Radiography of the cervical spine in trauma

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This article illustrates the typical clinical and radiographic findings of patients with injuries to the cervical spine and discusses basic treatment guidelines. Cervical spine injuries are frequently seen in multitrauma patients and can be devastating injuries, particularly if not identified in a timely manner. The initial evaluation is both clinical (questioning about neck pain, palpating the neck, and neurologic examination) and radiographic, if indicated. All trauma patients should be effectively immobilized until a cervical spine injury is ruled out.

The initial radiographic work-up consists of anteroposterior, lateral, and open-mouth odontoid views. If the C7-T1 junction is not seen on plain radiographs, a swimmer’s view of the cervical spine should be obtained. If this view remains inadequate, a computed tomography (CT) scan through the nonvisualized vertebral bodies should be obtained. Depending on the type of injury, additional radiographic studies may be indicated. Early recognition of cervical spine injury and consultation of a spine specialist is imperative for a good neurologic outcome.

Atlanto-occipital dislocation

Frequency/incidence

Atlanto-occipital dislocation (AOD) is present in up to 1% of patients with cervical spine injuries. AOD has been found in 19% to 35% of autopsies of fatal cervical spine injuries. There is a higher incidence of AOD among children [1].

Signs and symptoms

AOD is typically fatal [1,2]. Mortality is most frequently from anoxia caused by respiratory arrest. Among survivors, more than 70% have an associated head injury [3]. Cranial nerve palsies (especially types VI, IX and XII) are seen in 50% of cases. Complete quadriplegia or brainstem injury typically results in death. Brown-Séquard or central cord syndrome may also be observed. Patients will frequently deteriorate when placed in cervical traction. The patient may be completely neurologically intact and have a good outcome [1].

Etiology/pathophysiology

AOD is caused by violent trauma (typically, motor vehicle collision or pedestrian struck by car) and may be related to hyperextension with distraction [1,3]. In fatal cases, there is transection of the spinal cord; however, in cases in which the patient survived, there was angiographic evidence of vertebral artery injury at the C1 level where the artery penetrates the dura to become intracranial. From a mechanical view, the distal vertebral artery as well as the head is...
freely moveable in AOD, causing the artery to be injured at the C1 level as the vertebral artery then becomes anchored to the spine within the transverse foramen. At autopsy, none of these patients had evidence for mechanical injury or transection of the cord [4].

Image of choice for diagnosis

Radiographic diagnosis is difficult, which frequently delays diagnosis. Plain lateral radiographs are typically the first test ordered. Plain radiographic techniques for diagnosing this entity include the Power’s ratio, and the X-line method [5]. The opisthion and basion are often difficult to identify on plain films, making thin-slice CT (3-mm cuts) with sagittal reconstruction a more accurate way of identifying AOD (see Power’s ratio in the Image hallmarks section). If suspicion is high, reformatted CT is the test of choice.

Image hallmarks

There is typically massive retropharyngeal soft tissue swelling (Fig. 1). On plain lateral radiographs, the Power’s ratio is frequently employed. The distance from the basion to the posterior arch of the atlas divided by the distance from the opisthion to anterior arch of atlas is greater than 1.0 in all cases of AOD. A Power’s ratio of less than 0.9 is normal, whereas ratios of 0.9 to 1.0 are borderline, representing 7% of the normal population and no cases of AOD [2].

Management

Initial treatment involves strict immobilization of the cervical spine. Patients are typically reduced and placed in a halo vest. It is typically recommended that the patient subsequently undergo posterior occipital to cervical fusion [1,3].

Fig. 1. Lateral radiograph with massive soft tissue swelling.
Atlantoaxial rotatory subluxation/dislocation

Frequency/incidence

Rotatory subluxation at the C1-2 joint is relatively uncommon.

Signs and symptoms

Patients will frequently have torticollis, inability to rotate their head, facial flattening (if chronic), and upper cervical pain. The head position is sometimes described as “cock robin” (20° lateral tilt to one side, 20° rotation to the other side, and a slight flexion) [6].

Etiology/pathophysiology

Rotatory subluxation typically occurs in children because the facet joints are smaller and more steeply inclined, and children have a larger head-to-body ratio, making the joint prone to rotational damage [7]. It can be seen spontaneously, with minor or major trauma, and can occur in association with upper respiratory infections [6].

