Cervical spine trauma

Background and epidemiology
Cervical spine injury is the second most common injury to the spine, comprising 28.6% of spinal injuries1 and 55% of spinal cord injuries. C2 is the most common fractured vertebra, accounting for 24% of injuries.2 However, despite measures to detect spinal injuries, delayed diagnosis or suboptimal treatment remain common, with 3-25% of patients developing neurological complications.3 C-spine injury is less common in children and requires a more cautious imaging strategy.

Computed tomography (CT) is currently the mainstay of imaging in adult cervical spine trauma. Radiography has a limited role due to a high inadequate study rate and poor sensitivity compared with CT (39-52% vs 98%).4

Anatomy and biomechanics of the cervical spine
The neurocranium accommodates multiple sensory organs, notably vision and balance. These must be oriented in a direction of interest and this requires considerable flexibility and stability to be provided by the components of the cervical spine.

There are numerous ligaments that support the cervical spine and cranio-cervical junction. Figure 1 illustrates the most important ligamentous structures visible on the mid-sagittal section. The alar and transverse ligaments are visible on parasagittal sections.

Assessing the stability of the cervical spine
In a simple definition, stability of the spine is the ability of vertebrae to maintain their relationship and limit their relative movements during physiological postures or loads. Various methods have been developed to assess stability in the subaxial (C3 and caudal) spine based on radiography (Denis), mechanism (Allen-Ferguson) and CT/MRI (SLIC system).

Francis Denis developed the three-column spine model as a method to determine stability of spinal injury by radiological imaging, dividing the spine into three columns (table 1). In general, if two or more of these columns are damaged then the spine is considered unstable. Although developed for thoracolumbar spine injuries, the Denis model is adequate in many cases of subaxial cervical trauma.

The SLIC system uses a composite score based on morphology of the fracture, the state of the discoligamentous complex and the neurological status of the patient, which can be used to advise on surgical or conservative management.4

Clinical algorithms for imaging
The NEXUS study in 1998 developed a set of rules which aimed to identify those at minimal risk of serious injury for whom imaging could be omitted. The study identified five risk factors (focal neurological deficit; midline spinal tender-ness; altered level of consciousness; intoxication; and distracting injury). If all were absent, then radiography was not necessary.

Canadian C-Spine Rules
In 2001, the Canadian C-Spine Rules (CCR) were introduced and use both high and low risk factors. The high-risk markers are first checked and if any are present then imaging is recommended immediately. Otherwise, low-risk markers are checked to see whether a safe assessment of range of movement can be performed. If all low-risk markers are absent, imaging is performed. If one or more are present, then the patient is assessed for ability to actively rotate the neck 45 degrees left and right, with imaging performed if active motion is not possible.5

The Canadian C-Spine Rules are more sensitive than the NEXUS criteria6 and reduce the need for imaging by 44% (versus 33% for NEXUS). The CCR are the specified algorithm in the most recent NICE guidance.

NICE guidelines
The latest NICE guidelines (www.nice.org.uk/guidance/ng41) issued in February 2016 provide changed imaging advice. In adults, CT should be performed as first line imaging, and as part of whole body CT in a major trauma scenario. MRI is performed if, after CT, there are signs and symptoms suggestive of spinal cord injury. In children MR imaging is the first choice imaging modality to be used if there is strong clinical suspicion. X-rays are recommended in children who do not satisfy the clinical criteria for MR imaging but suspicion remains after repeated assessment.

Patterns of injury
Cranio-cervical junction injuries
Cranio-cervical dissociation
Cranio-cervical dissociation (CCD) is the disruption of the cranio-cervical junction and its ligamentous complex, due usually to hyperextension or hyperflexion-distraction injuries. While rare, it carries high mortality and morbidity. Survival rates in children are better. As primarily a ligamentous injury, approaches based on measurement have been developed to aid diagnosis (figure 2). The Power’s ratio is a useful way to assess for this type of injury. In normal individuals the ratio of BC:OA should be <1. If >1 then this is suggestive of atlanto-occipital dislocation since the atlas and axis move posteriorly in relation to the cranium.

Alternatives include the basion-dental interval (BD in figure 2) and basion-axial interval, both of which should be <12mm. However, the normal range may be different on CT, and the reliability of the basion-axial interval is questionable.8

Occipital condyle fractures
Anderson and Montesano described a classification of these rare injuries comprising three types9 (table 2). The type III fracture should be recognised as it is potentially unstable (figure 3).

C1 fractures
These fractures are usually classified into three types based on morphology (table 3). The atlanto-dens interval (ADI) can give an approximate indication of the ligamentous integrity. ADI is usually <3mm in adults and <5mm in children. In adults, a measure between 3-5mm, suggests transverse ligament disruption, but preservation of the alar and apical ligaments. If the ADI is >5mm the alar and apical ligaments have also been disrupted. On coronal imaging, misalignment of the lateral masses with C2 may also be present.
C2 fractures
The Anderson and D’Alonzo classification, based on fracture site is widely used (Table 4). The majority are type II fractures which are unstable. They most commonly occur in the elderly and have a high rate of non-union. Type I and type III fractures are uncommon but are less likely to be unstable.

