 re-examined patients, AFDLAJ was repositioned in the 10 cases who had non-surgical treatment and was fixed in the five cases

who underwent operation, which resulted in satisfactory clinical effect in four and bad effect in one (the extent of postoperative displacement was greater than that preoperatively).

3D images reconstructed with a slice thickness of 2 mm or 1.25 mm clearly and directly demonstrated the AFDLAJ. The spatial resolution of 3D images reconstructed with a slice thickness of 1.25 mm was higher than that with 5 mm.

Discussion

At present, the diagnosis of atlantoaxial subluxation can be established using X-ray plain film, CT and MRI.^{9–12} X-ray plain film and CT are more commonly used, and diagnosis is obtained by showing widened ADI and LO. Yet, rotatory dislocation type I does not have the widened ADI and normal people may have LO. So, the diagnosis is not completely accurate and may be classified as suspicious or missed diagnosis altogether. MRI, used in clinical application with no ionizing radiation,^{10–12} was thought to have the advantages of multiplanar imaging capacity and excellent depiction of soft tissues.¹³ But Laiho et al reported that MRI cannot detect the extent of unstable anterior atlantoaxial subluxation in rheumatic patients,¹¹ and Karhu et al recommended

Table. Diagnostic results from the imaging examinations of 54 patients with atlantoaxial subluxation

Imaging examination	Diagnosis of atlantoaxial subluxation, n (%)		
	Positive	Suspicious	Missed
3D CT (n = 54)	54 (100.00)	0	0
RCT (n = 41)	20 (48.78)	14 (34.15)	7 (17.07)*
X-ray (n = 13)	5 (38.46)	5 (38.46)	3 (23.07)*

*Represents the false-negative rate.

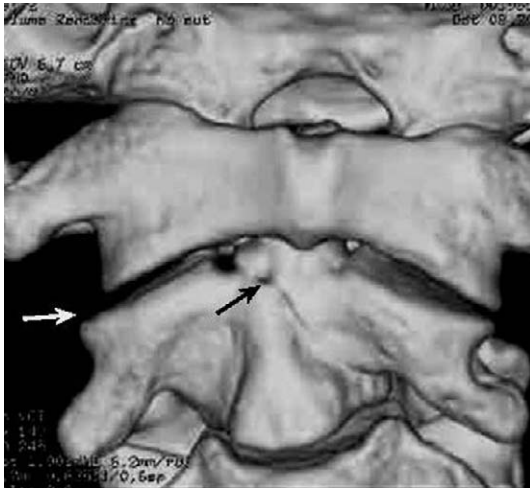


Figure 4. Surface shade display effect of volume rendering imaging of atlantoaxial rotatory posterior subluxation with fractures of C2 in neutral position (slice thickness of 1.25 mm). The anteroposterior view shows the AFDLAJ (white arrow, posterior subluxation extent on the right is larger than that on the left) and fracture of the basilar part of the odontoid process (black arrow).

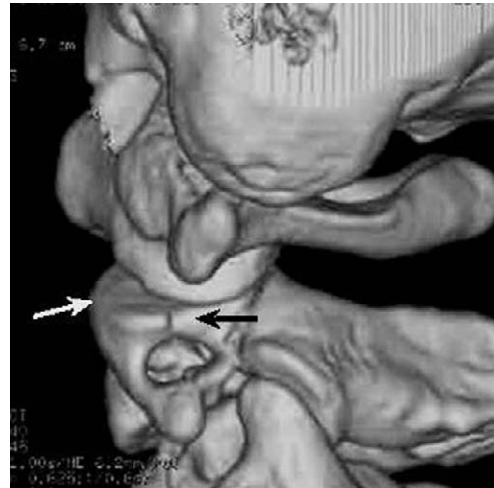


Figure 5. Surface shade display effect of volume rendering imaging of the same case as in Figure 4 in neutral position. The left lateral view shows the AFDLAJ (white arrow) and fracture of the articular facets of C2 (black arrow).

using conventional radiographs first.¹² Our study found that 3D CT can fill in the gaps of the above examination methods, clearly and directly defining the spatial relation of the atlantoaxial joint and show AFDLAJ. Arthrography was reported to be able to show the rupture of joint capsule in diagnosing atlantoaxial rotatory fixation,¹⁴ but its application needs further evaluation.

