

Radiographic Evaluation of Cervical Spine Injury

Introduction

The single most important treatment for those suspected of having incurred a cervical spine injury is immobilization. Soft cervical collar provide no stability and that a rigid cervical collar alone is not adequate protection for patients with a neck injury. Therapy should include the combination of the rigid collar sand bags and tape. A high index of suspicion and a detailed neurologic examination are the cornerstones for diagnosing spinal cord injuries. Due to an overlap in sensory dermatomes the sensory examination is less precise in determination of injury level than the motor examination.

<u>Nerve Root</u>	<u>Motor</u>	<u>Sensory</u>	<u>Reflex</u>
C3		Lower neck	
C4	Diaphragm	Clavicular area	
C5	Deltoid, Biceps	Lateral upper arm	Biceps
C6	Extensor carpi radialis	Thumb, Lateral forearm	Brachioradialis
C7	Triceps, Wrist flexors, Finger extensors	Middle finger	Triceps
C8	Finger flexors	Little finger	
T1	Hand intrinsics	Medial forearm	
T4	Intercostals	Nipple	

Table 1 - Nerve root level contributions

Incomplete Cord Injury

Incomplete cord injuries usually can be classified into one of three clinical syndromes: the **central cord syndrome**, the **anterior cord syndrome** and the **Brown-Sequard syndrome**.

The *central cord syndrome* is the most common and is defined as disproportionately greater paralysis of the upper compared with the lower extremities, bowel and bladder dysfunction and a variable degree of sensory loss below the level of injury. The fine motor function of the fingers is the first to be affected and the last to return. It is typically due to a hyperextension injury in older patients with decreased spinal diameter and arthritic changes. There also are cases in younger patients associated with extension rotation injuries. There are two proposed mechanisms of injury. The first involves the squeezing of the spinal cord by the inward bulging of the ligamentum flavum. The second theory is that of ischemia secondary to vertebral artery compression.

The *anterior cord syndrome* results from damage to the ventral cord involving the corticospinal and spinothalamic tracts. Characteristically there is a loss of motor function and sensation to pain and temperature below the level of injury. As the posterior columns are unaffected, proprioception and vibration sense are present. It is usually the result of a flexion injury. The proposed mechanisms are acutely herniated disk, thrombosis of the anterior spinal artery or posteriorly displaced fractured vertebral body.

The *Brown-Sequard syndrome* is a physical or clinical hemisection of the cord. This entity displays an ipsilateral paralysis and loss of proprioception and vibratory sensation below the level of the lesion, along with contralateral loss of pain and temperature sensation beginning one or two segments below the lesion. It is typically attributed to penetrating trauma but also is associated with rotational dislocation or subluxation injuries or with unilateral pedicle and laminar injuries.

Unfortunately, few lesions fit exactly into one of the above injury patterns. It is much more typical for the lesions to be a combination of any three of the incomplete syndromes. The primary concern should be distinguishing complete from incomplete lesions.

The single most important radiographic examination of the acutely injured patient is the cross-table lateral radiograph of the cervical spine. It is crucial that all seven cervical vertebral bodies are visualized, and every reasonable effort must be made to do so. If this is not possible, then the patient must remain immobilized until definitive imaging (CT scanning) can be performed.

If there are no obvious or severe fractures or dislocations on the lateral view and the patient's condition permits, then the complete radiographic examination is performed. This includes first the AP view and open-mouth view of the atlanto-axial articulation. Oblique views are particularly helpful in assessing facet joint alignment and posterior element fractures.

If a ligamentous injury is suspected or an injury of questionable stability is noted then lateral flexion and extension views may be obtained. The patient should perform the flexion and extension (it should never be forced by the physician or technologist). Flexion and extension views are absolutely contraindicated in documented unstable injuries.

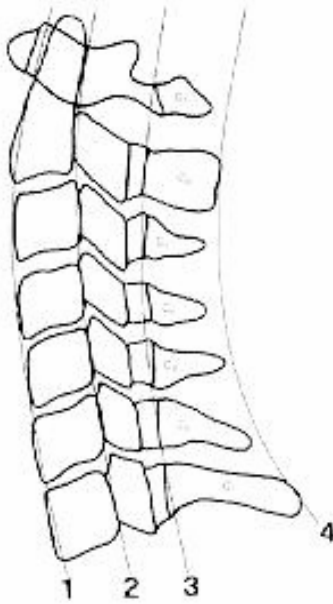
Additional imaging may be necessary in confusing cases. Computed axial tomography is the mainstay of such imaging, and should be performed after consultation with the neuroradiologic and neurosurgical staff. The relative merits of each for given injuries is beyond the scope of this monograph.

Normal Cervical Spine Anatomy and Alignment

The cervical spine consists of seven vertebrae (atlas, axis, and C3 - C7) as well as a complex ligamentous support system. Normal anatomy and alignment may be divided into two general segments, the **craniocervical junction** (base of skull, atlas and axis) and the **lower cervical spine** (C3 - C7). In each segment the bone elements will be discussed first along with the methods for assessment of normal alignment. Description of the ligaments and soft tissues will follow.

Contour Lines

A key element in assessing alignment is visualization of the four normal contour lines shown here. These are also important in defining the bony margins of the spinal canal and subsequent impingement on the spinal cord with malalignment. Disruption of any of these gently curving arcs indicates spinal malalignment.



Anterior Marginal Line (1)

- A smooth, gently curving arc convex anteriorly, formed by a line drawn along the anterior cortices of the vertebral bodies.

Posterior Marginal Line (2)

- A second similar arc formed by a line drawn along the posterior cortices of the vertebral bodies C2 - C7. This marks the anterior margin of the spinal canal.

Spinolaminar Line (3)

- A thin arc of cortex may be seen at each vertebral level where the laminae join the spinous processes. The spinolaminar line is the third gently curving arc formed by a line drawn along the bases of each spinous process C1 - C7. This marks the posterior margin of the spinal canal. At C1 the normal spinolaminar line may rarely be up to 1.0 mm behind those at C1 and C3.

Posterior Spinous Line (4)

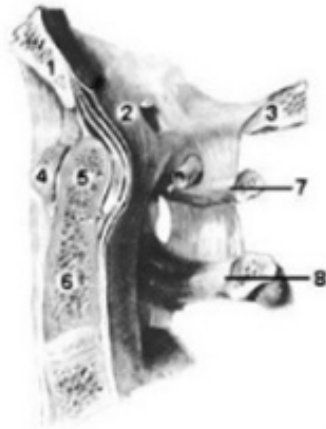
- The fourth gentle, anteriorly convex arc formed by a line drawn along the tips of the spinous processes C2 - C7.

Cranio-Cervical Junction (*Base of Skull and Craniocervical Articulation*)

The basilar occipital bone forms the margins of the *foramen magnum*. The sella turcica is formed by the sphenoid bone with its posterior aspect formed by the two lateral *posterior clinoid* processes and a bone bridge between them called the *dorsum sellae*. The *dorsum sellae* slants downward and posterior to the sphenoid-occipital synchondrosis. From this point the basilar portion of the occipital bone continues downward and posterior to the posterior rim of the *foramen magnum*.

When viewed laterally, a downward and posterior slanting surface is seen made up of the posterior portion of the sphenoid bone and the basilar portion of the occipital bone. This slanting surface forms the midline anterior wall of the posterior cranial fossa, and is termed the *clivus* (1). The posterior edge of the *clivus* forms the anterior rim of the *foramen magnum*, and when viewed laterally is called the *basion* (2). The posterior rim of the *foramen magnum* is seen in the lateral view as a beak-like projection termed the *opisthion* (4).

