# Trauma Imaging of the Acute Cervical Spine

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Abstract

Acute cervical spine trauma

frequent condition encountered in emergency departments.

Imaging plays a key role in

- screening for unstable lesions
- preventing undiagnosed spinal injuries.

devastating neurologic complications or death.

# Imaging Strategy

alert and asymptomatic patients in stable condition

## NEXUS low-risk criteria

## Canadian C-Spine Rule

- Normal level of alertness
- No evidence of intoxication
- No tenderness at the posterior midline of the cervical spine
- No focal neurologic deficit
- No clinically apparent pain that might distract the patient from the pain of a cervical spine injury

alert and asymptomatic patients in stable condition

**NEXUS low-risk criteria**

**Canadian C-Spine Rule**

In alert (GCS = 15) patients (> 16 yo):

- No high-risk factor:
  - Age ≥ 65 y.o
  - Paresthesias in extremities
  - Dangerous mechanism
- Presence of low-risk factor that allows safe assessment of ROM:
  - Simple rear-end motor vehicle collision
  - Sitting position in emergency department
  - Ambulatory at any time
  - Delayed onset of neck pain
  - Absence of midline cervical tenderness
- Able to actively rotate neck by 45 degrees left and right

# Imaging Strategy

Cervical spine imaging:

Three-view cervical spine series:
- Odontoid, or “open-mouth
- Anteroposterior, and
- Lateral.

Computed Tomography (CT)

Current literature → use CT first if available

primary modality for patients not meeting low-risk criteria supplemented with MRI

For < 9 yo patients:

Radiography as the first imaging modality

# Radiographic Assessment

Lateral, anteroposterior, and odontoid views must be appraised methodically after assessing their **quality (ABC's method)**

## Quality

- All seven cervical vertebrae must be demonstrated.
- The cervicothoracic junction (apophyseal joints of C7–T1) visualized.
- The mandible and articular facets superimposed.

# Radiographic Assessment

Lateral, anteroposterior, and odontoid views must be appraised methodically after assessing their **quality (ABC's method)**

## Alignment

- Drawing four lines on the lateral view.
- On the anteroposterior view, spinous processes should be in midline and regularly spaced, with no focal displacement.
- On the odontoid view, lateral masses should also be aligned.

## Bone integrity

- Bony landmarks must be identified, with no loss of vertebral body height and no fracture line

Fig. Normal standard **three-view series** (plain radiographs).

**lateral views**

the anterior (solid line), posterior (dotted line), spinolaminar (dashed line), and interspinous (dash-dotted line) must be smoothly drawn.
Soft tissue swelling can be assessed at C2 and C6 levels (asterisks).
A spheno-occipital synchondrosis may be seen in young adults and must not be mistaken as a fracture (black arrows).

**anteroposterior views**

spinous processes are in midline and regularly spaced (dashed line).
No vertebrae misalignment should be observed.

# Radiographic Assessment

Lateral, anteroposterior, and odontoid views must be appraised methodically after assessing their **quality (ABC's method)**

## Cartilage (joints)

No space abnormalities.

## Soft tissue

Retropharyngeal thickness should not:

- > 7 mm in children and adults at the C2 level,
- 14 mm (in children) or 22 mm (in adults) at the C6 level.

# Radiographic Assessment

## Lateral view

the most important radiograph to acquire.

⇩

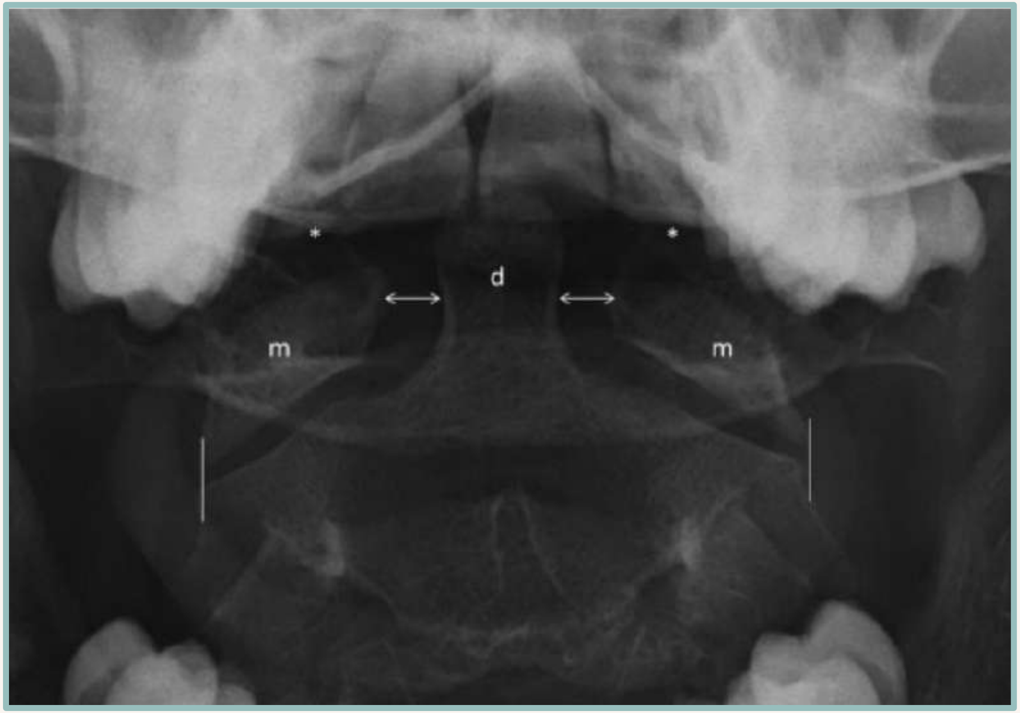
the cervicothoracic junction must be seen, supplemented by additional views (swimmer's or oblique views)

⇩

If inadequate or a lesion is suspected

⇩

**CT**




**odontoid views**

lateral masses of C1 **(m)** are equally distant (double-headed arrows) from the dens of the odontoid **(d)** and aligned with the articular facets of C2 (solid lines). Occipitoatlantal joints may be identified (asterisks).

## Cervical Spine Injuries

- Upper cervical spine injuries (C0 - C2)
  - Occipital Condyle Fractures (C0)
  - Occipitoatlantal Dislocation
  - Odontoid Process Fracture (C2)
  - Traumatic Spondylolisthesis of C2 (Hangman's Fracture)
  - Atlantoaxial Anteroposterior Dislocation
  - Atlantoaxial Rotary Subluxation
- Lower cervical region injuries (C3 - C7)
  - Compression Injuries
  - Teardrop Fractures
  - Distraction Injuries
  - Rotation/Translation Injuries
  - Clay-Shoveler's Fractures

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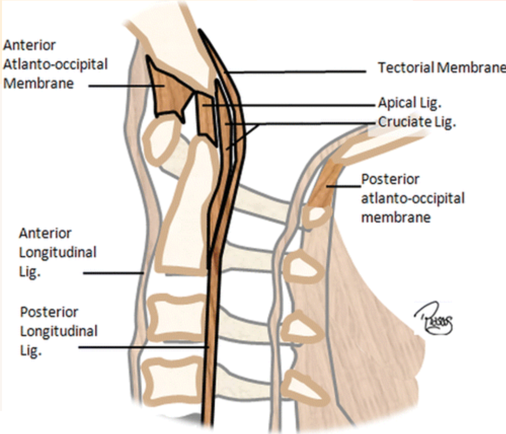
# Upper Cervical Spine Injuries

# Anatomy of the Occipitoatlantoaxial Joint Complex

**intrinsic ligaments:**

- The tectorial membrane ligament
- The cruciate ligament
- Bilateral alar ligaments

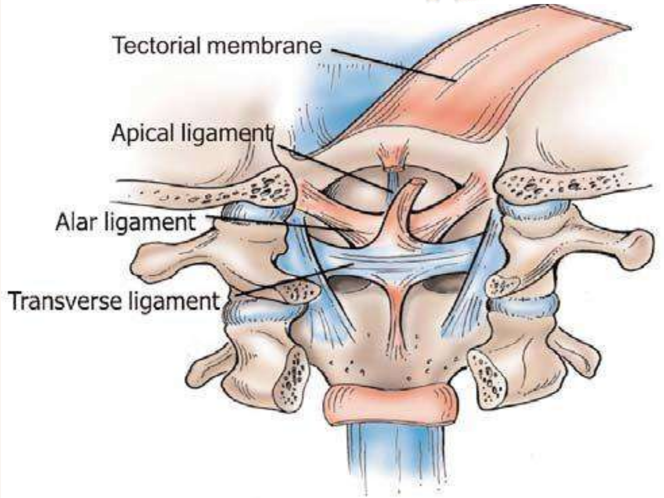



**extrinsic ligaments:**

- the articular capsule ligaments
- the anterior, posterior, and lateral atlantooccipital membranes

connecting the ring of C1 to the base of the skull.

