Imaging of Atlanto-Occipital and Atlantoaxial Traumatic Injuries: What the Radiologist Needs to Know[1]

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Approximately one-third of all cervical spine injuries involve the craniocervical junction (CCJ). Composed of the occiput and the first two cervical vertebrae, this important anatomic landmark, in conjunction with an intricate ligamentous complex, is essential to maintaining the stability of the cervical spine. The atlantoaxial joint is the most mobile portion of the spine, predominantly relying on the ligamentous framework for stability at that level. As acute onsite management of trauma patients continues to improve, CCJ injuries, which often lead to death onsite where the injury occurred, are increasingly being encountered in the emergency department. Understanding the anatomy of the CCJ is crucial in properly evaluating the cervical spine, allowing the radiologist to assess its stability in the trauma setting. The imaging findings of important CCJ injuries, such as atlanto-occipital dissociation, occipital condyle fractures, atlas fractures with transverse ligament rupture, atlantoaxial distraction, and traumatic rotatory subluxation, are important to recognize in the acute setting, often dictating patient management. Thin-section multidetector computed tomography with sagittal and coronal reformats is the study of choice in evaluating the extent of injury, allowing the radiologist to thoroughly evaluate the stability of the cervical spine. Furthermore, magnetic resonance (MR) imaging is increasingly being used to evaluate the spinal soft tissues and ligaments, and to identify associated spinal cord injury, if present. MR imaging is also indicated in patients whose neurologic status cannot be evaluated within 48 hours of injury.

Abbreviations: AOD = atlanto-occipital dissociation, CCJ = craniocervical junction

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SA-CME LEARNING OBJECTIVES

After completing this journal-based SA-CME activity, participants will be able to:

- Review the bone and ligamentous anatomy of the craniocervical junction.
- Describe the current classifications of craniocervical junction injuries.
- Identify relevant injuries with CT and MR imaging and their clinical effect.

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Introduction

Approximately one-third of all cervical spine injuries involve the craniocervical junction (CCJ). These injuries, which had previously often led to immediate death, are increasingly being seen in emergency departments due to the tremendous improvement in initially managing high-speed motor vehicle collisions. The aim of this review is to provide the radiologist with a review of the anatomy and mechanisms of CCJ trauma, focusing on atlanto-occipital and atlantoaxial injuries and to aid the clinician in understanding the role of imaging in diagnosis and treatment of these injuries.

Anatomy of the CCJ

Understanding the anatomy of the CCJ is essential to adequately evaluate the patient for potential injuries. The CCJ is composed of three bone structures: the first and second cervical vertebrae (also known as the atlas and axis, respectively), and the occiput. These structures are approximated at two major joints, the atlanto-occipital and atlantoaxial joints. The anatomy of the CCJ will be discussed in terms of bone anatomy, ligamentous anatomy, and craniometry (1).

TEACHING POINTS

- The main role of MR imaging in evaluating the traumatic cervical spine is to detect soft-tissue injury, especially to exclude spinal cord injury. MR imaging is also indicated for treatment planning of the unstable cervical spine and for patients with neurologic deficits, suspected ligamentous injury, and patients who cannot be clinically evaluated for more than 48 hours due to altered level of consciousness. MR imaging does not depict all major ligamentous disruptions but performs better in detection of spinal cord injuries.
- The basion-dens distance is a reliable imaging method to detect AOD. A distance greater than 10 mm is highly suggestive of dissociation. The ligamentous complex provides most of the stability at the atlanto-occipital joint, as there is otherwise not much inherent osseous stability at this joint. Although other ligaments are often injured during AOD, the alar ligament and the tectorial membrane are the most important stabilizing ligaments at the CCJ and their injury is most detrimental to the patient.
- Under the Tuli classification, Anderson and Montesano types I and II are grouped together as Tuli type 1, as they have the same treatment. Tuli type 2A fractures may require a rigid collar, whereas type 2B lesions require surgical intervention.
- Burst and lateral mass fractures can be associated with tears of the transverse ligament, which are unstable. Ruptures of the ligament can compromise the atlantodental relationship, causing dorsal displacement of the dens, and possibly resulting in compression of the thecal sac and its contents.
- Rotation as high as an average 79° was seen in one study of adult volunteers, and loss of contact of the articular facets of C1 and C2 during rotation as high as 74% –85%, seen in physiologic conditions, was seen in another (60). Therefore, diagnosis of subluxation of the atlanto-occipital joint should not be made based solely on the appearance of this joint at CT.

Two paired inferior protrusions, the occipital condyles, project from the inferior aspect of the occipital bone. These articulate with the superior articular surfaces of the lateral masses of the atlas. The anterior aspects of the occipital condyles contain foramina that allow the hypoglossal nerve to enter the skull. When evaluating the occipital condyles, it is important to remember that multiple variations may be present, such as precondylar tubercles, third occipital condyles, and ossification of the ligament of the odontoid process of the axis (2,3) (Fig 1).

The first cervical vertebra (C1), also known as the atlas, is the only vertebra that does not have a body and is not associated with an intervertebral disc. It is a ring-shaped vertebra with bilateral paired lateral masses joined by an anterior and a posterior arch (Fig 2). The dorsal aspect of the anterior arch has an articular surface for the odontoid process of the second cervical vertebra (C2; or axis), forming the atlantoaxial joint. The lateral masses articulate superiorly with the occipital condyles and inferiorly with C2, forming the atlanto-occipital and atlantoaxial joints,

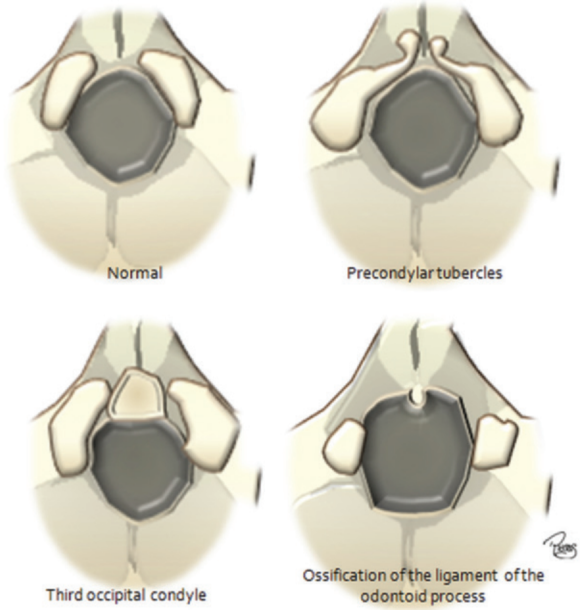


Figure 1. Anatomic variants of the occipital condyles. Diagrams demonstrate the normal configuration of the occipital condyles and the three most frequent anatomic variants: the precondylar tubercles, the third occipital condyle, and ossification of the ligament of the odontoid process.