There are two rounded bony projections from the occipital bone at the anterolateral aspects of the *foramen magnum*. These are the *occipital condyles* (3), which articulate with the lateral masses of the C1 vertebra (*atlas*).

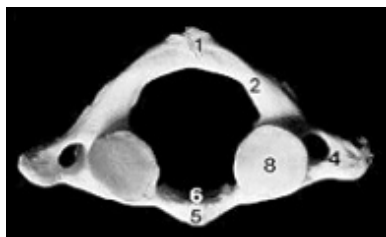


1. Clivus
2. Basion
3. Occipital condyle
4. Opisthion
5. Anterior arch of C1
6. Posterior arch of C1
7. C1 spinolaminar line

The Atlas (C1)

The atlas is a ring structure with an anterior and posterior arch. These arches are separated by two heavier sections of bone, one on each side termed the *lateral masses*. The superior surface of the lateral masses, or the *superior articular facets* (SAF), articulates with the occipital condyles forming the occipital-atlantal joints. The inferior surface of the lateral masses, or the *inferior articular facets* (IAF), articulate with the superior articular facets of C2 forming the C1 - C2 apophyseal joints.

The C2 *odontoid process* is the analogue of the C1 body. It is held in place by the *transverse atlantal ligament*. The anterior arch of C1 is fixed in relation to the odontoid process by the transverse atlantal ligament, which is attached to the medial aspects of the C1 lateral masses. Two synovial joints are formed, one between the transverse atlantal ligament and the posterior surface of the dens, and a second between the anterior surface of the dens and the posterior surface of the C1 anterior arch.



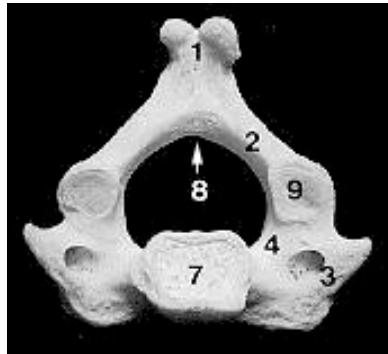
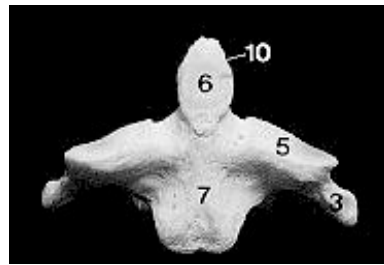
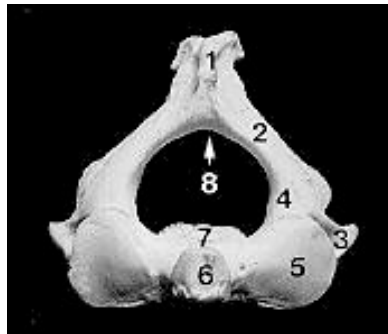
1. Posterior arch of C1
2. Pedicle of C1
3. Inferior articular facet of C1
4. Transverse process of C1



5. Anterior arch of C1
6. Anterior marginal line of C1
7. Lamina of C1
8. Superior articular facet of C1

Axis (C2)

The axis is the first vertebra with a heavy body. A superior projection of the body, the *odontoid process* or *dens*, articulates with the C1 anterior arch and is bound posteriorly by the transverse atlantal ligament. The *superior articular facets* lie on the top posterior aspect of the C2 body and articulate with the undersurface of the lateral masses of C1. The *inferior articular facets* lie posteriorly under the C2 pedicles and articulate with the SAF of C3. The C2 SAF lie significantly anterior to the IAF, separated by the thin inter-articular portion of the C2 pedicles.



1. Spinous process
2. Lamina of C2
3. Transverse process & foramen
4. Pedicle of C2
5. Superior articular facet
6. Dens (odontoid process) of C2
7. Body of C2
8. Spinolaminar line of C2
9. Inferior articular facet
10. Alar ligament impression

Atlanto-occipital Alignment

The occipital condyles should line up with the lateral masses and SAF of C1. On the lateral view this articulation may be obscured by the mastoid processes. The anterior margin of the foramen magnum should line up with the dens. A line projected downward from the dorsum sellae along the clivus to the basion should point to the dens. Conversely, the dens should point to the anterior rim of the foramen magnum. The posterior margin of foramen magnum should line up with the C1 spinolaminar line. A line drawn tangential to the C1 spinolaminar line should point to the opisthion (i.e. should line up with the posterior margin of the foramen magnum). The distance represents the spinal canal from the back of the odontoid to the C1 spinolaminar line. This should therefore lie directly below the foramen magnum. The atlanto-occipital joint allows flexion and extension of the head on the remainder of the cervical spine.



1. Basion
2. Occipital Condyle
3. Opisthion
4. Anterior arch of C1
5. Dens superimposed on C1
6. Body of C2
7. C2 Spinolaminar line
8. C2 Spinolaminar line

Assessment of Atlanto-occipital Alignment: (*Powers ratio*)



Four points should be located on the lateral view:

- B - Basion
- C - Spinolaminar line of C1
- O - Opisthion
- A - Posterior Cortex of C1 anterior arch

Two lines are constructed the first from the basion to the C1 spinolaminar line (B-C) and the second from the opisthion to the anterior arch of C1 (O-A). Each is measured and the ratio of the two calculated (B-C/O-A). The normal range of this measurement is 0.6 to 1.0, with the mean being 0.8. A ratio greater than 1.0 implies anterior cranio-cervical dislocation.

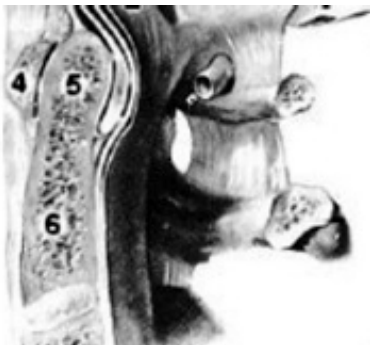
Atlanto-axial Alignment

The predental line (the distance from the odontoid to the posterior cortex of the anterior arch of C1) should be less than 3.0 mm. In children 5.0 mm is allowable during forward flexion. The odontoid and the body of C2 should be vertically aligned and confluent. Care must be taken to distinguish a fracture from a congenitally non-united odontoid or an accessory ossification center. On the A-P view the tips of the lateral masses of C1 should line up with the lateral margins of the SAF of C2. The distance from the dens to the lateral masses of C1 should be equal bilaterally. It is important to remember that these alignments will be affected by even small degrees of lateral flexion or rotation.



1. Odontoid process
2. Body of C2
3. Occipital condyles
4. Lateral mass of C1
5. Atlanto-Occipital joint
6. Atlanto-Axial joint

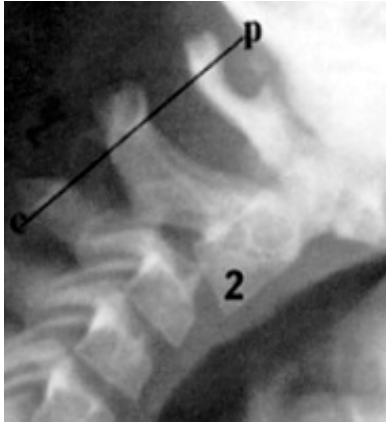
Note: the lateral margins of the atlas and axis should be aligned



The distance from the odontoid (5) to the posterior aspect of the anterior arch of C1 (4) should be less than 3.0 mm

Physiologic C2 - C3 Subluxation

This entity refers to normal anterior subluxation of C2 on C3 in children due to ligamentous laxity. The anterior cortex of C2 may lie 1-2 mm anterior to the anterior cortex of the C3 vertebral body. This may be difficult to distinguish from a true traumatic subluxation.