Absence of intervertebral discs



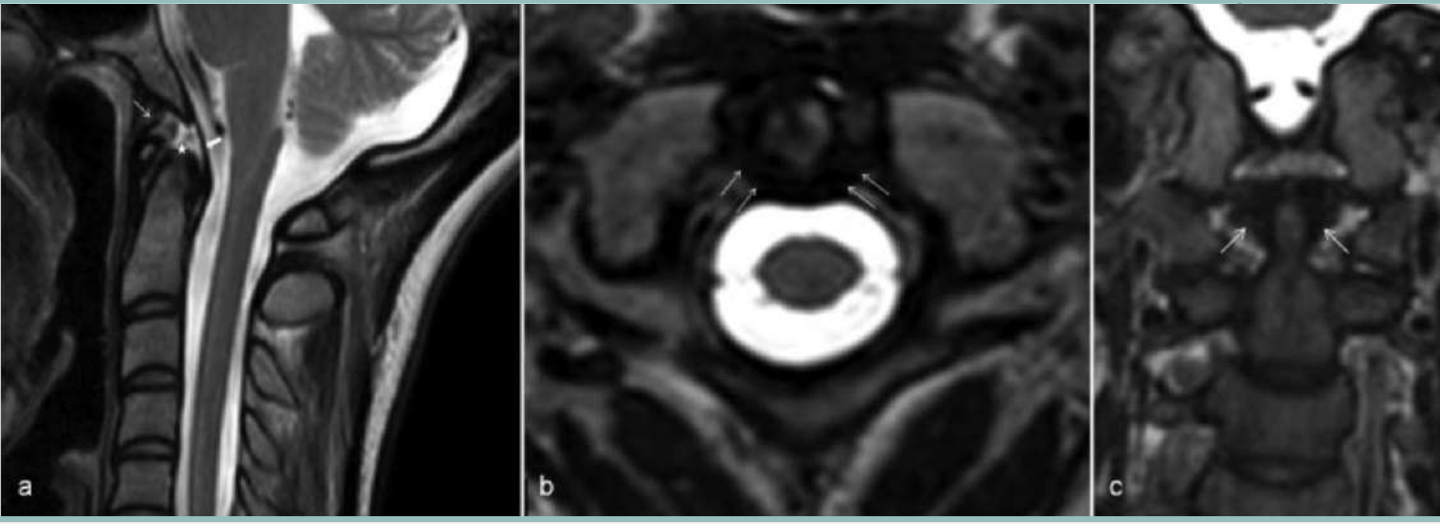



**Fig. Normal T2 -weighted MRI anatomy.**

**(a) Sagittal plane** demonstrating the hypointense anterior atlanto-occipital membrane (thin arrow), the apical ligament (white star), and the tectorial membrane (plain arrow).
**(b) Axial plane** demonstrating the transverse ligament (thin arrows).
**(c) Coronal plane** demonstrating the alar ligaments (thin arrows).

# Occipital Condyle Fractures (Co)

Lateral cervical spine radiography has a limited role in the detection of occipital condyle fractures.

CT imaging → the best modality

alignment of the craniocervical junction should be evaluated using

- Basion-dental interval (BDI)
- Basion-axial interval (BAI) methods

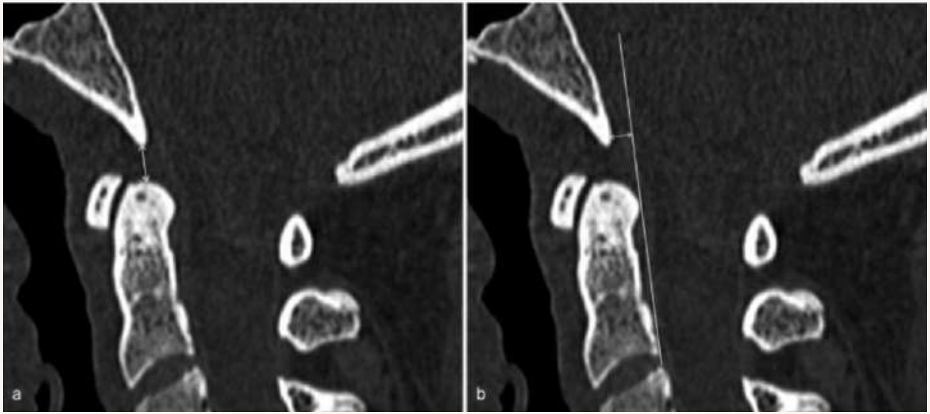



**Fig. Computed tomography (CT) assessment of the occipitoatlantoaxial joint complex (Harris's method).**

**(a)** **BDI** should not be > 12 mm in adults or children > 13 yo
**(b)** **BAI** should be between + 12 mm and - 4 mm.

Type I

Comminuted impaction fracture due to axial loading

# Classification of occipital condyle fractures (Anderson & Montosano)

Type II

Skull base fracture from the occipital bone to the condyle before reaching the foramen magnum.

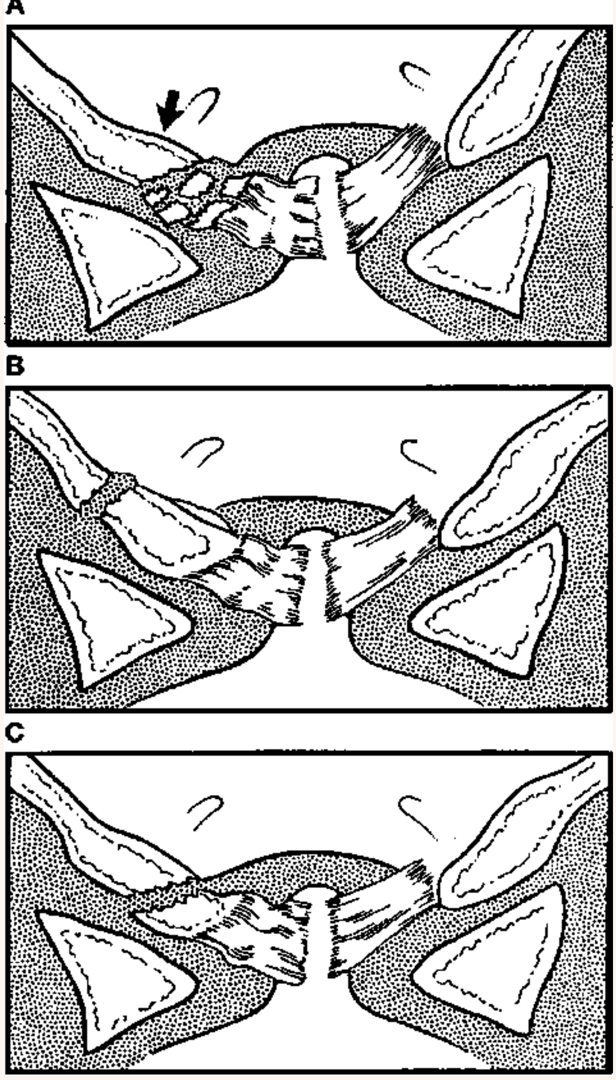
Type III

Avulsion fracture mediated through tension in an alar ligament. The most common type.