Image of choice for diagnosis

Diagnosis may be made with an open-mouth odontoid view; however, thin-cut CT from the occiput through C2 is the preferred imaging test.

Image hallmarks

On open-mouth odontoid view, there is typically asymmetry of the atlantoaxial joint (the C1 lateral mass that is rotated forward appears larger and closer to the midline; Fig. 2). The spinous process of the axis is tilted in one direction and rotated in the opposite direction. CT scan typically shows the rotation of the atlas on the axis [6,7].

Fig. 2. (A) Anteroposterior radiograph demonstrating “cock robin” head position described in atlantoaxial rotatory subluxation. (B) Lateral radiograph demonstrating rotation of C1 on C2. (C) CT scan demonstrating rotation of C1 on C2.
Management

If diagnosed early (<1 week), patients can frequently be treated with closed reduction using cervical traction or a soft collar and an exercise program. Longstanding or recurrent subluxation will often be treated with open reduction and fusion (C1-2) [7].

Dens fracture

Frequency/incidence

Dens fractures represent 10% to 15% of cervical spine fractures [2].

Signs and symptoms

Common symptoms associated with dens fracture involve upper cervical pain. Patients will frequently hold their head between their hands when changing from a supine to upright position. It is estimated that 25% to 40% of patients with this fracture die at the time of the accident. Patients who survive the injury are most frequently neurologically intact [2]. Approximately 20% of patients with dens fractures present with myelopathy. In a study by Apuzzo et al [8], 44 of 45 patients were neurologically normal within 4 weeks of the event.

Etiology/pathophysiology

Most dens fractures are probably the result of flexion injuries secondary to violent trauma. Extension injuries may cause dens fractures, particularly those associated with posterior displacement. In elderly and young patients, dens fractures have been reported following falls [9].

Image of choice for diagnosis

Dens fractures are typically seen on the open-mouth odontoid view. If the dens is not well visualized, anteroposterior (A-P) and lateral tomograms may be helpful. Axial CT images will frequently miss the fracture. If a CT scan is ordered, 2- to 3-mm cuts with sagittal reconstructions should be performed (when a dens fracture is suspected).

Image hallmarks

There are three types of dens fractures; type I fractures occur through the tip of the dens (very rare), type II fractures occur through the base of the neck of the dens (most common type of dens fracture; Fig. 3), and type III fractures occur through the body of C2.

Management

Type I and type III fractures are typically considered stable and treated using a hard collar for a period of 8 to 14 weeks. Type II fractures have a high rate of nonunion, particularly if there is displacement (>4–6 mm) or the patient is elderly [8]. In younger patients, if there is minimal displacement, these fractures will typically be treated using halo vest immobilization. If there is significant displacement or the patient is elderly, these fractures will typically require surgical fusion (odontoid screw or posterior C1-2 fusion) [8]. Type II fractures in children will nearly always heal with immobilization alone [9].
Fig. 3. (A) Lateral radiograph demonstrating a type II dens fracture. (B) Anteroposterior film demonstrating fracture through the base of the dens. (C) Tomogram demonstrating fracture through the base of the dens. (D) CT scan of type II dens fracture.
Jefferson fracture

Frequency/incidence

Jefferson fracture represents 10% of spine fractures [10] and is frequently associated with C2 fracture (>40% of cases) [2].

Signs and symptoms

Patients very rarely have neurologic symptoms; frequently, patients complain of neck pain. Twenty-one percent of patients also have a head injury [2].

Etiology/pathophysiology

Typically, an axial loading force to the skull causes this type of fracture [10]. Because the lateral masses of C1 and the occipital condyle have a wedge-shaped appearance, the axial loading widens the ring, resulting in four breaks in the C1 ring at their weakest locations—the bilateral lamina/vertebral artery groove junction and the bilateral anterior arch/lateral mass junction. Most fractures are also associated with tear of the transverse ligament, which allows ring widening to occur and also makes this a highly unstable injury at the C1-C2 level: tear of the transverse ligament may further injure the cord but at a lower level than the AOD.