The **posterior cervical line** may be used to determine whether C2 - C3 subjugation is physiologic or traumatic. This line is drawn between the spinolaminar lines of C1 and C3. It should either pass through the C2 spinolaminar line or lie within 2 mm anterior to the C2 spinolaminar line. If the C2 spinolaminar line lies anterior to the posterior cervical line the subluxation must be considered traumatic.

This radiograph demonstrates pseudo-subluxation of C2 on C3. The important finding in determination of pseudo-subluxation vs. frank subluxation is that the spinolaminar line of C2 touches the posterior cervical line (pc)

The Lower Cervical Spine

Vertebral Bodies

The vertebral bodies should line up with a gentle arc (normal cervical lordosis) using the anterior and posterior marginal lines on the lateral view. Alignment should also be present on A-P using the edges of the bodies and articular pillars. Each body should be rectangular in shape and roughly equal in size although some variability is allowed (overall height of C4 and C5 may be slightly less than C3 and C6). The anterior height should roughly equal posterior height (posterior may normally be slightly greater, up to 3 mm).

Disc Spaces

Disc spaces should be roughly equal in height at anterior and posterior margins, usually somewhat convex into the vertebral end plates centrally. Disc space height should also be equal at all levels.

Pedicles

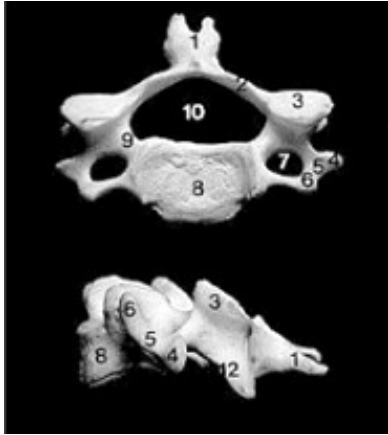
The pedicles project posteriorly to support the articular pillars, forming the superior and inferior margins of the intervertebral canals. The right and left pedicles should superimpose on a true lateral projection. Fractures may be difficult to identify especially if they are non-displaced. Oblique views may be helpful to better evaluate fractures, although CT may be needed for complete evaluation.

Lamina

The laminae join the articular pillars to the spinous processes. The pedicles, articular pillars and laminae form the lateral and posterior margins of the spinal canal. The cortical line seen on the lateral view at the junction of the laminae and the spinous processes is termed the *spinolaminar line*. This line marks the posterior margin of the spinal canal.

Spinous Processes

The base of the vertebral spinous processes should line up at the spinolaminar line from C1 - C7 and the tips should form a smooth curve (posterior spinous line) from C2 - C7. The distance between spinous processes should be roughly equal at all levels on both the A-P and lateral views. Vertical alignment should also be noted on the A-P view



1. Spinous process
2. Lamina
3. Superior articular facet
4. Posterior tubercle of the transverse process
5. Costotransverse bar of the transverse process
6. Anterior tubercle of the transverse process
7. Foramen transversarium
8. Vertebral body
9. Pedicle
10. Spinal canal
11. Inferior articular facet

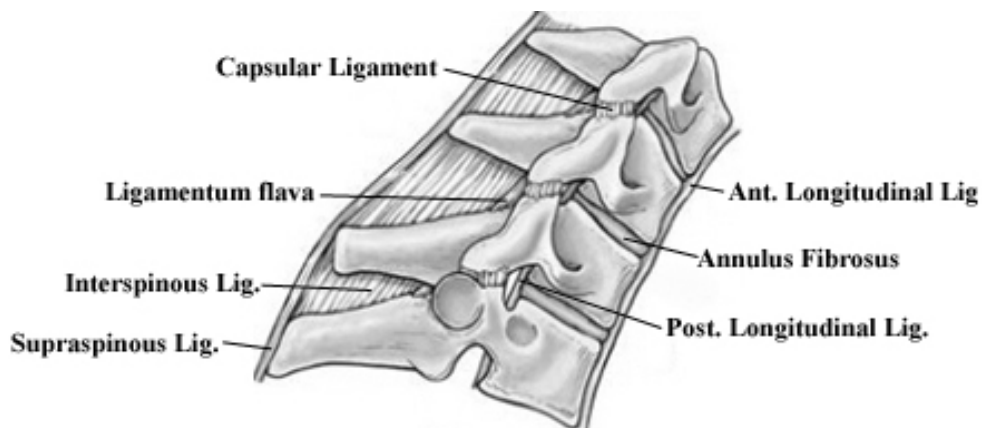
Articular Pillars, Facets and Apophyseal Joints

The articular pillars are bilateral bony masses posterolateral to the C3 - C7 vertebral bodies. They are attached to the vertebral bodies by the pedicles anteriorly and to the laminae posteriorly. On the lateral view they appear as rhomboid-shaped structures projecting downward and posterior. On a true lateral, the structure visualized is actually the two articular pillars superimposed. On the A-P view the pillars and facet joints are seen en face as bony masses lateral to the vertebral bodies.

In actual practice a true lateral view is rarely seen. There is usually at least a small degree of obliquity so that the pillars and facet joints are not exactly superimposed. This obliquity results in "double cortical lines" seen at the margins of the pillars and facet joints. If a steeper obliquity is obtained, the two articular pillars appear as two rhomboids in a "bow-tie" or "bat-wing" shape.

The superior and inferior surfaces of the articular pillars are known as the superior and inferior articular facets respectively (SAF and IAF). The IAF of a given vertebra presents an inclined surface that opposes the SAF of the subjacent vertebra, forming the Apophyseal Joint. The SAF and IAF at a given level should be parallel and aligned lengthwise in the A-P direction. The size of the joint space should be roughly equal at all levels.

Ligaments of the Cervical Spine



Anterior Longitudinal Ligament - this strong, narrow band of fibrous tissue extends from the axis to the sacrum. It is attached to the anterior margins of the vertebral bodies and the intervertebral discs.

Posterior Longitudinal Ligament - this narrow fibrous band located along the anterior surface of the spinal canal. it begins at C2 and extends to the sacrum, closely applied to the posterior margins of the vertebral bodies and intervertebral discs.

Annulus Fibrosus

Capsular Ligaments - surrounds the apophyseal joints of the cervical vertebrae. They possess some degree of laxity to allow slight separation with flexion.

Ligamentum Nuchae Complex - a complex structure extending from the external occipital protuberance, down the skull to the foramen magnum then inferiorly to the sacrum along the spinous processes. In its course it gives off fibers that pass between the spinous processes to form the interspinous ligaments. The posterior margin of the ligamentum nuchae forms the supraspinous ligament that directly attaches only to the tips of the C6 and C7 spinous processes.

Ligamentum Flava - connecting the laminae of adjacent vertebrae lining the posterolateral surface of the spinal canal. It is composed of elastic tissue to allow separation of the laminae with flexion.