## Anderson and Montesano Type I

## Anderson and Montesano Type II

## Anderson and Montesano Type III



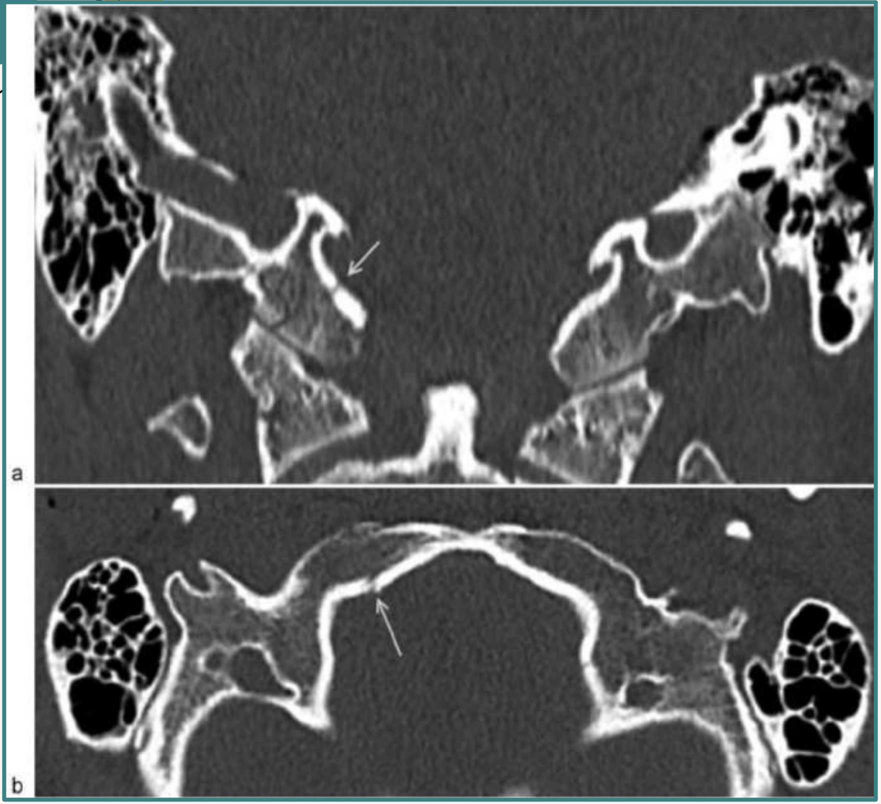



**Fig. Anderson and Montosano type II/Tuli type I right occipital condyle fracture (arrow),** on **(a) coronal** and **(b) axial** CT.

# Occipitoatlantal Dislocation (OAD)

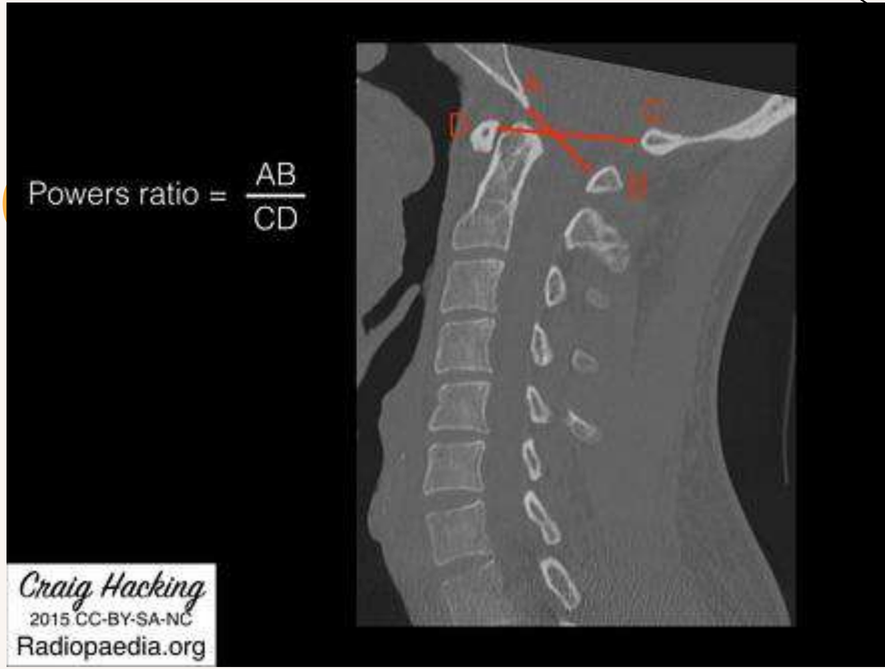
severe ligamentous injury of the craniocervical junction.

CT as the initial imaging modality, methods of diagnosis:

BDI-BAI (Harris's method)

Powers'ratio method

X-line method




Powers' ratio is the ratio of the **basion-posterior atlas** arch distance to the **opisthion-anterior arch distance**.

Values > 1 are pathologic.


line from **basion to the axis spinolaminar junction** does not intersect C2 or if a line from the **opisthion to the posteroinferior corner** of the body of the axis does not intersect C1.

# Classification of OAD (Horn et al)

## Grade I

Normal CT and equivocal MRI findings consisting of high posterior ligamentous or occipitoatlantal signal and mild to no signal change at the occipitoatlantal joint.

## Grade II

At least one abnormal finding on CT-or grossly abnormal MRI findings in the occipitoatlantal joints, tectorial membrane, alar ligaments, or cruciate ligaments.

# Atlas Fractures (C1)

- 3 – 13% of acute cervical spine injuries
- 1 – 3% of all spinal injuries.
- Common occur in patients > 50 yo.

**Manifestations:**

- Cervical pain
- Neck stiffness
- History of indirect trauma through axial compression (fall on the head) or violent hyperextension (automobile collision).
- No neurologic deficit