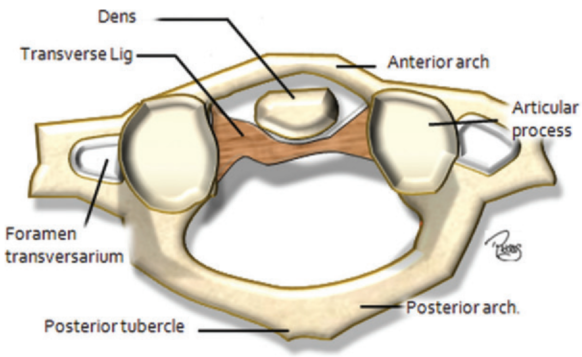
respectively. The superior aspect of the lateral masses of C1 contains a groove that allows passage of the vertebral artery before it enters the foramen magnum (4). C2 has paired superior articular processes that articulate with the lateral masses of the atlas and inferior articular processes that articulate with the third cervical vertebra (C3). It is a unique vertebra in that it has a superior projection, known as the odontoid process or dens.

Ligamentous Anatomy

A complex of ligaments stabilizes the atlanto-occipital and atlantoaxial joints, which are classified into the intrinsic and extrinsic ligaments (5).

The intrinsic ligaments form three layers anterior to the dura matter and include the odontoid ligaments, the cruciate ligament, and the tectorial membrane (6). The odontoid ligament is composed of the apical and alar ligaments, which act as stabilizers of the CCJ, limiting axial rotation. The apical or suspensory ligament spans the tip of the dens to the basion, of the anterior margin of the foramen magnum. The paired alar ligaments attach the posterolateral aspects of the dens to the medial aspect of the occipital condyles and the occipital bone, as well as the axis bilaterally (7,8).

The cross-shaped cruciate ligament is composed of the transverse ligament and the superior and inferior crura. The transverse ligament is the strongest and thickest of the ligaments (9). It



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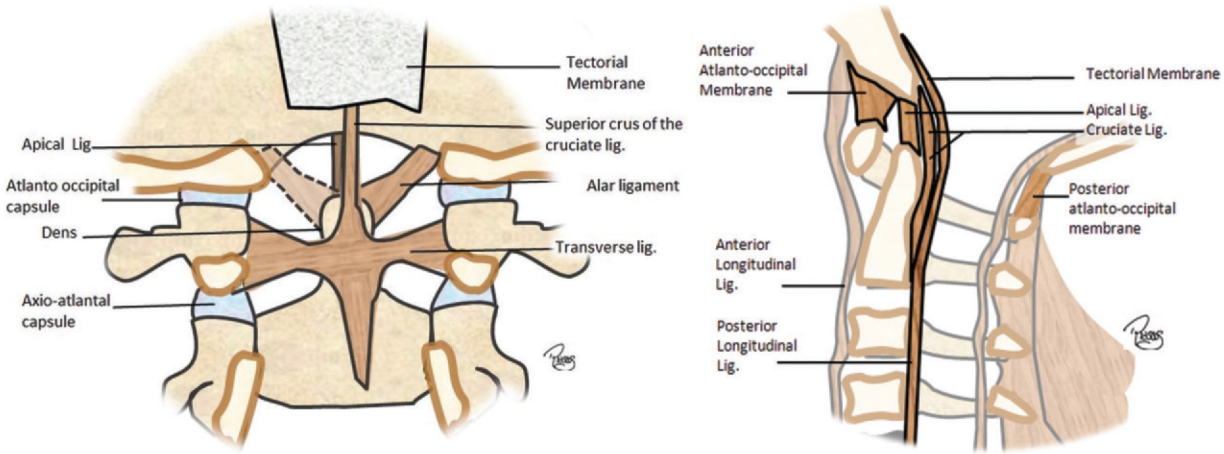


3a. 3b.

Figures 2, 3. **(2)** Anatomy of the atlas. Diagram shows the morphology of the first cervical vertebra. **(3)** Ligaments of the CCJ. **(a)** Diagram shows a view of the CCJ from the back; the posterior elements have been removed. The cruciate, alar, and apical ligaments are demonstrated. **(b)** Diagram shows a lateral view of the CCJ. The cruciate, anterior and posterior atlanto-occipital, and apical ligaments are demonstrated.

runs horizontally posterior to the anterior arch of the atlas and the dens, stabilizing the dens to the posterior aspect of the anterior arch of the atlas. Thus, it divides the ring of the atlas into two compartments: an anterior compartment that includes the dens and a posterior compartment that houses the thecal sac and its components. The crus superioris and crus inferioris are superior and inferior extensions of the cruciate ligament that arise from the transverse ligament. The crus superioris attaches to the lower margin of the occipital bone, and the crus inferioris attaches to the posterior surface of the body of the axis (9,10).

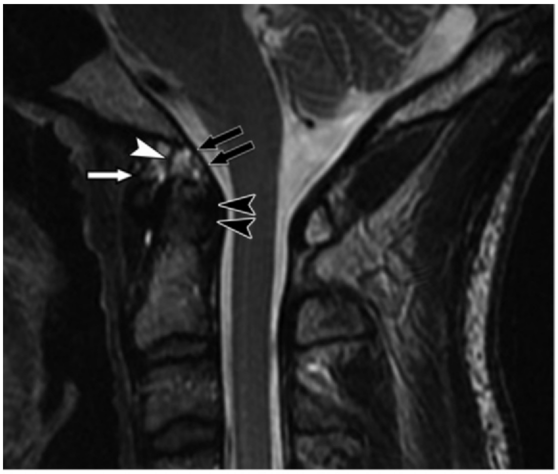
The tectorial membrane is the rostral continuation of the posterior longitudinal ligament. It is a thick ligamentous broad band that extends from the body of C2 to the occipital bone at the anterior margin of the foramen magnum. It serves as the posterior border of the supraodontoid space or apical cave (11). It runs posterior to the odontoid and cruciate ligaments and is in intimate contact with the dura matter (9). This membrane is composed of three layers, with nerves or vessels running through them (11) (Figs 2, 3).

Other ligaments of the CCJ have been described, such as the transverse occipital ligament, the accessory atlantoaxial ligament, the lateral atlanto-occipital ligament and Barkow ligament (9), all of which are thinner, have a lesser role in stabilization of the CCJ, and will not be part of this discussion.

The extrinsic ligaments are fibroelastic membranes that are rostral continuations of the anterior longitudinal ligaments and the ligamentum flava. One of the extrinsic ligaments, the nuchal ligament, is a continuation of the interspinous and supraspinous ligaments. It runs from the seventh cervical vertebra to the external occipital protuberance, where it attaches to the occipital bone, restricting hyperflexion. The posterior atlanto-occipital membrane is a broad band that extends from the posterior arch of the atlas to the posterior margin of the foramen magnum as a cephalic projection of the ligamentum flavum with minor effect on stability (12).