Posterior Ligament Complex - The capsular ligaments, ligamentum flavum and the ligamentum nuchae are known collectively as the posterior ligament complex

Prevertebral Soft Tissues

The prevertebral soft tissues (PVST) provide important clues as to the presence or absence of significant vertebral injury. Prevertebral soft tissue swelling in trauma is usually due to hematoma formation. While the presence of swelling is not diagnostic of vertebral injury, it should alert the physician to that possibility. If a vertebral injury is not obvious, additional studies are indicated to exclude a purely ligamentous injury. Other causes of PVST swelling are soft tissue injury without vertebral injury and retropharyngeal inflammation (i.e. foreign body or abscess). In children there is physiologic laxity of the upper retropharyngeal soft tissues that may simulate a mass or hematoma if films are not obtained in full extension and inspiration.

The absence of PVST swelling does not exclude a vertebral injury. in some cases, despite obvious fractures, the PVST are normal. Absence of PVST swelling despite a fracture is more often seen with flexion than extension injuries. Lastly, hematoma formation may be significant in and of itself in that it may compromise the airway or cause dysphagia.

The anterior longitudinal ligament lies closely applied to the vertebral bodies and the intervertebral discs. Anterior to the ALL is the prevertebral fascia, a thin space made up of loose areolar tissue. Anterior to this space is the pharyngeal constrictor muscle (C1 - C4) and the esophagus (C5 - C7). Standard normal measurements have been made for the maximum allowable thickness of the PVST. Measurements should be made perpendicular to the airway between the anterior-inferior cortex of each vertebral body and the posterior margin of the airway.



Maximum Allowable Thickness

- Nasopharyngeal space (C1) - 10 mm (adult)
- Retropharyngeal space (C2 - C4) - 5-7 mm
- Retrotracheal space (C5 - C7)
 - 14 mm (children)
 - 22 mm (adults)

❖ Measurements anterior to C1 are **not reliable** in children due to the presence of adenoidal tissue.

The prevertebral fascia is occasionally visualized as a vertical radiolucent fat stripe just anterior to the anterior longitudinal ligament. When visualized, this can provide an additional clue to the presence of a prevertebral hematoma if there is localized obliteration or deviation of the fat stripe.

Cervical Spine Traumatic Injuries

The classification of cervical spine injuries is difficult, and considerable variability exists in the literature. As with anatomy a useful first step in classification is the division into two major anatomic regions, the cranio-cervical junction and the lower cervical spine. Within each of these groups the principle method of classification is by the mechanism of injury.

The forces that may act on the spine include flexion (both forward and lateral), extension, axial compression, rotation and distraction. In practice cervical spine injuries usually do not involve a single pure mechanisms but rather they are due to a combination of several forces. Thus the different fractures and dislocations that may be seen are a spectrum rather than a given number of discrete entities.

The stability of a given injury is of crucial importance in the initial evaluation of cervical spine trauma. In the evaluation of stability the cervical spine may be thought of as three vertical columns. The anterior column consists of the vertebral bodies, the disc spaces, and the anterior and annulus fibrosus. Central column is composed to the posterior longitudinal ligament, facet joints and capsule and the ligamentum flavum. The posterior column consists of the spinous processes and the posterior ligamentous complex. In general if two of the three columns are intact the injury is stable. If two or more columns are disrupted, the injury is unstable.

For the purpose of discussion we have chosen to describe the classic injuries seen with each mechanism or certain very common combinations of forces. These classic injuries will be described next, as will the effect that they have on stability and clinical neurologic status.

Cranio-Cervical Junction (including atlas and axis)

Injury	Mechanism	Stability
Anterior Atlanto-Occipital Dislocation	Deceleration	Death *
Posterior Atlanto-Occipital Dislocation	Extension	Death *
Jefferson's Fracture	Axial Compression	Unstable
Bilateral C1 Neural Arch Fracture	Extension	Stable
Type I Odontoid Fracture		Stable
Anterior C1 - C2 Subluxation with Transverse Atlantal Ligament Rupture	Flexion	Unstable
Anterior C1 - C2 Subluxation with type II or III Odontoid Fracture	Flexion	Unstable
Posterior C1 - C2 Subluxation with type II Odontoid Fracture	Extension	Unstable
Hangman's Fracture	Extension	Unstable

Lower Cervical Spine

A. Primary Ligamentous Injuries (Flexion)

Injury	Mechanism	Stability
Posterior Ligament Complex Tear	Flexion	Stable
Anterior Subluxation without Fracture	Flexion	Unstable
Bilateral Interfacetal Dislocation	Flexion	Unstable

B. Primary Vertebral Injuries (Flexion)

Injury	Mechanism	Stability
Simple Wedge Fracture	Flexion	Stable
Axial Compression "Burst" Fracture	Axial Compression	Stable
Flexion Teardrop Fracture	Flexion with Compression	Unstable

C. Other Flexion Injuries (Flexion)

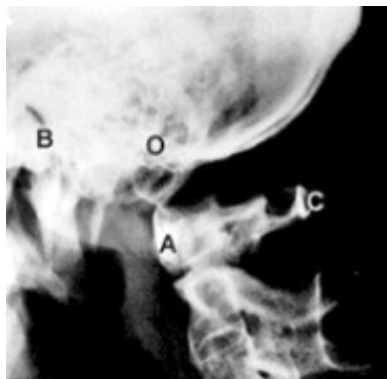
Injury	Mechanism	Stability
Unilateral Interfacetal Dislocation	Flexion with Rotation	Stable
Clay Shoveler's Fracture	Flexion or Direct Blow	Stable

D. Extension Injuries

Injury	Mechanism	Stability
Anterior Ligament Complex Tear	Extension	Stable
Isolated Posterior Element Fracture	Extension / Flexion	Stable
Extension Teardrop Fracture/Dislocation	Extension	Unstable

Injuries of the Cranio-Cervical Junction

Anterior Atlanto-Occipital Dislocation



Mechanism: Caused by a direct blow to the posterior skull or a severe deceleration force causing the momentum of the head to dislocate the skull on the atlas (most commonly in an auto accident). Often no spine fracture is present.

Ligaments: All anterior and posterior atlanto-occipital ligaments are disrupted. A large retropharyngeal hematoma is usually present, occasionally with air from a fractured pharynx.

Alignment: All markers and A-0 alignment are abnormal:

- Occipital condyles displaced anterior to SAP of C1
- Basion lies anterior to dens.
- Opisthion lies anterior to C1 spinolaminar line.

Use the ratio of the distance from the basion to the C1 spinolaminar line (B-C) to the distance from the opisthion to the anterior arch of the atlas (O-A). The Power's Ratio $B-C / O-A$ should be 1.0 or less. If greater than or equal to 1.0 then anterior A-0 dislocation has occurred.

Stability: This injury is usually fatal due to medullary transection. However cases of survival have been reported. Most have profound neurologic deficits, but a few have been intact. The high risk of severe delayed neurologic injury makes the diagnosis extremely important in surviving cases.

Posterior Atlanto-Occipital Dislocation

Mechanism: A blow to the face (i.e. against the dashboard in an auto accident) causes hyperextension of the head on the neck with some distraction. This injury requires significant forces usually provided by the forward momentum of the body with the head held in position.

Fracture: Often no fracture is presents although the downward force of the occiput may cause posterior element fractures of C1 and C2.

Ligaments: There are four major atlanto-occipital ligaments. The alar ligaments extend from the dens to the lateral margins of the foramen magnum. The apical dental ligament extends from the dens to the basion. The tectorial membrane is an extension of the posterior longitudinal ligament. The cruciate ligament is a cross-shaped structure fused with the transverse atlantal ligament. All of these are disrupted in atlanto-occipital dislocations.