Image of choice for diagnosis

These fractures are frequently missed on lateral radiographs of the spine but are usually identified on open-mouth odontoid view of the atlantoaxial region by the overhang of C1 lateral masses on C2. Most of these AOD exhibit very marked prevertebral soft tissue swelling not seen to this degree with other cervical spine injuries. A thin-section (2 mm with overlapping slices) CT scan from C1-C3 with sagittal and coronal reconstructions is the imaging method of choice [2]. The Power’s ratio is only good for anterior AOD, and is negative for dislocation if it is in a posterior or longitudinal direction. The X-lines are able to diagnose all three types of AOD. The difficulty with the plain radiographic methods is identifying reliably the basion and opisthion.

Image hallmarks

Open-mouth odontoid view shows outward displacement of the lateral most edges of the C1 lateral mass relative to those of C2. Fracture through the anterior and posterior neural arches of C1 is seen on CT scan (Fig. 4). There is typically significant retropharyngeal soft tissue swelling. Transverse ligament tear can be directly seen when there is avulsion of the transverse ligament tubercle with a chip of bone seen within the C1 ring on CT. The unaffected tubercle can be seen on the contralateral side. If the bone is not torn, transverse ligament tear can be inferred by marked widening of the predental space in relation to the anterior arch of C1 because of forward subluxation of C1 with respect to CT. Most of the time with AOD, there is also instability at the C1-C2 level as well.

Management

Nondisplaced fractures (no overhang of C1 on C2) are typically treated with a hard collar. Fractures with less than 7 mm of displacement are treated with a hard collar or halo vest immobilization. Fractures with greater than 7 mm of displacement (implies disruption of the transverse atlantal ligament) are treated with halo vest immobilization [2].
Hangman’s fracture (traumatic spondylolisthesis of the axis)

Frequency/incidence

Traumatic spondylolisthesis of the axis, or hangman’s fracture, represents about 7% of cervical spine fractures [11].

Signs and symptoms

Neck pain and pain with motion are frequently experienced. Patients rarely have neurologic deficits (<5%) related to the hangman’s fracture as long as they survive the initial traumatic forces. There is a high incidence of associated head injury (70%–80%) [2].

Etiology/pathophysiology

Hangman’s fractures historically have been caused by distraction and hyperextension as with an execution by hanging [12]; however, most modern hangman’s fractures are caused by hyperextension with axial loading as is frequently seen in automobile accidents. The classic scenario is an unrestrained passenger in a motor vehicle collision in which the chin of the passenger is forced into marked hyperextension on the dashboard or on the steering wheel.

Image of choice for diagnosis

Plain lateral radiographs identify 95% of cases based on the anterior subluxation of C2 with respect to C3 [2].
Fig. 5. (A) Lateral radiograph demonstrating fracture through pedicles of C2. (B) CT demonstrating bilateral C2 pedicle fractures.
Plain films do not demonstrate the bilateral arch fracture through the C2 pedicles well, whereas CT clearly shows the fracture (Fig. 5). Anterior subluxation of C2 on C3 is frequently seen on the plain radiographs. Less often, there may be an avulsion fracture from the anterior inferior corner of the body of C2; however, this avulsion fracture may occur by itself without a hangman’s fracture. Nevertheless, if this chip is seen, one must presume there is an associated hangman’s fracture, until the CT scan proves otherwise.

Management

Nonsurgical treatment is adequate in 95% of patients. For type I fractures (<3 mm of displacement), the patient may be treated with a hard collar or halo vest (for unreliable patients) for 12 weeks. Type II (angulation and translation of C2 on C3 of >3 mm) and type IIA (angulation without significant displacement) are treated with halo vest immobilization for 8 to 12 weeks followed by hard collar for a total of 3 to 4 months of immobilization. Type III fractures (pars fracture with bilateral facet dislocation at C2-3) typically require operative intervention (anterior cervical fusion of C2-3) [2].

Burst fracture

Frequency/Incidence

Burst fractures are common in the thoracolumbar spine but are rare in the cervical spine [13]. The teardrop fracture, which is the most common in the cervical spine, may be considered to be a variation of the burst fracture.

Signs and Symptoms

Symptoms can vary from neck pain, radiculopathy, to complete spinal cord injury depending on the degree of spinal canal compromise [13].

Etiology/Pathophysiology

Burst fractures are secondary to an axial loading injury [13].