Subaxial cervical spinal injuries

Extension teardrop fracture

The term “teardrop” is a description of an anterior-inferior corner fracture of a vertebral body. This can cause confusion as it can be seen in two distinct injuries. In the context of severe hyperextension, as may occur in sudden deceleration in RTAs, the teardrop represents an avulsion of the anterior longitudinal ligament from the vertebral body (Figure 5).

Flexion teardrop fracture

In severe hyperflexion and compression, a similar shaped fracture fragment may result. Often, there is retropulsion or collapse of the vertebral body. This feature is not usually present in extension teardrop fractures and can cause anterior cord injury. Three-column ligamentous injury can result, and commonly there is injury to the posterior ligaments, visible as widening of the interspinous spaces and facet joints.11

Facet joint fracture dislocation

The facet joints are uniformly superimposed and strongly supported by multiple ligaments and the joint capsule. In the case of a flexion-rotation injury, there can be disruption of the posterior ligament complex and the unilateral subluxation of a superior facet over the inferior facet of the involved joint, with or without associated fracture. The stabilizing effect of the ligamentous complex can result in realignment of the spine, even in the context of significant injury (Figure 6).

Bilateral facet dislocation is a very unstable injury and usually results from hyperflexion resulting in disruption of the ligamentous complexes of all three columns. The facet joints become locked and there is anterior vertebral body displacement resulting in severe narrowing of the spinal canal and therefore severe neurological sequelae.

Special circumstances

In ankylosing spondylitis and similar conditions, ossification of numerous ligaments occurs. The excess rigidity of the spine impairs energy absorption and, as the bone is often weakened, fractures may occur even with minimal trauma. Further, these fractures tend to be highly unstable, and treatment is difficult. An extremely low threshold for imaging should be applied in these patients.

Vascular trauma can occur up to around 13% of patients with blunt head and neck trauma.14 This is more common in patients with facet subluxation or dislocation and in those who have fracture lines that involve the foramen transversarium or internal carotid canal. This can be easily assessed with CT angiography.

Conclusion

Cervical spine trauma is common and an important cause of morbidity and mortality. In adults, CT should be the mainstay of imaging the acute phase, with MRI used to clarify the extent of injury, especially when there is neurological deficit. There are anatomical differences between the craniocervical junction and the subaxial cervical spine which lead to different patterns of injury with different prognoses.

References


<table>
<thead>
<tr>
<th>Anterior column</th>
<th>Anterior longitudinal ligament</th>
<th>Anterior annulus fibrosus</th>
<th>Anterior half of the vertebral body</th>
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</thead>
<tbody>
<tr>
<td>Middle column</td>
<td>Posterior annulus fibrosus</td>
<td>Posterior half of the vertebral body</td>
<td>Posterior longitudinal ligaments</td>
</tr>
<tr>
<td>Posterior column</td>
<td>Face joint ligamentum flavum</td>
<td>Interspinous ligament</td>
<td>Supraspinous ligament</td>
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**TABLE 1**
Denis three column model and its components.

<table>
<thead>
<tr>
<th>Type</th>
<th>Description</th>
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<tbody>
<tr>
<td>I</td>
<td>Isolated fracture of the anterior or posterior arch.</td>
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<tr>
<td>II</td>
<td>Bilateral fracture of the anterior AND posterior arches (Jefferson Burst fracture). Stability can be determined by the integrity of the transverse ligament.</td>
</tr>
<tr>
<td>III</td>
<td>Fracture of a unilateral C1 mass. Again stability is determined by the integrity of the transverse ligament.</td>
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**TABLE 2**
Anderson and Montesano classification of occipital condyle fractures.

<table>
<thead>
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<th>Type</th>
<th>Description</th>
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<tbody>
<tr>
<td>I</td>
<td>Commination of the occipital condyle due to compression between the atlanto-odontoid joint. Stable injury</td>
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<tr>
<td>II</td>
<td>Linear skull fracture that extends into the occipital condyles mostly because of a direct blow to the skull. Stable injury</td>
</tr>
<tr>
<td>III</td>
<td>Avulsion fracture of the condyle at the insertion of the alar ligament (forced contralateral bending). Unstable due to craniocervical ligamentous disruption (Figure 3).</td>
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**TABLE 3**
Classification of C1 fractures.
Figure 1
(A) schematic drawing of ligaments and relations of the craniocervical junction; (B) typical appearances on MRI.

Figure 2
Measurements at the craniocervical junction. (A) anterior arch of C1, (B) basion, (C) posterior arch of C1, (D) tip of odontoid, (O) opisthion.

Figure 3
Type III occipital condyle fracture (arrow) indicating avulsion of the alar ligament.

Figure 4
Sagittal image showing the typical location of the fracture line in a type II odontoid fracture. In this case alignment is preserved, but this fracture is frequently unstable.
Figure 5
Extension teardrop fracture. Sagittal CT (A) and MRI STIR (B) images. Disruption of the anterior longitudinal ligament (arrow) is visible on MRI, but there is no subluxation or disruption of the interspinous ligaments. This fracture is distinguished from the more serious flexion teardrop injury by absence of widening of the interspinous distances or interspinous ligamentous oedema.

Figure 6
Unifacet fracture. The CT (A-C) shows only a small fracture of the right C6 superior articular facet with normal alignment. However, the MRI shows that the injury is more extensive, including the disc. A defect in the ligamentum flavum is also visible, together with some interspinous oedema. The spinal cord is also compressed by haematoma (arrow). The Denis three column model can be misleading in cases such as this.