# Classification of Atlas Fractures (Landells et al)

## Type I

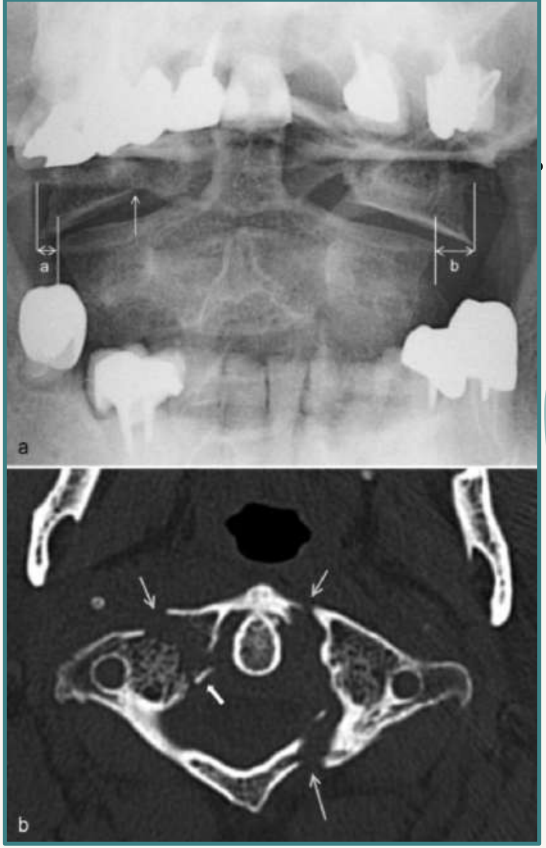
Single arch

## Type II

Both archs

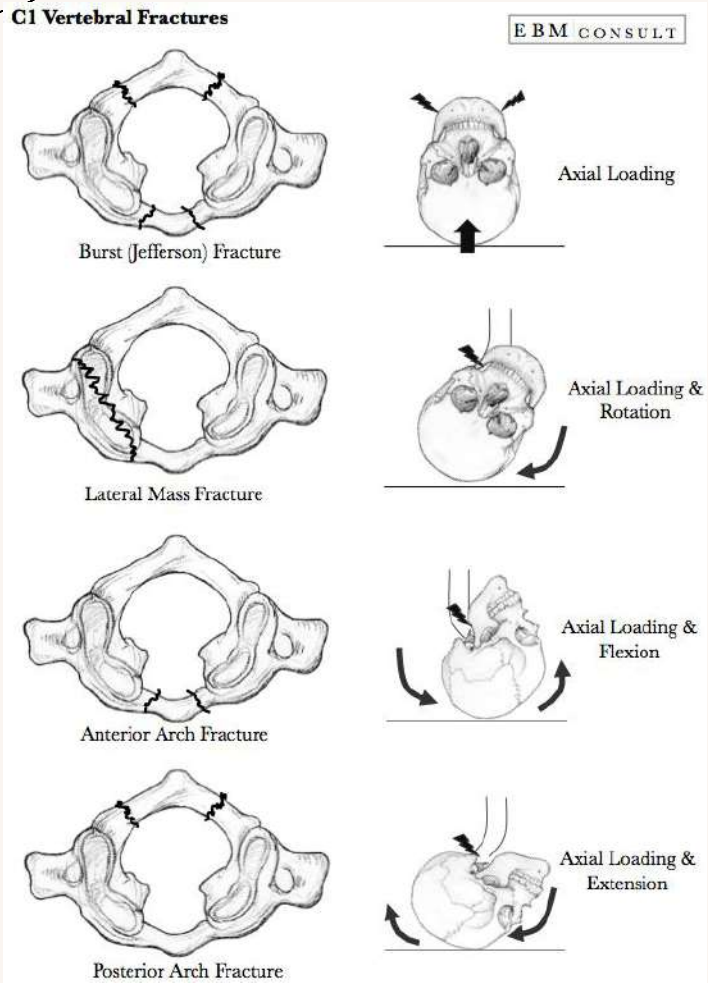
## Type III

Isolated fractures of a lateral mass.




Landell's type II Jefferson fracture variant (C1 , three sites).
**(a)** On odontoid views, displacement of lateral masses of C1 (a and b, double-headed arrows) may suggest a transversal ligament disruption if their sum is > 7 mm (a + b > 7 mm).
**(b)** Displacement and fracture sites (arrows) are better assessed on axial computed tomography reformation. An associated comminuted fracture of the right lateral mass of C1 (plain arrow) may lead to atlantoaxial anteroposterior instability through a transverse ligament injury (type IIB of Dickman's classification).

# Atlas fractures



# Odontoid Process Fracture (C2)

**Also known as dens fracture →** the most common traumatic lesion of the axis (C2),

Etiology:
- Young adult: head blunt trauma through cervical hyperflexion or hyperextension.
- Elderly: simple falls.

**Manifestations:**

- Neck pain, worsening with motion.
- Dysphagia → large retropharyngeal hematoma.
- Myelopathy (very rare)

# Odontoid Process Fracture (C2)

Classification (Anderson and D'Alonzo's):

- **Type I:**
  Oblique avulsion fracture of the tip of the odontoid, above the transverse ligament.

- **Type II:**
  Fracture at the base of the odontoid, between the level of the transverse ligament and the body of C2. The most common

- **Type III:**
  Fracture extending into the vertebral body.

# Anderson and D'Alonzo's Classificaiton

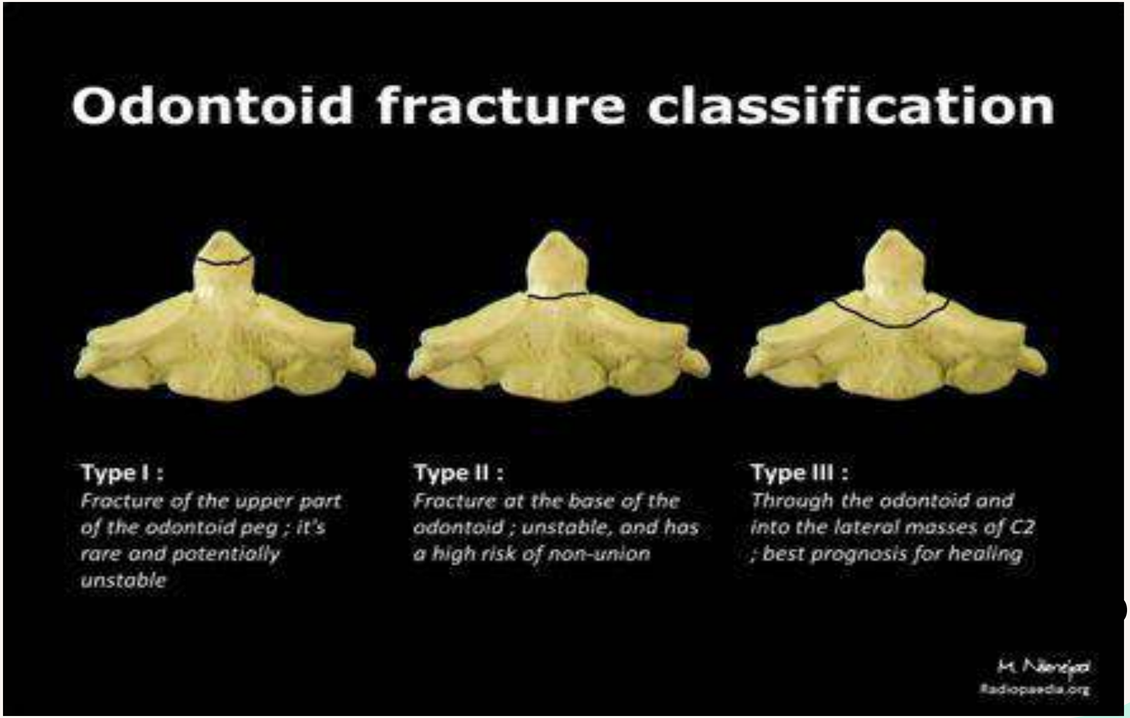



**Fig. Roy-Camille "oblique odontoid fracture sloping backward**," on (a) lateral view and (b) sagittal computed tomography reformation.

# Odontoid Process Fracture (C2)

**Flexion-extension radiographs**
are important optional views to diagnose atlantoaxial instability in type I fractures and variants (os odontoideum).

**CT**
is the imaging modality of choice for fracture delineation and assessing its stability.

**CT angiogram**
is required to determine the location of the vertebral artery prior to posterior instrumentation procedures.

**MRI**
is indicated if neurologic symptoms are present.

# Traumatic Spondylolisthesis of C2 (Hangman's Fracture)

corresponds to the fracture of both "pars interarticularis" (isthmus) of C2 .