Image of choice for diagnosis

Burst fractures are typically seen on lateral radiographs of the spine. Anteroposterior views are often helpful in differentiating from compression fractures (increased interpedicular distance is often seen in burst fractures). CT scan is the diagnostic test of choice as it allows accurate assessment of spinal canal compromise. Magnetic resonance imaging (MRI) is helpful in identifying associated ligamentous injuries but is not necessary in most cases of burst fracture.

Image hallmarks

Typically, there is loss of body height and increased interpedicular distance seen on plain radiographs (Fig. 6A). Retropulsion of bony fragments is typically seen on plain radiographs. CT scans will often show a comminuted fracture of the vertebral body and demonstrate the associated posterior element fracture (pedicle, lamina, spinous process; Fig. 6B).

Management

Burst fractures are typically treated with anterior body corpectomy and fusion. At times, rigid bracing or posterior fusion may be recommended [13].
Fig. 6. (A) Lateral radiograph of C6 burst fracture. (B) Comminuted burst fracture including bilateral laminar fractures.
Compression/wedge fracture

Frequency/incidence

Simple compression fractures with wedge deformity of the body are uncommon in the cervical spine but more commonly seen in the thoracic and lumbar regions.

Signs and symptoms

Patients frequently complain of neck pain at the site of the fracture. Neurologic deficits are rare with compression fractures (neurologic injury would imply instability and a more significant injury than a simple compression fracture).

Etiology/pathophysiology

Compression fractures are thought to be caused by flexion/axial loading forces.

Image of choice for diagnosis

Compression fractures are seen on plain lateral radiographs. CT scanning is helpful to ensure that there is no spinal canal compromise as would be seen in a burst fracture.

Image hallmarks

On plain radiographs, there is loss of vertebral body height anteriorly with preservation of the posterior vertebral body height (wedge-shaped vertebral body; Fig. 7A). On CT scan, there is cortical disruption of the anterior cortical margin of the vertebral body (Fig. 7B).

Management

Patients with compression fractures are typically treated using rigid immobilization (hard collar) for 6 to 12 weeks. Prior to removal of the hard collar, flexion-extension cervical spine radiographs should be obtained because there are several reports of instability associated with cervical compression fractures [14]. This instability implies ligamentous injury as well, because the simple wedge fractures are not unstable injuries unless there has been an acute loss in height of more than 50%.

Subluxation facet fracture/lock

Frequency/incidence

Facet fractures with subluxation represent approximately 7% of cervical spine injuries according to a study by Sonntag and Hadley [15]. Bilateral and unilateral fractures are most commonly found at the C6-7 level.

Signs and symptoms

Patients with unilateral facet fracture-dislocation can have a variable presentation. Sonntag and Hadley [15] found that of 31 patients, 6 were neurologically intact with pain only, 7 had root deficits only, 10 had incomplete spinal cord injuries, and 7 had complete neurologic injuries. Bilateral facet fracture-dislocations tend to have more significant neurologic injuries. In a study of 37 patients, 31 patients had complete spinal cord injuries and 6 had incomplete spinal cord injuries [15].
Etiology/pathophysiology

Unilateral facet fracture-dislocations are thought to be caused by a flexion-rotation injury, whereas bilateral facet fracture-dislocations are thought to be caused by hyperflexion injury.

Fig. 7. (A) Lateral radiograph demonstrating wedging of the C7 vertebral body as typically seen in a compression fracture. (B) CT scan of fracture through anterior portion of vertebral body.
**Image of choice for diagnosis**

Plain lateral radiographs are adequate in the diagnosis of unilateral and bilateral facet fracture-dislocations. A CT scan through the area will be helpful in determining the degree of disruption of the superior and inferior articular processes of the facet.

**Image hallmarks**

With unilateral facet fracture-dislocation, there is subluxation of approximately 25% of the superior vertebral body relative to the inferior vertebral body (Fig. 8). Typically there is also evidence of rotation. With bilateral facet fracture-dislocation, there is approximately 50% or greater subluxation without evidence of rotation. On CT, the affected facet joint appears to be two semicircles with the curved surfaces abutting each other, thus uncovering the facet joint itself. Normally, the flat surfaces abut each other such that the facet joint is not seen, and the two facets have an ovoid shape.