Mechanical Stabilization

The major stabilizers of the atlantoaxial joint are the transverse ligament, which allows axial rotation, and the alar ligaments, which limit excessive rotation (13,14). The joint capsules of the atlanto-occipital and atlantoaxial axial joints stabilize the CCJ. The mechanical properties of the atlanto-occipital joint are mostly flexion and extension with minimal involvement in axial



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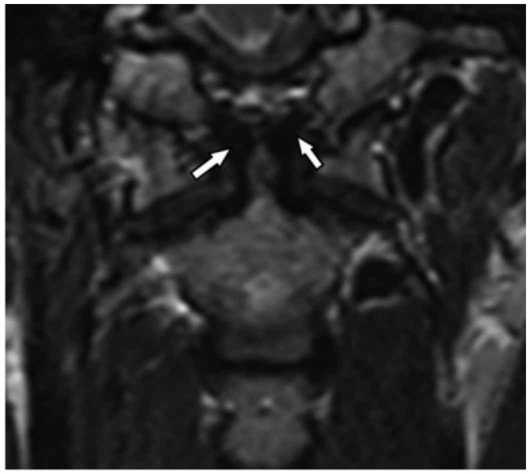


5.

Figures 4, 5. **(4)** CCJ ligaments. Sagittal T2-weighted MR image of the cervical spine demonstrates the anterior atlanto-occipital ligament (white arrow), the apical ligament (white arrowhead), the tectorial membrane (black arrows), and the transverse ligament (black arrowheads). **(5)** Alar ligaments. Coronal MR image demonstrates the alar ligaments extending from the odontoid process to the occipital bone (arrows).

rotation (15). These mechanics are determined by the bone structures (16). The atlantoaxial joint is mostly responsible for axial rotation with some contribution to flexion and extension. The mechanical forces of this joint are determined by the ligaments (9). The transverse and the alar ligaments are the two strongest ligaments, stabilizing the CCJ (9), with the transverse ligament being the stronger of the two. Therefore, these structures are of major importance when evaluating the CCJ.

The impingement of the odontoid on the basion is the major restrictor of flexion, whereas the tectorial membrane restricts extension. The alar ligaments are the main restrictors of lateral flexion (9,15,16).

Disruptions of the integrity of the joint capsules may indicate instability. Lesions of the capsular joints can be divided into isolated atlantoaxial injuries (type I) and combined atlantoaxial and atlanto-occipital injuries (type II). The latter are associated with higher incidence of spinal cord injuries (17).

Imaging Approach

Computed tomography (CT) is the study of choice when injury of the cervical spine is suspected. Its performance is superior to that of conventional radiographs (18,19). The introduction of thinner-section isovolumetric protocols has allowed multiplanar reformatting and increased injury detection rates. The recommended section thickness for sagittal and coronal reconstructions is 1.25 mm (20) or thinner. Multiplanar reformatted sagittal and coronal reconstructions provide high-quality images that improve interpretation with an increased challenge as the number of images increases (21,22). Although newer scanners have decreased radiation exposure, radiation exposure remains higher than with conventional radiography. CT should therefore be limited to patients at high risk of cervical spine injury on the basis of the National Emergency X-Radiography Utilization Study (NEXUS) low-risk criteria or the Canadian C-Spine Rule (23,24).

The main role of magnetic resonance (MR) imaging in evaluating the traumatic cervical spine is to detect soft-tissue injury, especially to exclude spinal cord injury (25). MR imaging is also indicated for treatment planning of the unstable cervical spine and for patients with neurologic deficits, suspected ligamentous injury, and patients who cannot be clinically evaluated for more than 48 hours due to altered level of consciousness. MR imaging does not depict all major ligamentous disruptions (25) but performs better in detection of spinal cord injuries. A study comparing MR imaging with radiography in cadaveric specimens found that MR missed around half of the ligamentous injuries. However, this conclusion was made using 1.5-T images over a decade ago (26). Increased magnetic field strength and new imaging sequences have improved ligamentous visualization (27–29) (Figs 4–7).

Atlanto-Occipital Dissociation

Atlanto-occipital dissociation (AOD) results from high-energy trauma including from motor vehicle collisions. It is associated with high mortality rates due to brainstem and vascular lesions. It is seen in up to one-third of high-velocity motor vehicle injuries (30–32). Classically, AOD is classified into three types: type I is the most common and includes ventral dislocations of the

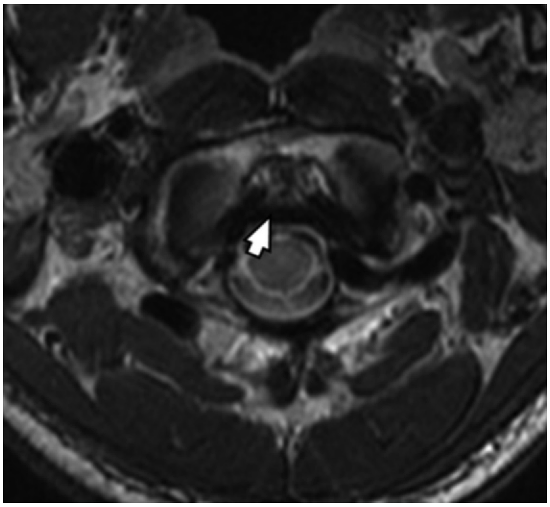
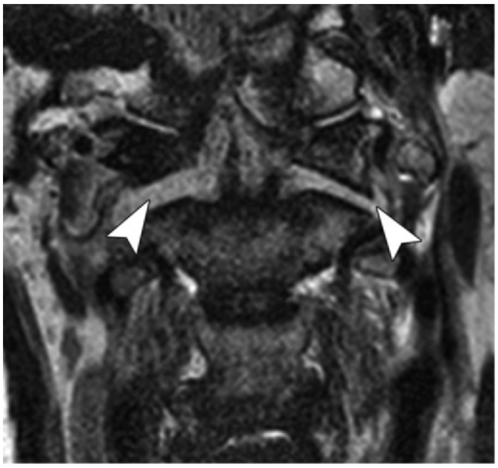


Figure 6. Transverse ligament. Axial T2-weighted MR image shows the transverse ligament (arrow) spanning from the lateral masses of the atlas.



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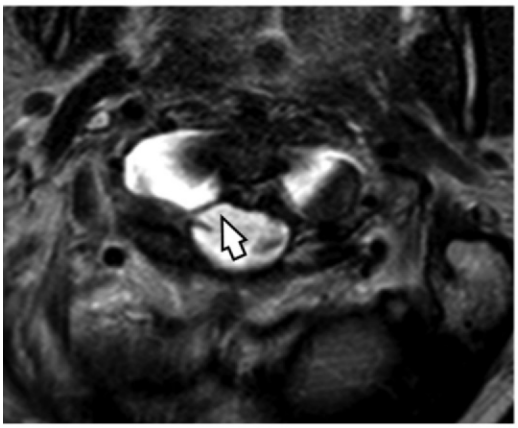

c.

Figure 7. Ligamentous injuries in CCJ trauma at T2-weighted MR imaging. **(a)** Coronal view demonstrates bilateral widening of the C1-C2 (atlantoaxial) joint with fluid (arrowheads). **(b)** Sagittal view demonstrates tears (arrow) of the apical ligament, cruciate ligament, and tectorial membrane, along with cord injury and hemorrhage. **(c)** Axial view reveals injury to the right limb of the transverse ligament (arrow) in addition to the cord injury.

occiput, type II is the most unstable and involves longitudinal distractions of the occiput, and type III results in dorsal dislocations of the occiput (33) (Figs 8–11). The mechanisms of injury are believed to be extreme hyperextension with injury to the tectorial membrane, accompanied by lateral flexion (33). These dislocations are far more common in children (34), possibly due to the shallow nature of the facet joints of the atlas and the occipital condyles (35).