**Etiology:**

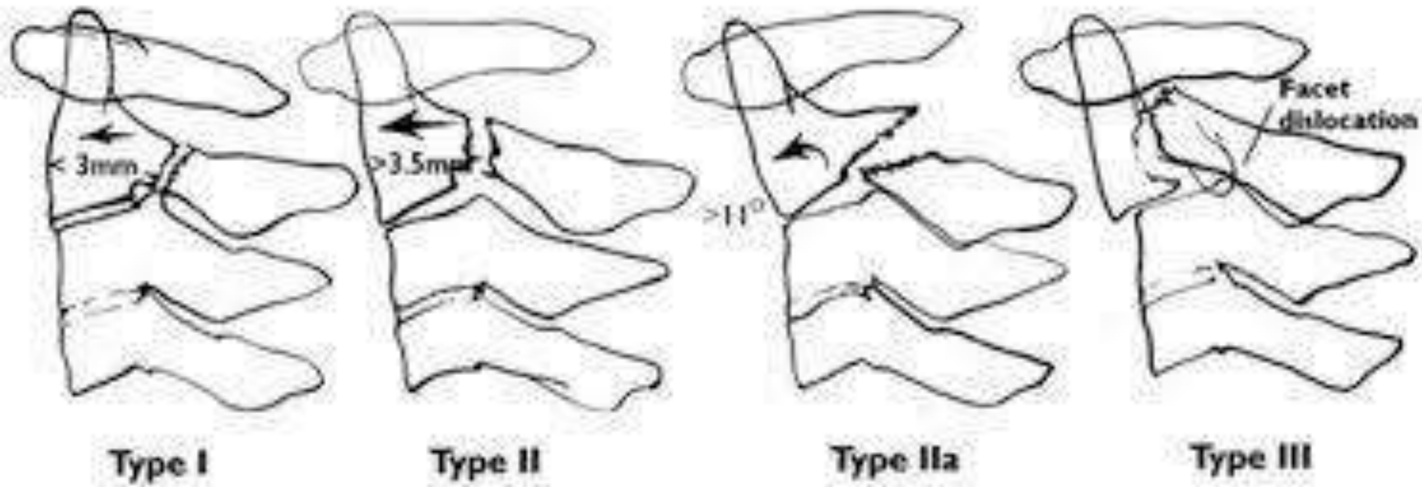
- Sudden cervical spine hyperextension and distraction,
- Tearing apart the longitudinal ligaments and the intervertebral disc

**Manifestations:**

- Neck pain.
- No neurologic deficit.

Have a good prognosis

# Hangman's Fracture
# Classified by Effendi et al (modified by Levine and Edwards)




**Levine and Edwards type I (nondisplaced) hangman's fracture (arrows),**

**(a) axial** and **(b) parasagittal** CT reformations. The anterior C2 –C3 intersomatic space is initially widened (star) on the sagittal CT reformation **(c),** suggesting a disc injury and potential instability, confirmed by an anterior subluxation of C2 (double-headed arrow) demonstrated 3 months later **(d).**

# Traumatic Spondylolisthesis of C2 (Hangman's Fracture)

### Plain radiographs

Anomalies could be subtle

### CT

the study of choice to delineate fracture pattern.

### MRI

- evaluate discoligamentous structures
- if there are neurologic symptoms and/or a suspicion of a vertebral artery injury.

# Atlantoaxial Anteroposterior Dislocation

The transverse ligament is the sole element preventing C1 from being dislocated anteriorly and the dens from being displaced posteriorly.

Classification to describe ligamentous injuries following AAD (Dickman et al):

| Type I: Pure transverse ligament injuries | Type II: Injuries involving a bone fracture |
| --- | --- |
| • IA: midportion disruption | • IIA: avulsion fracture of a tubercle |
| • IB: disruption at its insertion without fracture of the tubercle. | • IIB: comminuted lateral mass fracture |

# Dickman classification

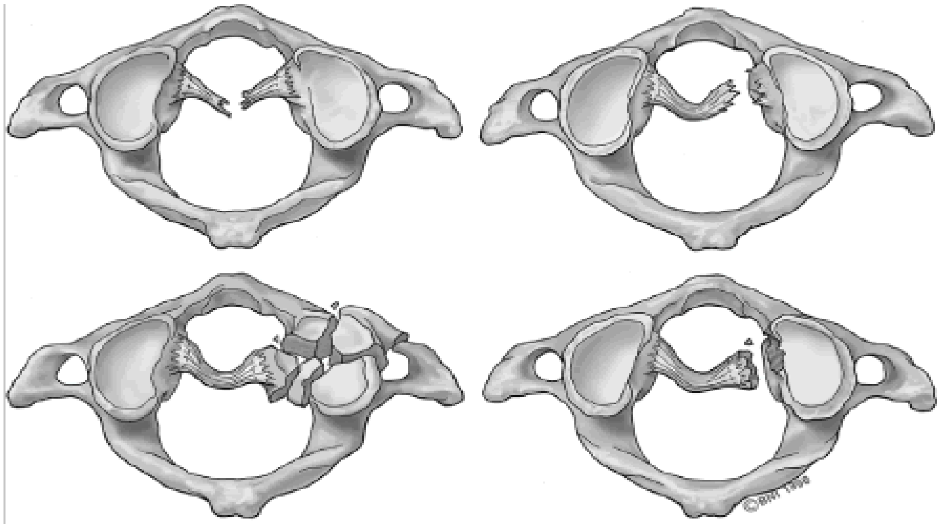
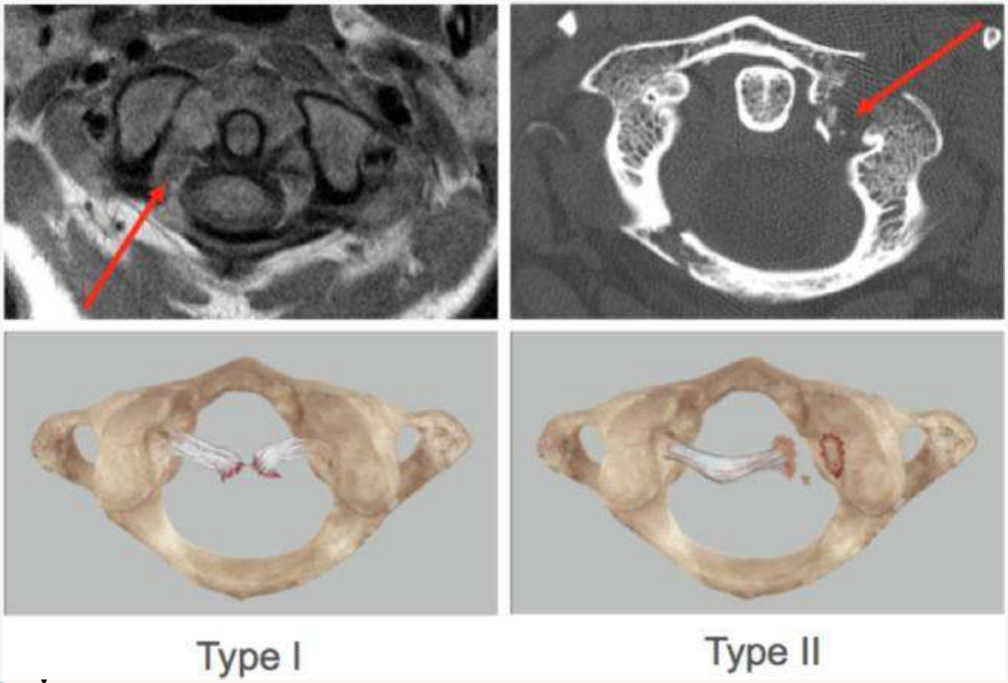


**Figure 11:** Dickman Classification. Clockwise from top left picture. Picture A (top left)= Disruption of the transverse ligament in the mid-portion. B (top right) = Bony evulsion. C (Bottom left)= Disruption of the transverse ligament at the insertion of medial tubercle. D (bottom right) = Bony evulsion.

A&C= Dickman type I  B&D = Dickman type II

# Dickman Classification



# Atlantoaxial Rotary Subluxation

More common in children.

Etiology:
- Trauma with sudden head rotation.
- Inflammatory process (rare)

Transverse ligament and C1–C2 joint capsules keep the atlantoaxial joint from shifting in a sagittal plane

The alar ligaments prevent excessive rotation.