Alignment: All markers for A-0 alignment are displaced:

- occipital condyles are displaced posterior to SAP of C1.
- basion lies posterior to the dens.
- opisthion lies posterior to the C1 spinolaminar line.
- B-C / O-A ratio is decreased. This ratio should be less than 1.0, and while exact numbers for posterior dislocation have not been determined, a value of 0.6 or less should strongly raise the possibility of posterior atlanto-occipital dislocation. (This measurement should be correlated with the alignment abnormalities 1-3 above).

In this radiograph the tip of the basion (arrowhead) is posterior to the posterior cortex of the dens (arrow) with marked retropharyngeal soft tissue swelling (*)

Stability: Almost always fatal due to medullary transection. Cases of survival have been reported, however, so it is extremely important to be able to recognize this injury perimortem.

Jefferson's Fracture



Mechanism: Axial blow to the vertex of the head with force transmitted to the spine via the occipital condyles. Because the lateral masses of C1 are wedge shaped, they are forced outward.

Fracture: Bursting fracture of the C1 ring causes bilateral anterior and posterior neural arch (solid arrowhead) fractures. The ring fractures in the four weakest spots with the fragments displaced centrifugally. Fracture lines may occasionally be seen on the lateral view, but are usually subtle. CT is particularly well suited for optimum demonstration of this fracture.

Ligaments: The transverse atlantal ligament is torn by tension from



the outwardly displaced lateral masses. Other individual ligaments are grossly intact but stability is poor because osseous attachments are so severely comminuted.

Alignment:

- On the odontoid view the lateral margins of the C1 lateral masses do not line up vertically with the C2 superior articular facets. The distance between the dens and the medial aspects of the C1 lateral masses is increased bilaterally.
- The spinolaminar line of C1 may be displaced posteriorly.
- Increased distance between the odontoid and the anterior arch of C1 on the lateral view.
- Slight degrees of rotation or lateral flexion must be carefully noted as these cause confusing changes on the odontoid view which may in some respects resemble a C1 ring fracture.

Stability: This represents an unstable fracture. However, patients are usually intact neurologically since the fragments burst outward and the cord is not compromised.

Bilateral Neural Arch Fracture of the Atlas

Mechanism: Hyperextension injury with the posterior neural arch of C1 compressed between the occiput and C2.



Fracture:

- a. Bilateral posterior neural arch fractures occur at the junction of the posterior arch and the lateral masses. These are at the grooves where the vertebral arteries cross the posterior arch (the two weakest points). The fracture lines are best seen on the lateral view.
- b. Fractures must be distinguished from congenital defects of the posterior arch which tend to be smooth, rounded, and have sclerotic borders. Such defects may be in the lateral aspects of the arch, the ring being completed by fibrous union.
- c. In incomplete posterior fusion of C1, or rachischisis, the posterior arch of C1 appears shorter than that of C2. no spinolaminar line is visible at C1.
- d. The short posterior arch does not line up with the spinolaminar line inferiorly thus simulating subluxation.

Ligaments: Remain intact.

Alignment: Minimal posterior displacement of the posterior neural arch of C1 may be present.

Stability: Stable, minimal risk of neurologic damage.

Odontoid Fractures and Atlanto-Axial Subluxation

Injuries to the odontoid and the atlanto-axial articulation are difficult to classify. Odontoid fractures are divided into three types each with their own significance. Overall, however, injuries to the atlanto-axial complex are best classified by their mechanism of injury, with subclassification depending on the presence or absence and type of odontoid fracture.

Odontoid Fractures

Because the fractures are classified independent of the mechanism (unlike subluxation) they are best described first. The subluxation is then classified by mechanism, with discussion of the relationship of each to the different fracture types.



Type I

Small avulsion fracture of the tip of the dens. The avulsion is probably at the attachment of the apical dental ligament that runs vertically from the dens to the clivus. The incidence of this fracture is unclear, but it is uncommonly recognized. There is no associated subluxation and the injury is stable.

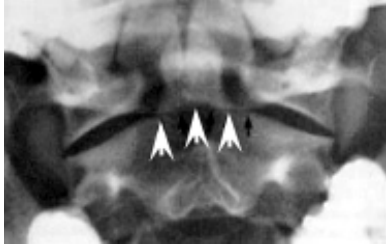
Type II

Transverse fracture at the junction of the dens and the C2 body. This is the most commonly recognized type of odontoid fracture. The fracture line is usually best seen on the AP view but visualization depends on the orientation of the fracture plane. Alignment is usually normal on the AP view, variable on the lateral. The major significance of this type of fracture is a high incidence of non-union.

Type III

Oblique fracture extending from the base of the dens (posterosuperior) into the body of C2 (anterior-inferior). It is usually best seen on the lateral view. Ninety percent unite without complication. Depending on the mechanism, odontoid fractures may be associated with a C1 neural arch fracture or a Jefferson's fracture.

Certain congenital anomalies may simulate an odontoid fracture. An accessory ossification center at the tip of the dens is called an *os terminale*. This sits in a cleft in the odontoid apex and may be mistaken for a type I fracture. Another defect is apparent non-fusion of the dens to the C2 body (this is termed an *os odontoideum*). There is some controversy as to whether these represent non-fusion of the primary odontoid ossification center or an old non-united traumatic injury. In either event, it may be confused with a type II fracture.



Artifacts such as a *Mach Band* across the base of the dens may simulate a type II fracture. This is most commonly caused by overlap of the arches of the atlas. Overlap of the incisor teeth may give the appearance of a vertical fracture but should not cause confusion as such a fracture has never been described.

CT is becoming the definitive study in cervical spine trauma. However, because of the near axial orientation of odontoid fractures they may be very difficult to see on axial CT. This remains the one major type of C-spine injury best evaluated by planar film and/or pluridirectional tomography.

Anterior C₁ - C₂ Subluxation with Transverse Ligament Rupture



Mechanism: This injury is usually associated with minimal or no trauma. The basic defect is weakness and rupture of the transverse atlantal ligament. This is most commonly due to ligamentous erosion in rheumatoid arthritis as the joint between the transverse atlantal ligament (TAL) and the posterior surface of the dens is synovial. Complete erosive destruction of the dens may be seen.

Other clinical situations in which this may occur are chronic nasopharyngeal infections and syndromes with maldevelopment of the odontoid or TAL. These include Down's syndrome, achondroplasia, Morquio's Disease, metatropic dwarfism and spondylo-epiphyseal dysplasia.

While trauma is usually not a major factor, minor trauma in the face of weakened or abnormally developed ligaments may lead to severe subluxation. No actual fracture occurs in the pure form of this injury.

Ligaments: The TAL usually resists forward subluxation of C1 on C2 as it is forced against the dens from behind. If the ligament is weak, it will rupture, allowing C1 to sublux. The anterior longitudinal ligament and posterior ligament complex are ruptured to a variable degree depending on the degree of subluxation.

Alignment

- The odontoid remains attached to C1. As C1 and the occiput slide forward, the basion will lie anterior to the tip of the dens. The other markers of A-0 alignment are intact.
- The anterior marginal line and the spinolaminar line will "step-off" posteriorly C1 relative to C2.
- The distance between the dens and the anterior arch of C1 (predental space) will be widened (greater than 3.0 mm in-adults, 5.0 mm in children). This is the key radiographic feature of this injury.
- Decreased distance between the dens and the posterior arch of C1 (this represents the narrowed spinal canal).