With regard to the clinical value of AFDLAJ and its relation to atlantoaxial subluxation, exhibiting AFDLAJ can reflect the pathologic change in atlantoaxial subluxation. When AFDLAJ was found in neutral position or fixed rotation or asymmetric rotation in rotary position, the atlantoaxial subluxation can be ascertained. By showing the AFDLAJ and measuring its size on 3D images, we

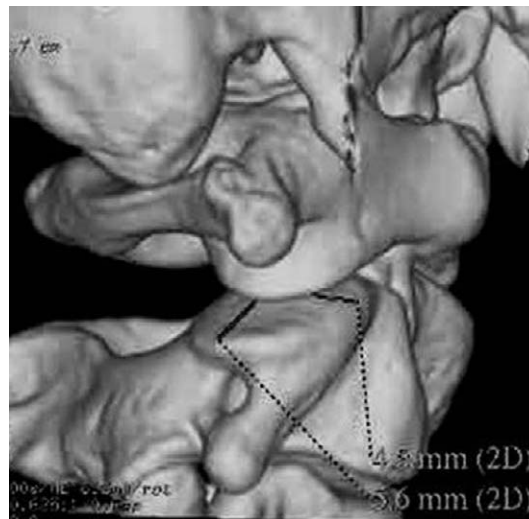


Figure 6. Surface shade display effect of volume rendering imaging of the same case as in Figure 4 in neutral position. The right lateral and slightly inferior–posterior view shows the AFDLAJ posterior displacement by 4.5 mm and left lateral displacement by 5.6 mm.

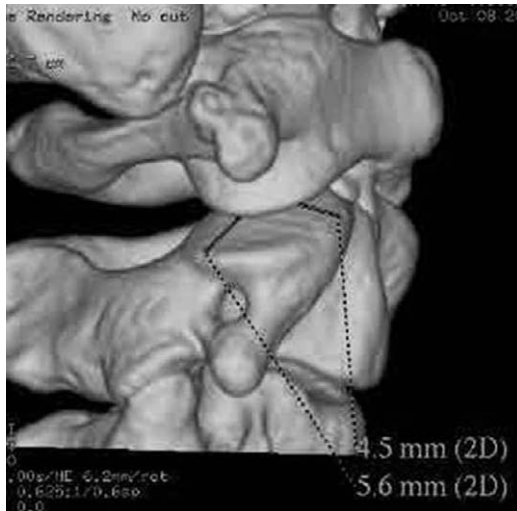


Figure 7. Surface shade display effect of volume rendering imaging of the same case as in Figure 4 in right rotary position. The right lateral and slightly inferior–posterior view shows the extent of displacement of AFDLAJ similar to that in neutral position—a sign of fixed rotation.

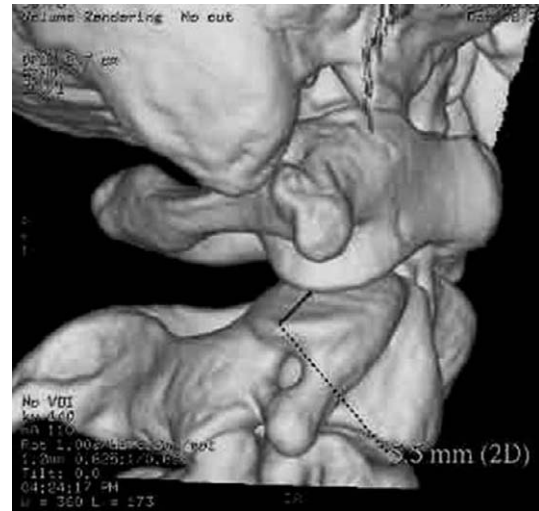


Figure 8. Surface shade display effect of volume rendering imaging of the same case as in Figure 4 in left rotary position. The right lateral and slightly inferior–posterior view shows the extent of displacement of AFDLAJ similar to that in neutral position—a sign of fixed rotation.

can get the extent and type of the subluxation, increase the accuracy of diagnosis and reduce the number of suspicious and missed diagnoses. In our study, 3D CT changed the original diagnosis of RCT and X-ray in 29 cases (53.7%). The accuracy of 3D CT was higher than that of RCT or X-ray. In addition, by measuring the size of AFDLAJ prior to and after treatment, we can evaluate the effect of treating atlantoaxial subluxation. Our results showed that if there is atlantoaxial subluxation, AFDLAJ will surely be found, and vice versa. Some reports found that the demonstration of AFDLAJ on 3D CT is very valuable in diagnosing atlantoaxial subluxation,^{3,7,8,15} and it is easy and simple to measure the extent of displacement of AFDLAJ on 3D images. Of course, AFDLAJ may be accompanied by other signs of dislocation, such as widened ADI, LO, dysplastic dens, fracture of C1 and/or C2, and trauma to surrounding ligaments. Widened ADI, always highly valued by researchers and clinicians, is another direct sign of atlantoaxial subluxation. But the criterion of widened ADI varies (more than 3 mm, 4 mm or 5 mm) depending on patient age.^{10,16,17} LO, dysplastic dens, peg fracture and injury to surrounding ligaments are indirect signs of dislocation, which suggest the possibility of atlantoaxial