Rotation of C1 over C2 is fixed, the head is blocked in lateral rotation and muscle contracture

↓

cervical pain.

# Atlantoaxial Rotary Subluxation

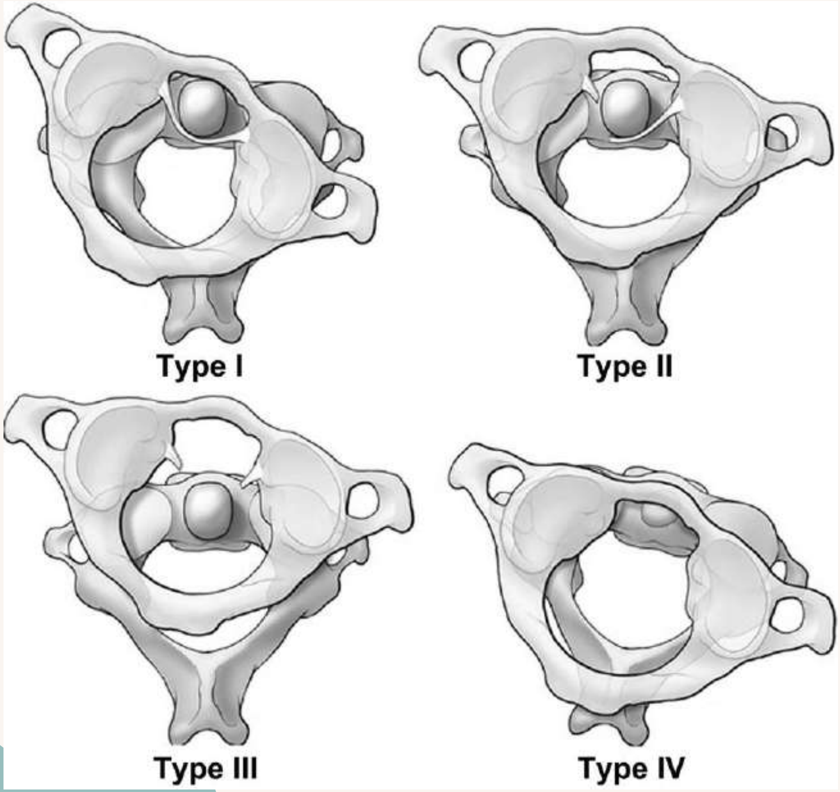
CT is essential for diagnosis

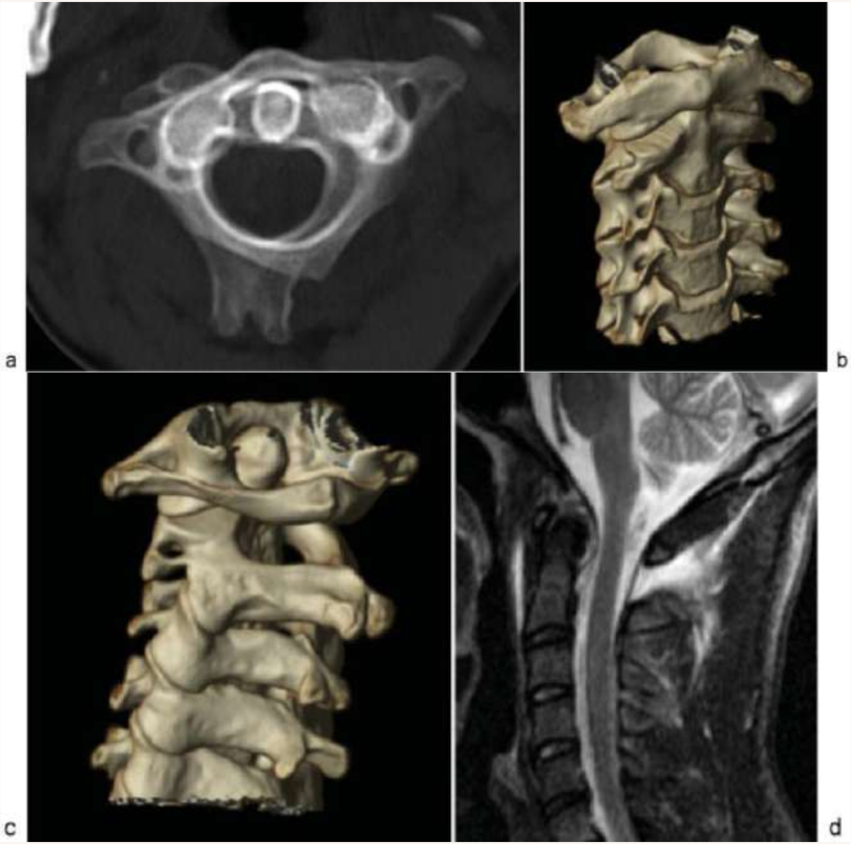
- Evaluation of the ADI (Atlanto Dens Interval)
- Anatomical relationship between C1 and C2 in an axial plane

**4 types of rotary subluxations (Fielding and Hawkins):**

1. Type 1: Rotary subluxation without anterior shift.
2. Type 2: Rotary fixation with 3- to 5-mm anterior shift.
3. Type 3: Rotary fixation with > 5 mm anterior shift.
4. Type 4: Rotary fixation with posterior shift (rare).

# Fielding and Hawkins Classification






**Atlantoaxial rotary subluxation (ARS)**

On CT, **(a) axial** and **(b, c)** volume rendering reformations demonstrate a rotation of the atlas over the axis, with no significant anterior shift (< 5 mm). This type 1 ARS does not radiologically differ from a physiologic rotation of the head on the initial examination. However, subluxation was not reducible on a control CT scan (similar appearance, not shown).
MRI revealed some prevertebral and posterior edema on sagittal proton-density-weighted short tau inversion recovery acquisitions **(d),** without any alar or transverse ligament disruption.

02

# Lower Cervical Spine Injuries

## Subaxial Cervical Spine Injury Classification System

| | | |
|---|---|---|
| **Morphology** | - No abnormality | 0 |
| | - Compression | 1 |
| | o Burst | + 1 = 2 |
| | - Distraction | 3 |
| | - Rotation/translation | 4 |
| **Discoligamentous complex** | - Intact | 0 |
| | - Indeterminate | 1 |
| | - Disrupted | 2 |
| **Neurologic status** | - Intact | 0 |
| | - Root injury | 1 |
| | - Complete cord injury | 2 |
| | - Incomplete cord injury | 3 |
| | - Continuous cord compression in setting of neurologic deficit (Neuro Modifier) | + 1 |

# Compression Injuries

**Vertical compression** injuries occur when sufficient axial strength is exerted through the spinal column.

**Minor vertical compression** results in central cupping of vertebral end plates and/or sagittal/coronal split fractures.