The basion-dens distance is a reliable imaging method to detect AOD. A distance greater than 10 mm is highly suggestive of dissociation (17,36). The ligamentous complex provides most of the stability at the atlanto-occipital joint, as there is otherwise not much inherent osseous stability at this joint. Although other ligaments are often injured during AOD, the alar ligament and the tectorial membrane are the most important stabilizing ligaments at the CCJ and their injury is most detrimental to the patient. Condylar avulsion fractures are associated with disruption of the alar ligaments and AOD (37–39). Evaluation for

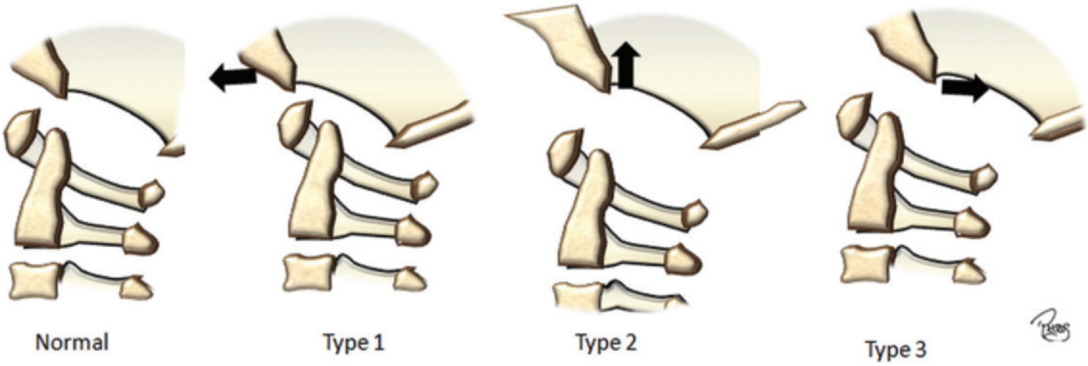

Figure 8. Craniocervical dissociation classification. Lateral diagrams demonstrate the normal alignments of the CCJ and the types of craniocervical dissociation: type I, anterior displacement of the skull; type II, vertical dissociation; and type III, posterior displacement.

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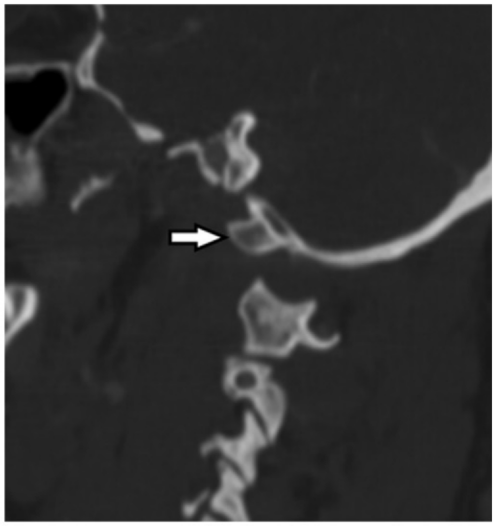

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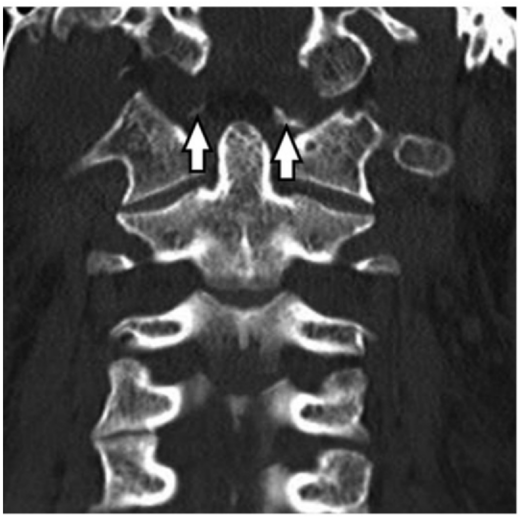


10a.

10b.

Figures 9, 10. **(9)** Type I AOD. **(a)** Sagittal CT image shows anterior displacement of the head with respect to the cervical spine with kinking of the medulla oblongata (arrow). **(b)** Left parasagittal CT image shows anterior displacement of the occipital condyle (arrow) with respect to the lateral mass of C1. **(10)** Type II AOD. **(a)** Coronal CT image shows bilateral avulsion (arrows) of the anterior inferior corner of the occipital condyles. **(b)** Sagittal T2-weighted MR image show disruption of the tectorial membrane (arrow), apical ligament, and anterior longitudinal ligament with surrounding hemorrhage.

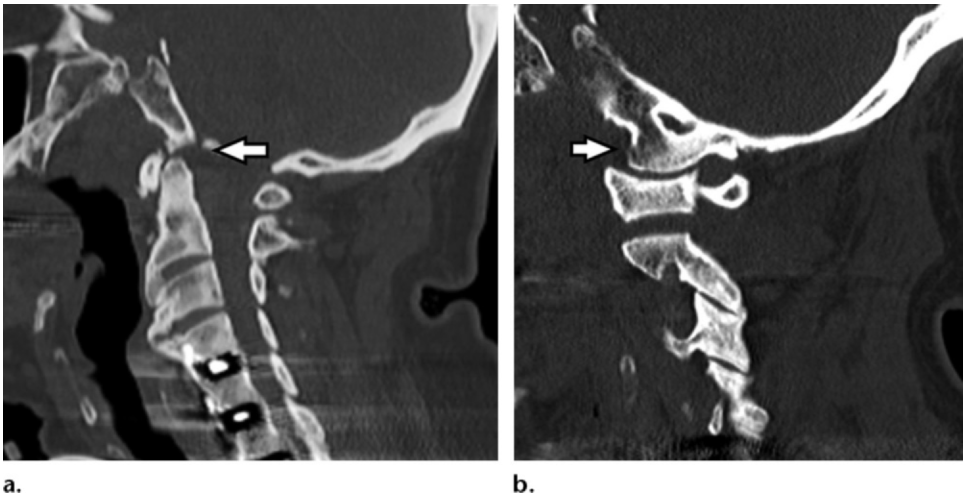


Figure 11. Type III AOD. **(a)** Sagittal CT image shows posterior displacement of the head with respect to the cervical spine. A fragment of the occipital bone is seen near the basion (arrow). **(b)** Left parasagittal reformatted CT image shows posterior displacement of the occipital condyle (arrow) with respect to the lateral mass of C1.