Stability: Unstable due to severe ligamentous disruption. Due to the width of the spinal canal at C1 - C2 there is a significant margin of safety. Up to 50% subluxation may occur without significant neurologic

damage. Above 50% subluxation, however, the cord is pinched between the posterior arch of C1 and the dens, and severe neurologic damage may result.

Due to the gradual nature of this injury, it must be carefully looked for in patients with rheumatoid arthritis. Any minimal widening of the distance between the C1 anterior arch and the dens must be noted. If neurologic symptoms are present or if minimal widening is noted, then flexion views must be obtained under fluoroscopic control (with a physician in attendance) to determine the degree of instability.

Anterior C₁ - C₂ Subluxation with Odontoid Fracture

Mechanism: Hyperflexion injury with C1 forced forward on C2.

Ligaments: the transverse atlantal ligament resists forward subluxation of C1 on C2 as it is forced against the odontoid from behind. If the force is sufficient and the TAL remains intact, the dens is fractured or "pulled off" the C2 body by the TAL as C1 subluxes forward on C2.



Fracture: Either type II or type III (arrow) odontoid fracture occurs. Type III fractures are seen almost exclusively with hyperflexion injuries (as opposed to Type II that may occur with either flexion or extension injuries).

Alignment:

- Odontoid remains in place between the anterior arch of C1 and the transverse ligament so the dens and C1 sublux together. All markers of A-0 alignment are intact.
- Odontoid normally aligned with the anterior arch of C1 (*normal predental space, less than 3.0 mm separation*).
- Anterior marginal line and spinolaminar line both "step-off" posteriorly C1 on C2.

Stability: This is an unstable fracture because most or all attachments of C1 to C2 are disrupted both anterior and posterior. The width of the spinal canal is greatest at C1 - C2, however; neurologic damage is usually not severe. There is a 50% margin of safety at this level, meaning that 50% subluxation of C1 on C2 must occur for the cord to be pinched between the C1 posterior arch and the C2 body. If this degree of subluxation occurs severe cord damage may result.

Posterior C₁ - C₂ Subluxation with Odontoid Fracture

Mechanism: Hyperextension injury with C1 forced backward on C2. The anterior arch of C1 resists backward subluxation of C1 on C1 as it is forced against the odontoid from in front. If the force is sufficient, the odontoid is fractured from the C2 body.

Ligaments: The transverse atlantal ligament remains intact. The anterior longitudinal ligament and the posterior ligament complex are all ruptured to a variable degree depending on the degree of subluxation.



Fracture: Type II fracture of the odontoid (arrowheads).

Alignment:

- The odontoid remains in place between the C1 anterior arch and the TAL, so C1 and the dens move together. Therefore all markers of atlanto-occipital alignment are intact.
- Odontoid normally aligned with the anterior arch of C1 (normal predental space, less than 3.0 mm separation in adults, 5.0 mm in children).
- Anterior marginal line and spinolaminar line both "step-off" anteriorly C1 to C1.

Stability: This is an unstable fracture because most or all ligamentous connections of C1 to C2 are disrupted. The width of the spinal canal is greatest at C1 - C2, however, so there is a 50% margin of safety. This means that with less than 50% subluxation, the cord is still not compromised. If subluxation is greater than 50% then the cord will be pinched between the odontoid and the laminae of C2, and severe neurologic damage may result.

Hangman's Fracture

Mechanism: Hyperextension of the head on the necks as when the chin or forehead strikes the dashboard in an auto accident. This fracture involves C2 and C3. The vertebral body of C2 is displaced upward; the inferior articular facets of C3 are displaced downward. The thin interarticular portion of the C2 pedicles "snaps".



Fracture: Bilateral C2 pedicle fractures (arrowhead) are best seen in the lateral view. The fractures are posterior to the C1 superior articular facets and anterior to the C2 inferior articular facets. The fractures extend from posterior-superior to anterior-inferior. Oblique views or computed tomography may be needed for complete evaluation of the extent of the fractures. There may be an associated posterior neural arch fracture of C1 or an avulsion fracture from either the anterior-inferior margin of C2 or the anterior-superior margin of C3.

Ligaments: The anterior longitudinal ligament is disrupted via tension. This tension may cause a vertebral body avulsion fracture as described above. The disc and PLL are also torn at the C2 - C3 level, but the capsular ligaments remain intact. The remainder of the posterior ligament complex may be torn at the C1 - C2 level. The transverse atlantal ligament remains intact so the C1 and C2 bodies move together.

Alignment:

- Body and SAF of C2 are separated from intra-articular pedicles (IAP) and posterior elements of C2. The body is free to move forward, taking all superior elements with it. Posterior elements remain in alignment with all inferior elements.
- There may be anterior subluxation of C2 on C3. The anterior and posterior marginal lines jog posteriorly at C2 - C3. (The vertebral body of C2 is normally aligned with C1 with the dens intact. The posterior elements and IAP of C2 are normally aligned with C3.)
- The spinolaminar line jogs posteriorly at C1 - C2.
- Atlanto-occipital alignment is normal and alignment of all bodies below C2 remains normal.

Stability: This is an unstable but neurologic deficit is surprisingly rare unless C2 - C3 subluxation is severe. This is because the spinal canal width is greatest at this level and the bilateral pedicle fractures permit the cord to decompress itself. Peripheral nerve deficits are more common than cord lesions. The vertebral-artery is usually intact despite the proximity of the fracture to the foramen transversarium. This fracture will usually stabilize with halo fixation, but anterior fusion may be needed due to delayed instability. The classic hangman's fracture has minimal anterior C2 - C3 subluxation. An understanding of the mechanism of this fracture explains how minimal anterior subluxation occurs following an extension injury.

Lower Cervical Spine Injuries

The classification of lower cervical spine injuries is somewhat less well defined than that of the craniocervical junction. This outline is limited to the discussion of certain discrete entities, but in practice they are not usually seen, in their pure form. When viewing actual cases in the emergency room or the teaching file you will have the opportunity to see how they blur into a spectrum.

Flexion and compression injuries may be generally divided into primarily ligamentous and primarily vertebral injuries. In primarily ligamentous injuries three general groups are seen which differ only in the degree of ligamentous disruption. In primarily vertebral injuries three general entities are seen which differ mainly in the relative contribution of each mechanism: forward flexion and axial compression. Other flexion injuries are then described which do not clearly fit into the above scheme. Three general groups of extension injuries are seen, again differing mainly in the degree of severity.

Hopefully this classification will help in gaining an overall understanding of lower cervical spine fractures and dislocations. The discussion of individual cases in the teaching file will emphasize how the different forces have combined to cause the injury, as well as the effect that these injuries have on stability and neurologic status.

Posterior Ligament Complex Tear: Hyperflexion Sprain

Mechanism: Flexion force causes disruption of the posterior ligament complex (supraspinous, interspinous and capsular ligaments and ligamentum flavum) and the posterior longitudinal ligament. There is also a short horizontal tear of the intervertebral disc. Most of the disc and the anterior longitudinal ligament remain intact. The vertebral body pivots or rotates anteriorly on its anterior-inferior corner.

Radiographic Findings: This is a purely ligamentous injury, and as such it is not as easily recognized as most fractures. The injury primarily involves one or more of the C3 - C7 vertebrae. The findings may be subtle on the lateral view in neutral position and in such cases controlled flexion views under fluoroscopic guidance may be needed.