**Management**

For unilateral facet fractures, closed reduction using cervical traction is attempted. If closed reduction is successful (18 of 29 of acute fractures in the Sonntag and Hadley study), the patient is typically immobilized in a halo. If unable to achieve closed reduction, open reduction and...
Fig. 8 (continued)
internal fixation using interspinous cables or lateral mass plates are typically undertaken. A similar treatment is attempted with bilateral facet fracture-dislocations; however, the likelihood of achieving adequate closed reduction is lower (20 of 37 acute fractures) [15].

Teardrop fracture

Frequency/incidence

Teardrop fractures represent approximately 5% of cervical spine fractures [2].

Signs and symptoms

Patients are frequently quadriplegic. They are rarely neurologically intact [2].

Etiology/pathophysiology

Teardrop fractures are typically seen in the setting of an acute flexion injury with severe axial loading [16]—most commonly sustained from diving into a shallow body of water. An unrestrained automobile passenger with the head flexed and then driven into the dashboard may also sustain this injury. Even though the teardrop bony fragment itself involves the anterior body, it is the associated retropulsion of the posterior body into the canal that injures the spinal cord. This persistent retropulsion of the body is seen on plain radiographs in most patients [17].
Teardrop fractures are usually seen on lateral radiographs; however, to differentiate them from a simple avulsion fracture of the anteroinferior corner of the vertebral body, a CT scan through the area in question is helpful. Teardrop fractures are associated with retropulsion of the fractured body, sagittal body fracture, and laminar fractures, which are not seen with simple avulsion fractures [17]. MRI may also be useful in evaluating the degree of ligamentous injury, the presence of an associated disc herniation, and spinal cord injury.

A triangular piece of bone is typically seen at the anterior inferior edge of the fractured vertebral body (the “teardrop”; Fig. 9A). Frequently, there is an associated sagittal fracture of the vertebral body. This is difficult to see on the A-P view of the cervical spine because of confusing lines from the tracheal air column, nasogastric tubes, or endotracheal tubes. The fractured vertebral body is usually displaced posteriorly relative to the vertebral body below. Kyphosis is frequently seen at the site of the fracture, and there may be evidence of facet disruption. The subjacent disc space is often narrowed. There may be significant soft tissue swelling. CT scanning may better show the sagittal vertebral body fracture, which is frequently present, and more accurately assess the degree of spinal canal compromise (Fig. 9B) [2].

If the ligamentous structures (including the disc) are intact and there is no spinal cord compression, the teardrop fracture may be treated with halo immobilization for 8 to 12 weeks followed by flexion-extension cervical-spine X rays to ensure stability. If there is a large anterior fragment with spinal cord compression, an anterior corpectomy and fusion is typically
indicated. If there is associated posterior ligamentous injury, a combined anterior-posterior fusion may be indicated [2].

Clay shoveler’s fracture

Frequency/incidence

Clay shoveler’s fracture is uncommonly seen in trauma. It is usually seen in patients performing excessive manual labor, such as grave diggers [18].

Signs and symptoms

Patients complain of pain between their shoulders, which is made worse with pulling and/or lifting. There is no neurologic deficit. Patients have tenderness to palpation along the lower cervical/upper thoracic spine and increased pain with flexion of the head [18].

Etiology/pathophysiology

Avulsion of the spinous process occurs by forces transmitted from the trapezius and other muscles attached to the spinous process. This fracture is also seen in hyperflexion and hyperextension injuries [18,19]. As the shoveler attempts to throw the dirt off his shovel by tossing it behind his head, the clay sticks to the shovel causing a forced hyperextension load to the neck, which crowds the lower cervical posterior spinous process leading to fracture.
Fig. 10. (A) C6 spinous process fracture. (B) CT of fracture through spinous process.
**Image of choice for diagnosis**

Clay shoveler’s fracture is typically seen on plain lateral radiograph; however, if there is a laminar fracture, CT may be necessary to determine if there is any encroachment on the canal.

**Image hallmarks**

There is fracture of spinous process of C7, C6, or T1 (in decreasing frequency; Fig. 10) [18].

**Management**

This is a stable fracture. Evaluation should include flexion-extension cervical-spine radiographs and, if negative, only pain medication should be required. Hard-collar immobilization may be used as needed for pain control [2].

**References**