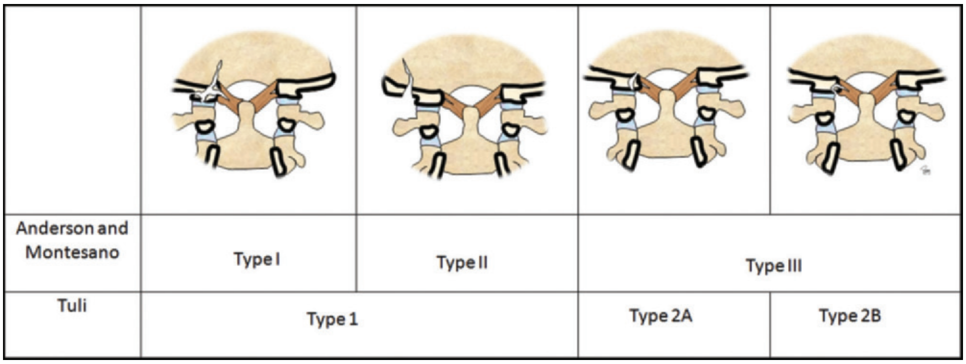


Figure 12. Occipital condylar fractures. Diagrams show the different types of condylar fractures and the two classifications described by Anderson and Montesano and by Tuli et al (46).

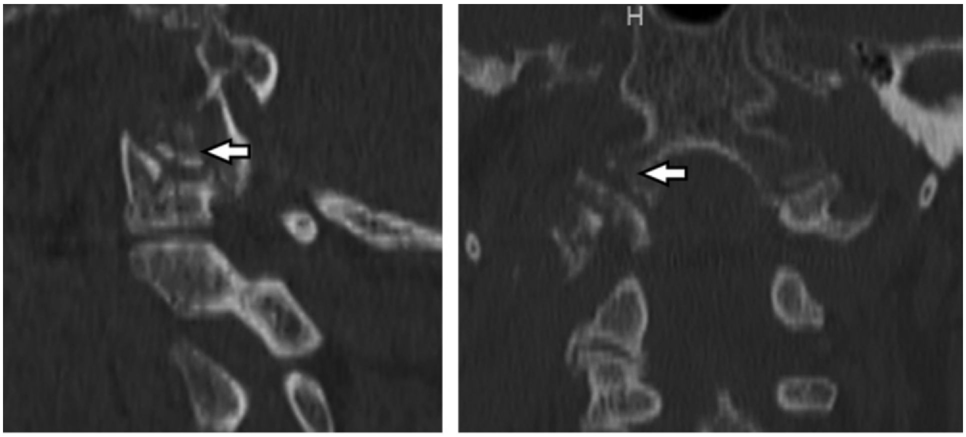
proximal spinal cord injury, as well as for other injuries such as traction of the lower cranial nerves or the upper cervical roots, is crucial (34,40).

Other attempts to identify AOD through imaging and to normalize the measurement of the CCJ have been made. The detection of widening of the atlanto-occipital joint spaces may lead to the diagnosis of AOD. Gire et al (41) evaluated the atlanto-occipital space on sagittal multidetector CT reconstructions. Measurements were taken from the midpoint of the condyle to the midpoint of the articular surface of the lateral mass at the greatest area of widening. Chang et al (42) found improved accuracy in detection of AOD by adding the atlanto-occipital distance bilaterally (ie, the condylar sum).

Horn et al (43) suggested classification of AOD into two grades: grade I is for patients with normal CT findings and equivocal clinical findings of ligamentous injury; grade II is for patients with at least one abnormal CT finding or abnormal MR imaging findings. Grade II patients should be treated with internal fixation. MR imaging plays a crucial role in detection of ligamentous or capsular injuries not identified at CT.

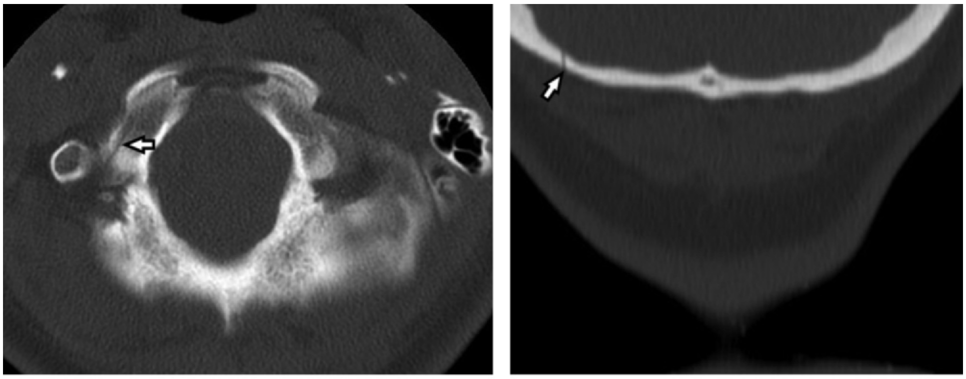
Occipital Condyle Fractures

Fractures of the occipital condyles are uncommon in the setting of blunt trauma to the cervical spine. Anderson and Montesano (Fig 12) classified such fractures into three types: type I includes comminuted fractures without displaced fractures into the foramen magnum (Fig 13), type II includes linear skull fractures that extend to involve the occipital condyle (Fig 14), and type III includes avulsion injuries of the occipital condyle (44) (Fig 15). Type I lesions are related to compression injuries to the occiput, type II are associated with direct blows to the head, and type III with avulsion injury of the alar ligament (45). Modern imaging techniques are able to depict small avulsion injuries and ligamentous interruptions that were a challenge in the past. Tuli et al (46) have suggested a new



a. b.

Figure 13. Anderson and Montesano type I occipital condyle fracture. Sagittal **(a)** and coronal **(b)** CT reformations of the same patient demonstrate the extent of the comminuted fracture (arrow) of the right occipital condyle.



a. b.

Figure 14. Anderson and Montesano type II occipital condyle fracture. **(a)** Axial CT image demonstrates a linear fracture (arrow) in the right occipital condyle. **(b)** Coronal CT reformatted image demonstrates that the fracture (arrow) extends from the lateral aspect of the occipital bone.

classification based on the presence of fragment displacement, stability of the atlanto-occipital and atlantoaxial joints, and MR imaging evidence of ligamentous injury. They propose the following classification: type 1 includes nondisplaced fractures; type 2A includes displaced fractures with no ligamentous instability; and type 2B includes displaced fractures with ligamentous instability. Under the Tuli classification, Anderson and Montesano types I and II are grouped together as Tuli type 1, as they have the same treatment. Tuli type 2A fractures may require a rigid collar, whereas type 2B lesions require surgical intervention (46,47) (Fig 12).

Fractures of the Atlas and Transverse Ligament Rupture

A burst fracture of C1 results from axial loading on the skull. These may be isolated or associated with transverse ligament disruptions or odontoid process fractures (48). These injuries account for 2%–13% of acute cervical fractures (49). The anterior and the posterior arches are the weakest points of this vertebral body and the most frequently involved. As the atlas is a ring, it tends to fracture in more than one place. C1 fractures, also known as Jefferson fractures, are classified into posterior arch, burst, and lateral mass injuries (Fig 16). Posterior arch fractures are associated with hyperextension injuries and tend to be stable; burst fractures are typically seen after axial load to the skull; and lateral mass fractures are associated with lateral flexion and frequently involve one side of the vertebra (6). Displacement of the lateral aspect of the lateral mass of the atlas in relation to the lateral borders of the C2 body in the coronal plane is an indicator of a fracture of the atlas (Fig 17). Historically, this was evaluated with radiography using an anteroposterior open-mouth view.