- Localized kyphosis limited to the level of injury. This localized angulation is the key to distinguishing hyperflexion sprain from physiologic reversal of the normal cervical lordosis. In cervical sprain the bodies above and below the sprain level retain their normal lordosis. This finding is neutralized in extension and accentuated in the lateral flexion view.
- "Fanning" or widening of interspinous space with increased separation of the spinous processes at the affected level. This is seen in both AP and lateral views. This reflects torn interspinous and supraspinous ligaments. This is the most important (and may be the only) finding.
- Anterior narrowing and posterior widening of the intervertebral disc space with minimal widening of the facet joints.

Stability / Complications: Delayed instability is seen in 20%. This is defined as abnormal mobility between any pair of vertebrae, with or without pain or other clinical manifestations, when lateral views are taken in flexion after conservative treatment. It is caused by failure of the ligaments to heal, with the high incidence due to the frequent failure to properly diagnose this entity. If not diagnosed, treatment is insufficient and ligaments heal poorly.

Anterior Subluxation without Fracture

Mechanism: Pure flexion force.



Ligaments: This injury differs from the posterior ligament complex tear in the degree of ligamentous disruption. In addition to tears of the posterior ligament complex and posterior longitudinal ligament there is disruption of the intervertebral disc and partial or complete disruption of the anterior longitudinal ligament.

Alignment:

- Localized kyphosis at the level of injury.
- Anterior subluxation of the vertebral bodies limited to less than 50% of the vertebral body depth.
- Partial anterior subluxation of the facet joints (small arrowhead). The posterior aspect of the supra-jacent inferior articular facets lie just behind the anterior aspect of the subjacent superior articular facets. This position is termed "perched facets".
- Anterior narrowing (solid arrow) and posterior widening of the disc space

Fanning of the spinous processes in both the AP and lateral views (large arrowhead).

Stability: The presence of subluxation differentiates this injury from the posterior ligament complex tear (hyperflexion sprain). The majority of both the anterior and posterior ligament complexes are disrupted, making the injury unstable. Neurologic deficit is variable depending on the degree of subluxation. Fixation may be necessary to prevent delayed instability.

Bilateral Interfacetal Dislocation

Mechanism: Flexion with or without some element of distraction. In either mechanism one vertebra is forced forward on the subjacent vertebra.

Fracture: With flexion and distraction the vertebrae sublux without a fracture. More commonly there is predominantly flexion, causing a shearing type injury. As the suprajacent inferior articular facets are forced against the subjacent superior articular facets there will be a fracture on one or both sides. The fracture may involve the posterior portion of each IAF (most common) or the anterior portion of each SAF. Oblique views and/or tomography (computed or pluridirectional) may be necessary to fully evaluate facet fractures. Due to the mechanism, there may also be an associated flexion type fracture at another level.

Ligaments: All supporting ligaments are disrupted: anterior longitudinal ligament, intervertebral disc, posterior longitudinal ligament, and posterior ligament complex.



Alignment: The dislocated facets pass upward and forward over the superior articular facets of the subjacent vertebrae coming to rest in the intervertebral foramina. This requires greater than 50% anterior subluxation of vertebral bodies at the level of injury. The subluxation is obvious on the lateral view, with rather abrupt anterior angulation at the injury level and increased interspinous distance. Flexion/extension views are obviously contraindicated.

Stability: This is an unstable injury because all supporting ligamentous structures are disrupted. Profound neurologic injury (both cord. and peripheral nerve) is common due to the high degree of subluxation at levels where the spinal canal diameter is not significantly greater than that of the cord.

Simple Wedge Fracture

Mechanism: Flexion with minimal axial compression.



Fracture: This mechanism forces the anterior aspects of the vertebral bodies together. A given vertebra may be 'sandwiched' between the bodies above and below, causing a compression or wedge fracture of its anterior aspect (arrows). This is the least severe of the flexion mechanism fractures as no ligamentous disruption occurs and there is no subluxation.

Ligaments: Without subluxation no ligaments are disrupted. It is extremely important to remember that the absence of subluxation on the initial lateral view (in cervical collar) does not mean that subluxation and ligamentous damage did not occur at the time of injury, with the subluxation subsequently reduced.

Alignment: There will be acute anterior angulation (localized kyphosis) with the apex at the fractured vertebra. The contour lines will reflect this abnormal arc, but will not show any "step-off". The vertebral canal is not narrowed in AP diameter.

Stability: Stable due to intact ligaments, Patients are almost always neurologically intact, but severe deficits have been known to occur. Stability and ligamentous preservation must be proven rather than assumed so that a more severe occult dislocation is not overlooked. Fluoroscopically controlled flexion views in the lateral projection are helpful and CT may aid in ruling out a more significant fracture or posterior fragment.

Axial Compression or Burst Fracture

Mechanism: Axial compression forces cause rupture of the nucleus pulposus into the vertebral body with fracture of the end-plate and "bursting" of the vertebral body.

Fracture: The vertebral body is compressed and bursts. A prominent sagittally oriented fracture cleft on the AP view is characteristic of axial compression fractures. The anterior fragments are displaced forward; the lateral fragments may be displaced laterally. Most important is displacement of the posterior fragments into the spinal canal.



Ligaments: The posterior longitudinal ligament is ruptured. The anterior longitudinal ligament and the posterior ligament complex remain intact.

Alignment:

- a. The posterior fragment may contain the attachment between the articular facet and all vertebrae above, in which case these will be displaced posterior to all subjacent vertebral elements.
- b. The posterior marginal line, spinolaminar line, and posterior spinal line all jog forward below the fracture site.
- c. The anterior marginal line may be displaced anteriorly around the anterior fracture fragments.

Stability: Because the anterior longitudinal ligament, capsular ligaments, and posterior ligament complex are intact, the injury is considered stable. However, the risk of cord damage is significant due to posterior displacement of the posterior fracture fragments.

Immediate paralysis and specific sensory changes characterize the anterior cord syndrome resulting from such fractures. There is loss of anterior column sensation (pain and temperature) below the fracture level with preservation of posterior column sensation (vibration, position, and motion).

Flexion Teardrop Fracture

Mechanism: Flexion and axial compression

Fracture: As with the simple wedge fracture a given vertebra is compressed between the bodies above and below. A triangular fracture fragment (the teardrop) is separated from the anterior-inferior margin of the involved vertebra. The posterior aspect of the involved vertebra is fragmented and driven posteriorly into the spinal canal by the wedge effect of the adjacent bodies. The amount of flexion force determines the degree of subluxation of the suprajacent body on the fractured vertebra and also places tension on the posterior ligament complex. Besides ligamentous rupture, there are often associated distraction fractures of the posterior elements.



Ligaments: The anterior ligament complex is disrupted by subluxation. The posterior longitudinal ligament and the posterior ligament complex are ruptured by tension.

Alignment:

- a. Acute anterior angulation (localized kyphosis) with the apex at the fractured vertebra.
- b. Posterior subluxation of the fractured vertebral body on the subjacent vertebra.
- c. If flexion force is great enough - anterior subluxation of the suprajacent body on the fractured vertebra.
- d. The anterior marginal line jogs anteriorly around the teardrop fragment.
- e. The posterior marginal line jogs anteriorly below the fractured vertebra and posteriorly above the fracture.
- f. The spinolaminar line and posterior spinous line are variably disrupted depending on the degree of subluxation and associated posterior element fractures.