With high-energy compression mechanisms, typical burst fractures show severe vertebral body height loss and may extend to the posterior column

compressive hyperflexion injuries → severe neural damages

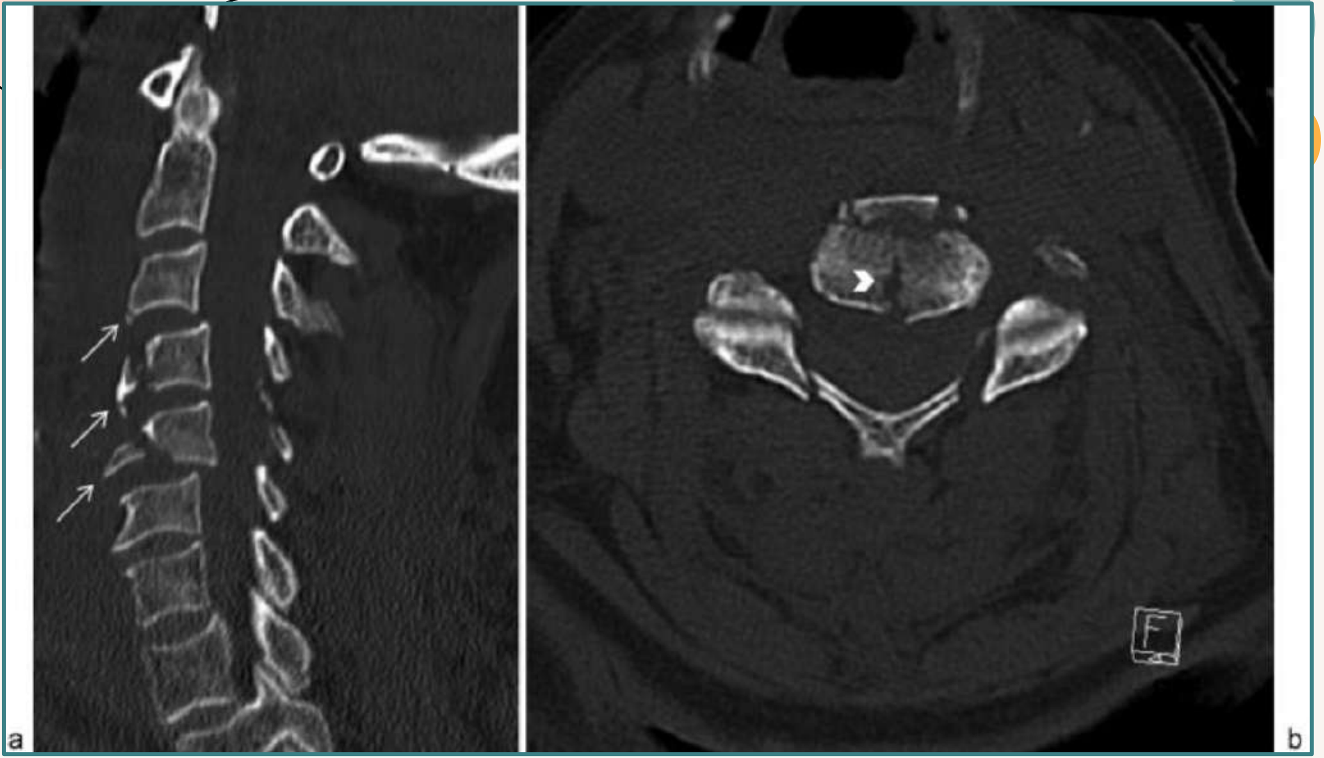

**Complex vertebral fracture**

on **(a)** sagittal CT and **(b)** T2 -weighted MRI acquisitions.
Burst fracture of C7 (star) is best seen on CT, whereas soft tissues and distraction lesions are best explored on MRI: prevertebral hematoma with disruption of anterior and posterior longitudinal vertebral ligaments (arrows) leading to anterior subluxation of C6 , spinal cord contusions (asterisk), and posterior edema suggesting supraspinous and interspinous ligamentous injuries (plain arrow).

# Teardrop fractures

**Classification teardrop fractures (Korres et al):**

- Type I: Incomplete or occult sagittal fractures, with an anterior fragment < 3 mm.
- Type II: Complete sagittal fractures, without posterior displacement.
- Type III: Type II + posterior displacement (IIIa: < 4 mm; IIIb: > 4 mm).
- Type IV: Type IIIb + locked facet (the inferior articular facet is dislocated and locked over the superior articular process of the subjacent vertebra) and anterior dislocation of the above vertebra.



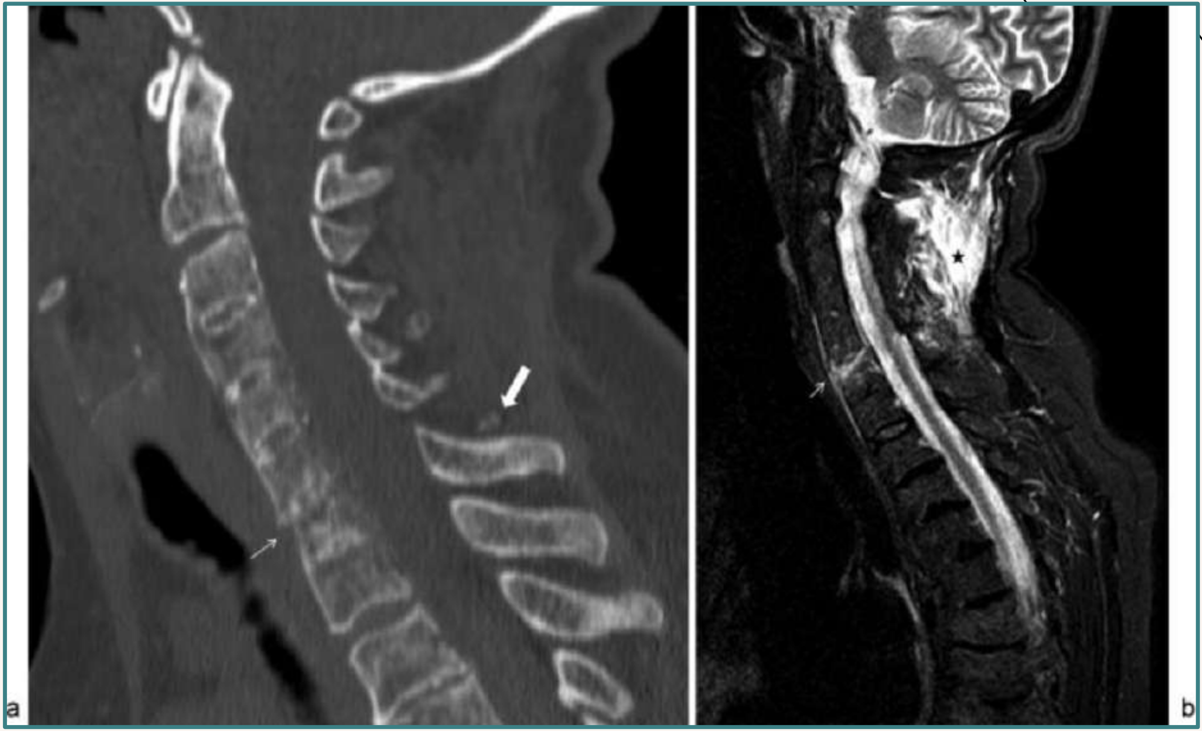

**Teardrop fractures.**

**(a)** A triangular fragment is seen at the anterior and inferior corner of C3 –C5 vertebral bodies (arrows) on sagittal CT reformations. **(b)** The sagittal fracture line (arrowhead) is best seen on axial CT reformations.

# Distraction Injuries

the anatomical dissociation in the vertical axis, with severe discoligamentous lesions.

- The posterior column is affected first.
- The supraspinous ligament begins to disrupt, followed by the interspinous ligament, facet capsular ligaments, and the ligamentum flava
- Minor compressive forces are frequently present → vertebral end-plate fractures.