Burst and lateral mass fractures can be associated with tears of the transverse ligament, which are unstable. Ruptures of the ligament

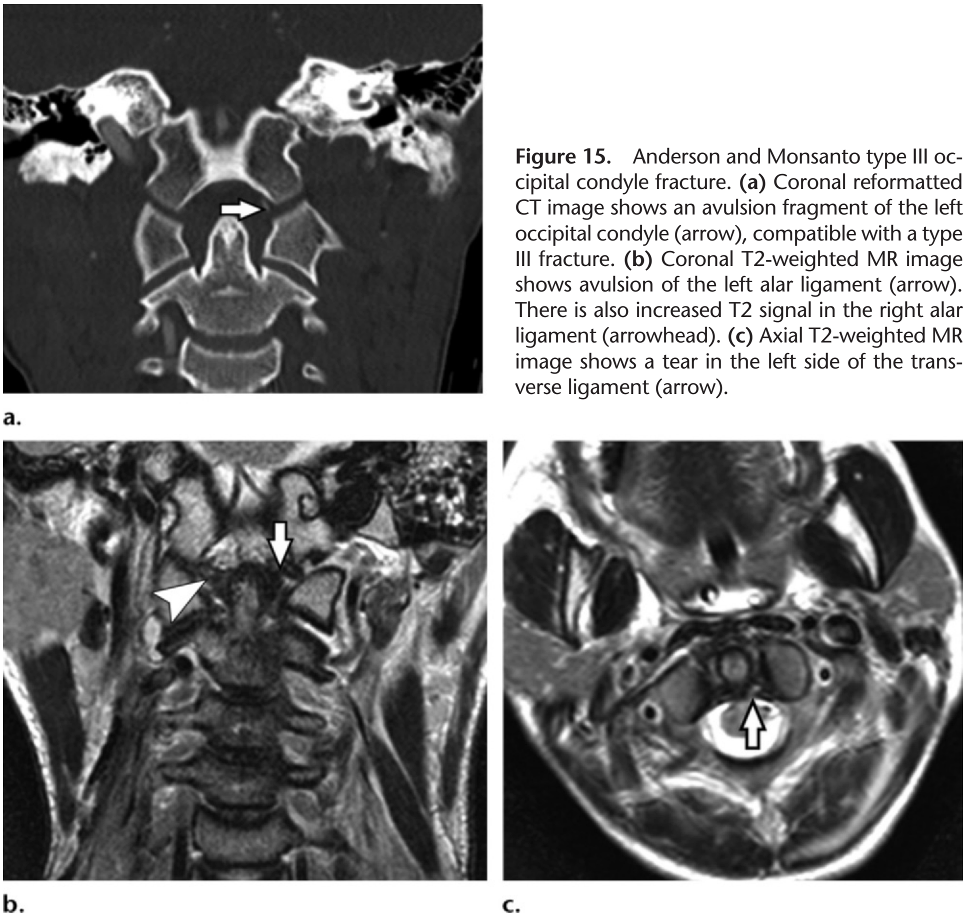


Figure 15. Anderson and Monsanto type III occipital condyle fracture. (a) Coronal reformatted CT image shows an avulsion fragment of the left occipital condyle (arrow), compatible with a type III fracture. (b) Coronal T2-weighted MR image shows avulsion of the left alar ligament (arrow). There is also increased T2 signal in the right alar ligament (arrowhead). (c) Axial T2-weighted MR image shows a tear in the left side of the transverse ligament (arrow).

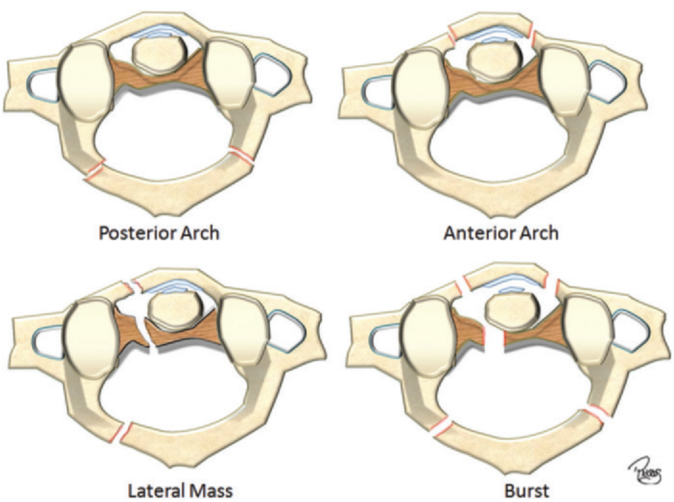


Figure 16. C1 fractures of the posterior arch, anterior arch, and lateral mass, and burst fractures. Bilateral displacement of the lateral masses of the atlas is a sign of fracture of the atlas.

can compromise the atlantodental relationship, causing dorsal displacement of the dens, and possibly resulting in compression of the thecal sac and its contents (50,51). Disruption of the transverse ligament without a fracture of the C1 ring may also occur and is usually accompanied by disruption of the alar ligaments. Evaluation of the transverse ligament is an essential prognostic indicator (Fig 18).

CT is the best imaging study to delineate the compromise of C1 and should be the imaging study of choice in the acute setting. MR imaging is a helpful tool to further assess the ligaments. On T2 or gradient-echo–weighted images, the signal intensity

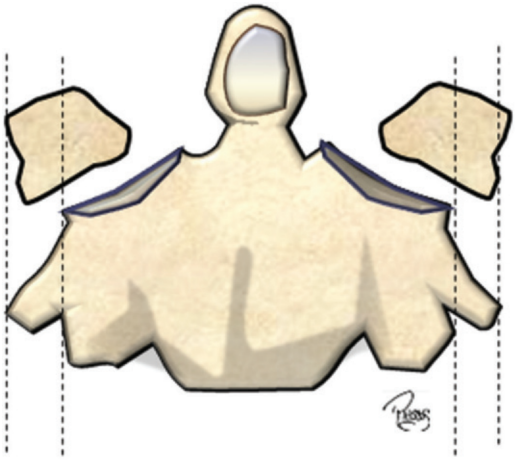
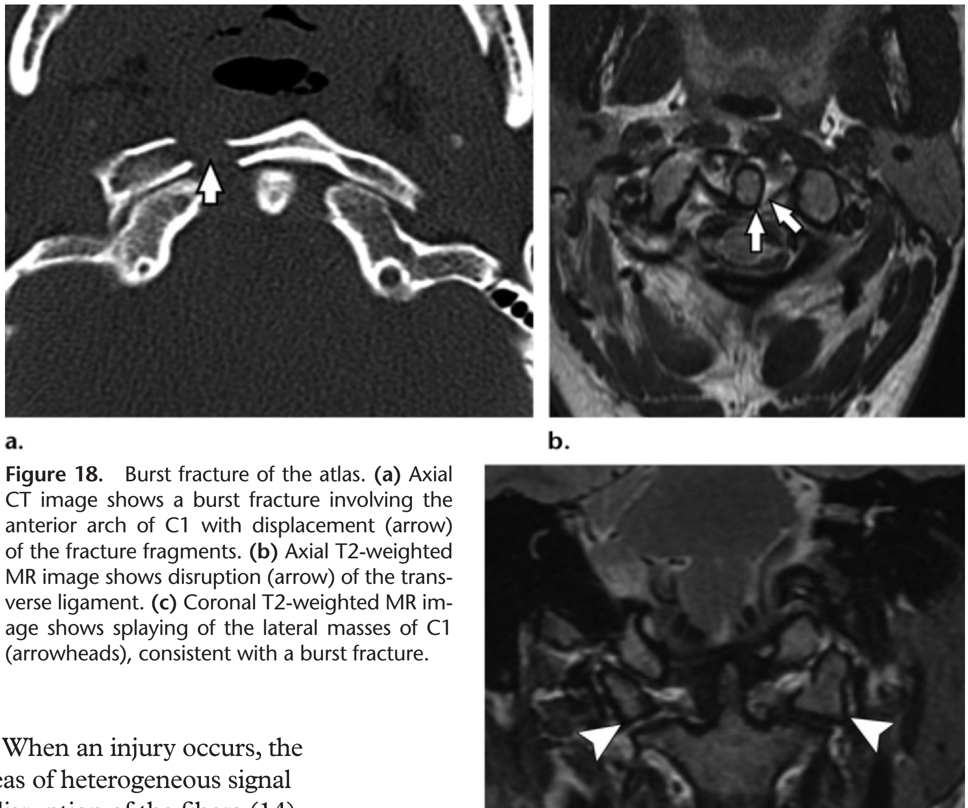