subluxation.¹⁸ But to ascertain the diagnosis, they should be combined with the signs of AFDLAJ or widened ADI. There was not enough emphasis on the relationship between AFDLAJ and injury to surrounding ligaments in this study. Lu et al's experimental study reported that RCT and MRI can well show the surrounding ligaments of the atlantoaxial joint, but the latter shows it better.¹³ This conclusion gives a valuable indication to future studies on diagnosing atlantoaxial subluxation using CT and MRI. In other words, the authors recommend 3D CT as a routine examination in the diagnosis of atlantoaxial subluxation or instability.

With regard to factors that influence the display of AFDLAJ, AFDLAJ is observed in neutral position, where the patient must lie in the supine position with the sagittal plane of the head and Reid's line perpendicular to the horizontal. If the position is not accurate, e.g. the patient's head turns to the left or right (the frequency of this was about 10% in our study), the 3D image will show rotational facet displacement of lateral atlantoaxial joint and induce a sign similar to AFDLAJ. The key point to use in differentiating between them is that the head's rotation appears as a symmetrical rotational facet displacement and

the head's rotational angle in the left and right rotary position, while AFDLAJ appears as an articulating facet displacement of lateral atlantoaxial joint in neutral position and fixed rotation or asymmetric rotation in rotary position. In addition, it is important to set scanning slice thickness. The thinner the slice thickness, the higher the spatial resolution of the 3D image, and the clearer the AFDLAJ. Observing the 3D images from different directions may have different results. For example, false subluxation sign may appear on anteroposterior view but not on lateral view.^{7,8}

Examination feasibility and the influence of the CT scanner: in order to observe rotational function of the atlantoaxial joint, we first set the patient in neutral position, then let him turn his head to the right and left with maximum angle in rotary position, with no outside force, to ensure there was no danger during examination. The head's rotational angle completely depends on the function of the atlantoaxial joints. If the function is normal, the rotational angle may be larger; if abnormal, the rotational angle may be smaller or zero. In our study, 25 cases were examined in rotary position, and no examination accident occurred. Scan with both single-detector row spiral CT (SDCT) and MDCT can obtain volume data, and the axial images can meet the demand of 3D imaging. MDCT has the characteristics of quicker scan and thinner slice thickness. Quick scan has advantages in scanning moving organs such as the heart, but it is not necessary for scanning the atlantoaxial joint. Though thinner slice thickness can get more satisfactory 3D images, those from 2 mm can accurately show AFDLAJ, which was proved by an experimental study with SDCT. There was no significant difference in the measurement of AFDLAJ of specimen models and that of 3D images.⁷ So there are the same good effects in the 3D imaging of atlantoaxial joints with SDCT and MDCT. Of course, MDCT has more advantages on the 3D imaging, especially 64-slice MDCT which can obtain RCT images as well as the images used in 3D CT imaging.

With regard to re-examination and radiation dose, there are different reports on how to select the methods of treatment of atlantoaxial subluxation and follow-up the effects of post-treatment.¹⁹⁻²⁴ In our study, we found that the patients with nonsurgical treatment had good effects (10/10) and surgical treatment did not always get satisfactory results (4/5), which suggest that it is very important for doctors to select suitable methods. By measuring AFDLAJ, we can compare the extent of subluxation, and quantify displacement prior to and after treatment and evaluate the effects of treatment with nonsurgical or surgical treatment. In our study, the radiation dose did not substantially increase, because 3D imaging may be performed directly with the image of 5-mm slice thickness or that retrospectively reconstructed with 2.4-mm increment, with 64-slice MDCT, we can get images of different slice thicknesses used for 3D imaging in one scan. Lower kVp and mAs are recommended when 3D imaging in additional left and right rotary position is used in diagnosing difficult or suspicious cases. In our study, atlantoaxial joints scanned with a current of 110 mA, voltage of 120 kVp and 0.8 sec/rot resulted in satisfactory 3D image with half the radiation of a routine scan, and the current or voltage can be further reduced.⁸

In summary, AFDLAJ, found in all patients with atlantoaxial subluxation, can be clearly and directly shown by 3D CT imaging. With this sign, not only the correct diagnosis of subluxation can be obtained, but also the type and extent of subluxation can be ascertained. Recognition of the sign will increase the accuracy of diagnosing atlantoaxial subluxation, and reduce the number of suspicious and missed diagnoses. AFDLAJ is a vital direct sign in diagnosing atlantoaxial subluxation.

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