Stability: This is the *most severe flexion fracture* as all ligaments are disrupted and a posterior fragment is driven into the spinal canal. As such it is a combination of the worst elements of a compression burst fracture and a flexion fracture/ dislocation. Profound neurologic deficit is common, usually an acute anterior cord syndrome.

Unilateral Interfacetal Dislocation

Mechanism: This injury combines rotation with either forward or lateral flexion.

Fracture: If the mechanism is lateral flexion with rotation there will be no fracture. This is because lateral flexion allows distraction of the facet joint before subluxation occurs. If forward flexion and rotation are present, there will be a fracture of the posterior margin of the facet above the injury or the anterior margin of the subjacent facet. This is because with forward flexion the articular facets impact against each other and must fracture before dislocating.

Ligaments: The capsular ligaments are disrupted unilaterally. The posterior and anterior longitudinal ligaments are only partially torn on the side of subluxation.



Alignment: The inferior articular facet on one side rides upward, forward and over the top of the subjacent superior articular facet, coming to rest in the intervertebral foramen anterior to the subjacent articular mass. This is the origin of the term unilateral "locked" facet.

- a. On the lateral view the spine above the injury will be seen in true lateral, while the spine below is seen in the oblique view (or vice-versa). This reflects the rotational component of the injury.
- b. On the AP view the spinous processes above or below are displaced laterally so that they form two separate vertical lines above and below the site of injury.
- c. Partial anterior vertebral body subluxation in the lateral view (less than 50% of the vertebral body depth).

Stability: Stable even though the posterior ligament complex is disrupted (the vertebrae are 'locked' in this position). Neurologic deficit is uncommon, and when present is usually a peripheral nerve deficit due to compromise of the intervertebral foramen. Oblique views are particularly helpful in assessing malalignment of the facet joints.

Clay Shoveler's Fracture



Mechanism: Either 1) a direct blow to the back of the neck or 2) Hyperflexion with tension on the ligamentum.nuchae. Since the supraspinous ligament is attached to the tips of the C6 and C7 spinous processes tension on the ligament may lead to an avulsion type fracture (may also occur at T1 or T2).

Fracture: This fracture most commonly involves the spinous processes of C6 or C7 (arrowhead), with inferior displacement of the spinous process tip. The fracture line is best seen on the lateral view. Involvement of the inferior portion of the laminae may occur.

Alignment: In a simple Clay Shoveler's fracture the vertebrae are normally aligned.

Ligaments: While there may be a small-localized tear of the supraspinous and interspinous ligaments they are usually grossly intact as the fracture absorbs the force of the injury.

Stability: The clay shoveler's fracture is a stable, benign injury that should cause no significant problems even if non-union occurs. Some authors will include more extensive posterior ligament disruptions and posterior element fractures (when due to flexion) under the term clay shoveler's fracture. This practice should be strictly avoided so that the benign nature of this injury is clearly understood.

Posterior element fractures are stable if isolated but they may be unstable if associated with a more severe fracture or fracture/dislocation complex (i.e. fracture of the spinous process with concurrent laminar fracture). Neurologic deficit is uncommon. This is a disturbing group of fractures as they are often underestimated on plain film evaluation. Evaluation of cervical spine trauma by CT often shows extensive posterior element involvement when plain film findings are minimal or absent. Involvement of the laminae differentiates this fracture from a simple Clay Shoveler's fracture. More extensive posterior element involvement may occur with isolated fractures or they may be part of a more severe fracture/dislocation complex.

Anterior Ligament Complex Tear: Hyperextension Sprain

Mechanism: The mechanism is hyperextension and is usually seen in patients who fall forward striking their forehead forcing their head backwards. The well-known "whiplash injury" occurs via a similar mechanism (sudden acceleration of the body forward throws the head back into extreme extension).

Fracture: None

Ligament and Soft Tissues: Extension force causes disruption of the anterior longitudinal ligament and a horizontal tear of a portion of the intervertebral disc. The posterior portion of the disc, posterior longitudinal ligament and the posterior ligament complex are intact. There is also damage to the anterior paraspinal muscles, including the scalenus longus collie and sternocleidomastoids. This is the major cause of neck pain in these injuries. Trauma to the larynx and sympathetic chain may also occur.

Radiographic Findings: This is a purely ligamentous injury, and as such it is not as easily recognized as most fractures. Findings may be absent or subtle an the lateral view in neutral position, and in such cases controlled extension views under fluoroscopy may be needed.

- a. Prevertebral soft tissue swelling due to hematoma formation.
- b. Most have normal alignment. Another term for this injury is "Extension Injury with Normal X-rays".
- c. Straightening or reversal of the normal lordotic curve due to muscle spasm is the other common pattern.
- d. If asymmetric force is applied torticollis may result.

Stability: Only a portion of the anterior ligament complex is torn so the injury is stable. However, hemorrhage into the cord may occur due to pinching between the posterior elements. Underlying degenerative changes with posterior spurring will predispose to more severe cord pinching. In such cases the most common neurologic sequela is an acute central cord syndrome.

Isolated Posterior Element Fracture

Mechanism: Isolated posterior element fractures are most commonly due to extension forces. Overall however, posterior element fractures are more often seen in association with other more significant fracture complexes, and as such may be seen with either extension or flexion injuries. In flexion injuries the fracture is due to tension on the posterior ligament complex. In extension injuries the fracture is due to jamming together of the posterior elements. If some lateral flexion force is present the fracture may be primarily unilateral.

Fracture: Most commonly the fracture is oblique extending from posterior-superior in the spinous process, anteriorly into the laminar and ending anterior-inferiorly at the junction of the laminae and the

lateral masses. The fracture is variable, however, and many other forms may be seen. Involvement of the laminae in an asymmetric fashion may be seen with or without spinous process involvement. Fractures may extend into the lateral masses, involve the articular facets and extend more anteriorly into the pedicle or transverse process. CT is the best modality for assessment of posterior element fractures.

Ligaments: In pure extension injuries the posterior ligament complex buckles and does not tear. In flexion injuries the tension force on the posterior ligament complex is taken up by the fracture. While certain degrees of posterior ligament complex disruption may occur, it is generally less than that present without a fracture. Severe ligamentous disruption may occur if the fracture is part of a more severe fracture/dislocation complex.

Alignment:

- a. Usually grossly normal. Isolated posterior element fractures are rarely significantly displaced.
- b. If displacement is present it is usually inferior displacement of the posterior fracture fragment. This is best seen as an increased interspinous distance above the fracture, decreased below.
- c. Tomography or oblique views may show facet joint involvement.

Extension Teardrop Fracture

Mechanism: Hyperextension places tension on the anterior longitudinal ligament.

Fracture: The ligament may rupture without a fracture, or may avulse a fragment from adjacent vertebrae usually the anteroinferior portion. This small triangular piece of bone is the "teardrop". If the fracture is at the C2 - C3 level then an associated Hangman's Fracture must be ruled out. Spinous processes or laminae may be fractured by compression.

Alignment:

- a. May be normal.
- b. The disc space is widened anteriorly, narrow posteriorly with decreased interspinous distance at the fracture level.
- c. May have posterior subluxation of the fractured body on the subjacent vertebrae with altered marginal lines.
- d. May have partial apophyseal joint subluxation.

Stability: Stability is variable but best considered unstable, especially in extension. A significant portion of the posterior ligament complex may remain intact if subluxation is not severe. Neurologic deficit is common due to cord hemorrhage and edema, often presenting with an acute central cord syndrome.

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