Figure 17. Bilateral displacement of the lateral masses of the atlas.



a. b. c.

Figure 18. Burst fracture of the atlas. **(a)** Axial CT image shows a burst fracture involving the anterior arch of C1 with displacement (arrow) of the fracture fragments. **(b)** Axial T2-weighted MR image shows disruption (arrow) of the transverse ligament. **(c)** Coronal T2-weighted MR image shows splaying of the lateral masses of C1 (arrowheads), consistent with a burst fracture.

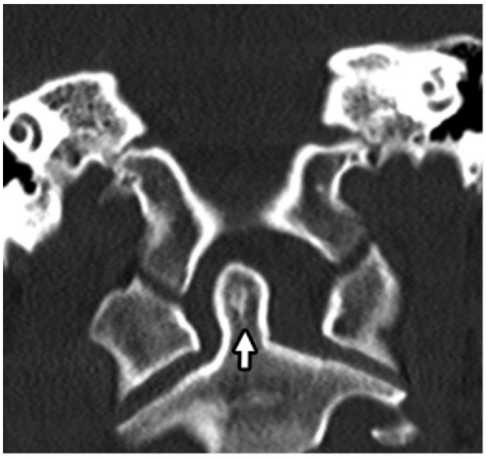
of the ligaments is low. When an injury occurs, the ligament may show areas of heterogeneous signal intensity or complete disruption of the fibers (14).

Atlantoaxial Distraction and Rotatory Deformity–Alar Ligament Tear

Evaluation of traumatic widening of the atlantoaxial interval is a big challenge, as many times injuries can be symmetric. Studies have shown the upper limit of the interval to be broad. These discrepancies may be due to the different age populations described. In the older population, degenerative changes accompanied by cartilage volume loss may account for a tighter joint space (36,52). Vertical atlantoaxial distraction is a rare entity that could be life-threatening.

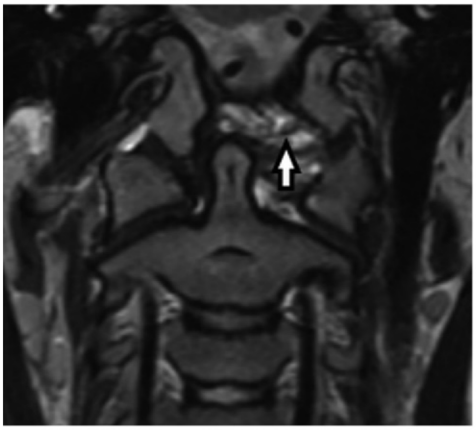
Traumatic rotatory subluxation usually occurs secondary to flexion and rotation forces leading to injury of the alar ligament (53). This condition is more prevalent in children than in adults. The atlantoaxial joint is the most mobile portion of the spine with articular facets that are mostly flat, allowing ample movement in multiple directions.

Nontraumatic subluxation of the atlantoaxial joint is a heterogeneous condition that comprises many different entities, including spontaneous hyperemic dislocation, atlantoaxial rotatory (or rotary) dislocation, distention luxation, nasopharyngeal torticollis (Grisel syndrome), atlantoaxial rotatory subluxation (AARS), and atlantoaxial rotatory fixation (AARF). Rotatory subluxation



a.

Figure 19. Patient with history of Ehlers-Danlos syndrome with minor trauma and torticollis. **(a)** Coronal reformatted CT image shows asymmetric position of the dens (arrow). **(b)** Coronal T2-weighted MR image shows widening of the left dens–lateral mass interval, with rupture of the left alar ligament (arrow). **(c)** Axial T2-weighted MR image shows an intact transverse ligament (arrow).



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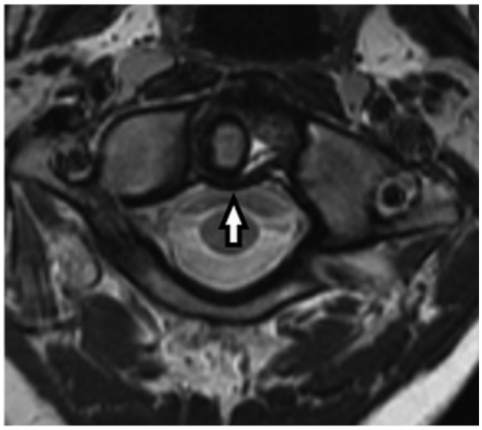


c.

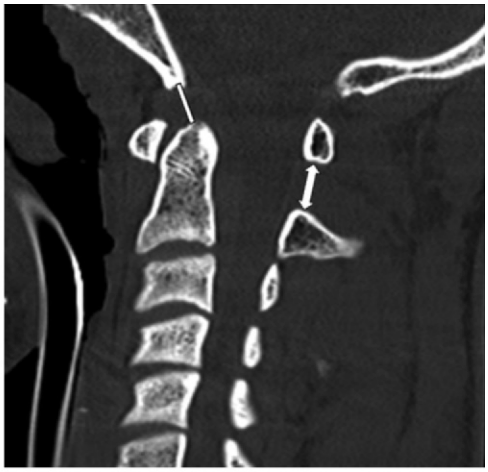
is a rare condition with increased incidence in patients with ligamentous laxity (such as rheumatoid arthritis and Down, Morquio, and Marfan syndromes) or congenital atlantoaxial abnormalities (such as incomplete odontoid process or incomplete transverse ligament (54) (Figs 19, 20). Grisel syndrome, defined as subluxation of the atlantoaxial joint not associated with trauma or bone disease, is found primarily in children. It may occur in association with any condition that results in hyperemia and pathologic relaxation of the transverse ligament of the atlantoaxial joint. Several common otolaryngeal conditions have been associated with the syndrome: pharyngitis, adenotonsillitis, tonsillar abscess, cervical abscess, and otitis media (55). The diagnostic criteria of AARS and AARF were described in the pre-CT era. On the basis of dynamic CT studies in normal volunteers (58) and in patients with torticollis without trauma or with minor trauma (53), it has become evident that a wide range of rotations of the atlanto-occipital joint occurs. Rotation as high as an average 79° was seen in one study of adult volunteers (59), and loss of contact of the articular facets of C1 and C2 during rotation as high as 74%–85%, seen in physiologic conditions, was seen in another (60) (Fig 21). Therefore, diagnosis of subluxation of the atlanto-occipital joint should not be made based solely on the appearance of this joint at CT.

Conclusion

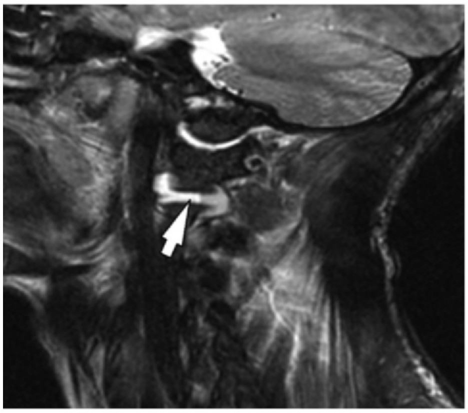
Thin-section multidetector CT should be the primary screening study for suspected cervical spine injury, with sagittal and coronal multiplanar reconstruction to improve identification and characterization of fractures and subluxations.

The sensitivity and specificity of MR imaging for detection of ligament disruption and its clinical relevance in ligament injuries in patients without CT evidence of instability is controversial in the literature. The American College of Radiology (ACR) recommends that MR imaging be used to evaluate the cervical spine in patients whose neurologic status cannot be fully evaluated within 48 hours of injury, including those in whom the CT examination is normal.

The atlantoaxial joint is the most mobile portion of the spine with articular facets that are mostly flat, allowing ample movement in multiple directions. The stability at this level depends significantly on the integrity of the ligaments. The



a.



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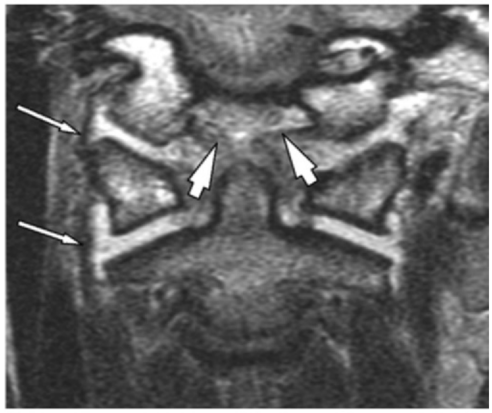

c.

Figure 20. Atlanto-occipital and atlantoaxial dislocations in a 17-year-old boy with neck pain after a bicycle-versus–motor vehicle accident. **(a)** Midline sagittal reformatted CT image shows a normal basion-dens interval (line) and widening (double arrow) of the C1-C2 spinolaminar line to 11 mm. **(b, c)** T2-weighted MR images obtained 1 day later. **(b)** Sagittal view shows that atlanto-occipital and atlantoaxial widening worsened in the interval, with increase of the basion-dens interval (not seen). The C1-C2 articular capsule is distended, with a blood-fluid level (arrow). **(c)** Coronal view shows that disruption of the alar ligaments (thick arrows) is present. Note the distended capsules (thin arrows) of the atlanto-occipital and atlantoaxial joints.

alar ligaments and transverse ligament are the most important stabilizing ligaments in the CCJ.

Pediatric patients younger than 8–10 years of age are at higher risk for atlanto-occipital dislocation injury than are older children and adolescents because of the disproportionately larger head-to-body ratio, flatter atlanto-occipital joints, and more flexible and weaker ligaments.

The classifications of cervical spine injuries are useful to identify patients who are in unstable condition and may need additional workup.

Rotatory atlantoaxial subluxation is a rare entity. The diagnostic criteria have been described using plain radiography. With the widespread use of CT, it has become evident that considerable rotation and loss of contact of the C1-C2 articulations occurs physiologically, and this diagnosis will need to be reevaluated.

Many CCJ injuries are not isolated. Therefore, a detailed examination of the different bone and soft-tissue structures is essential for optimal patient care.

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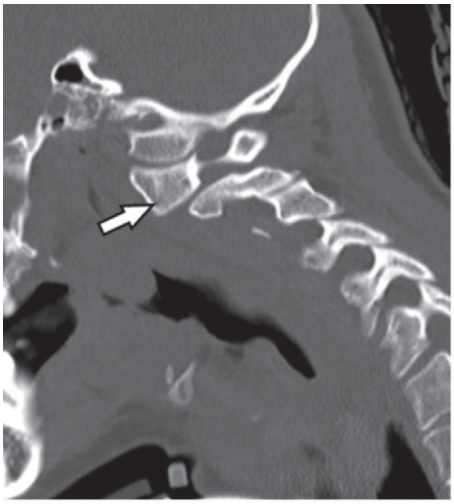
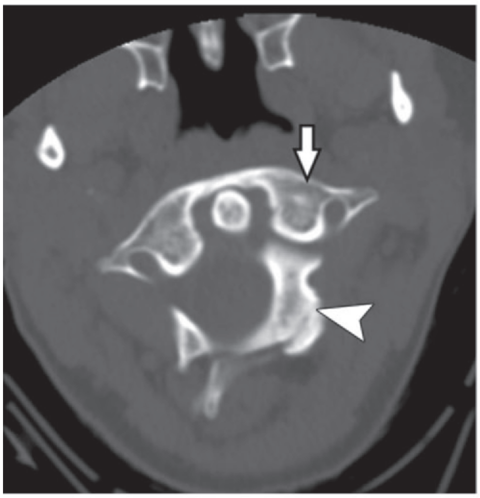


a.

Figure 21. Rotatory subluxation. **(a)** Sagittal CT image shows anterior displacement of the atlas (arrow) on the left atlantoaxial joint. **(b)** Axial CT image shows rotatory subluxation of the atlas (arrow) in relation to the axis (arrowhead). **(c)** Three-dimensional volume-rendered image from below shows the naked inferior facet joint (arrow).



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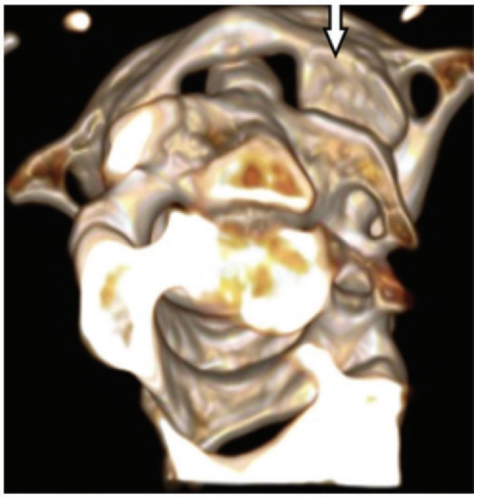

c.

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