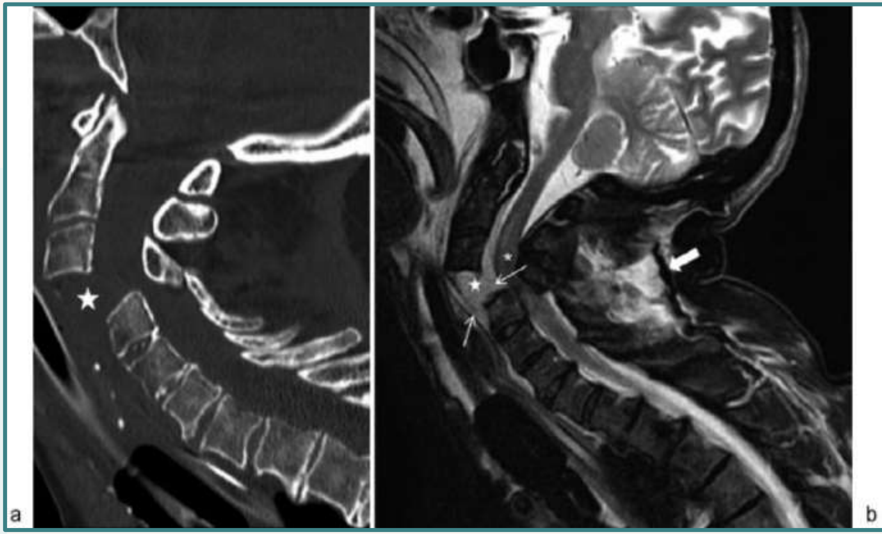



**Transdiscal fracture following a distraction injury on an ankylosed cervical spine.**

Sagittal CT reformations
**(a)** show a widened interspinous space, with a fractured bone fragment from a spinous process (plain arrow) and a fracture of the superior end plate
**(b).** Hyperintense posterior soft tissues (black star) suggest supraspinous and interspinous ligament injuries.

# Rotation/Translation Injuries

- The highest score for the SLIC severity scale (morphology component) is given when a horizontal translation > 3.5 mm or a sagittal angulation > 11 degrees.
- Anterior and posterior structures are injured through these trauma mechanisms



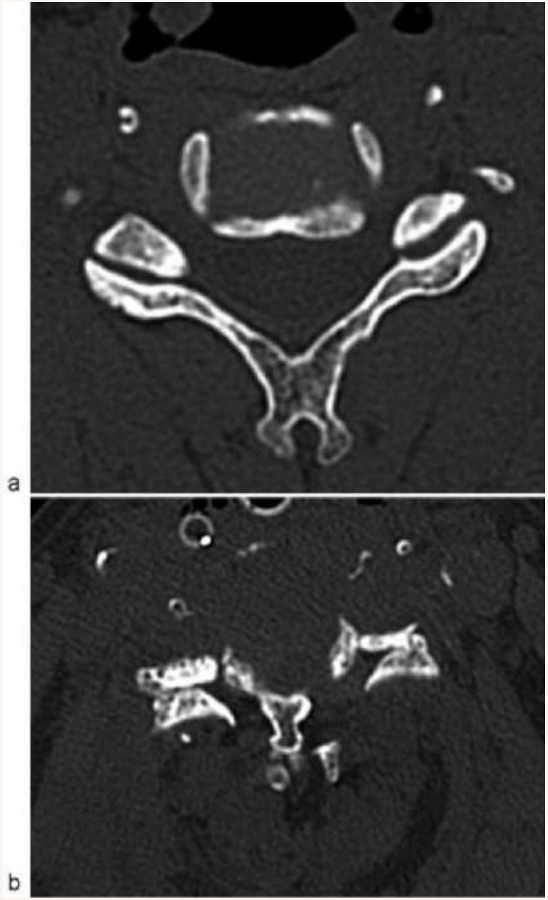
**Transdiscal fracture following a distraction injury, with severe vertebral translation.**

**(a)** Sagittal CT reformations and **(b)** T2-weighted short tau inversion recovery MRI acquisitions show a large intersomatic C3–C4 space widening (white star), posterior soft tissue edema (plain arrow), spinal cord contusions (asterisk), and disruption of the anterior and posterior vertebral longitudinal ligaments (thin arrows).

# Rotation/Translation Injuries

**Several signs on axial images were described to ease facet joint dislocation diagnosis:**

- The “reverse hamburger sign,”
- The “naked facet sign,”
- The “headphones sign,”




Axial CT reformations showing normal articular facets **(a)** that are reversed when dislocated (“reverse hamburger sign,” **b).**

# Clay-Shoveler's Fractures

Clay-shoveler's fractures are isolated spinous process fractures of a lower cervical vertebra, affecting mostly C7.

Etiology:

- Direct blow to the posterior aspect of the neck
- Cervical hyperextension and hyperflexion injuries.

This pain may radiate up to the head and down to the arms.

# Clay Shoveler's Fracture

# Clay-Shoveler's Fractures

## Imaging:

**Anteroposterior views →**
double spinous process shadow at the affected level.

**Lateral views →**
Downward displacement of fractured bone fragments.

**CT & MRI:**

Detecting more serious spinal fractures.

**MRI:**

demonstrating ligamentous disruptions

# Conclusion

Unstable lesions can lead to severe neurologic complications

Rigorous imaging management and interpretation are required

patient not demonstrating low-risk criteria

**CT imaging**

**MRI**
when a discoligamentous or spinal cord injury is suspected

# Thank You

**bilateral occipitoatlantoaxial joint complex injury** can be used as a marker for instability.

To guide neurosurgical management

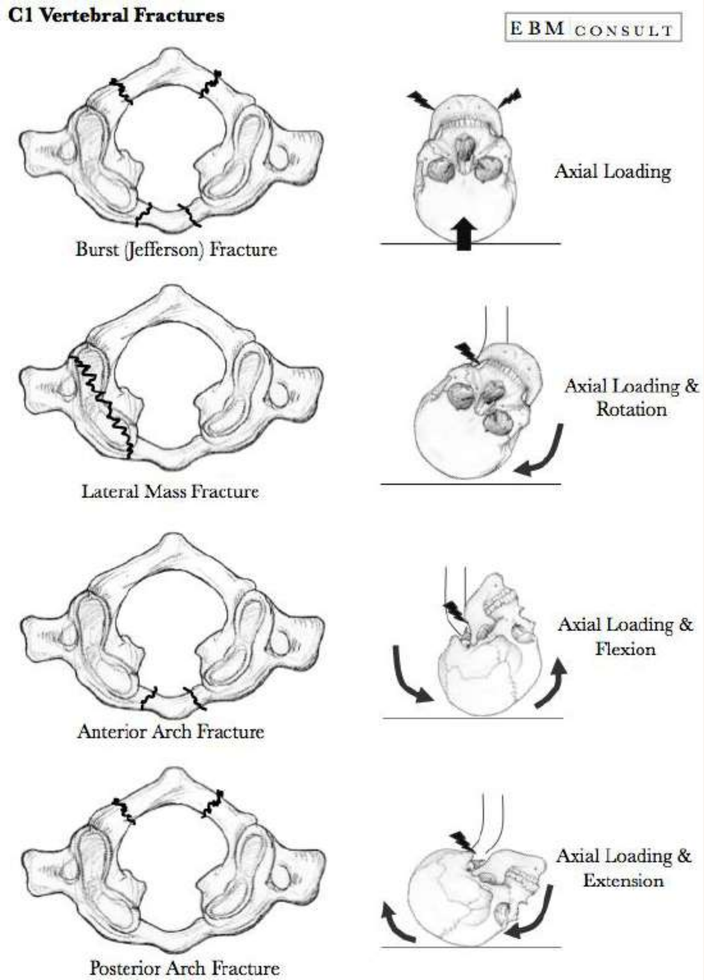
classification that includes **ligamentous integrity (Tuli et al)**

**Type 1:**
Nondisplaced occipital condyle fracture

**Type 2A:**
Displaced (at least 2 mm) occipital condyle fracture with intact ligaments. There is no radiographic evidence of occipitoatlantoaxial instability or ligamentous disruption

**Type 2B:**
Displaced (at least 2 mm) occipital condyle fracture with radiographic evidence of craniocervical junction instability

# Atlas fractures



# Atlantoaxial Anteroposterior Dislocation

Open-mouth views

- If the sum of each lateral mass displacement is > 7 mm, the transverse ligament is likely to be disrupted ("rule of Spence")
- Avulsion fragment of the medial aspect of a lateral mass of C1 could also be visible

Lateral views

- ligamentous instability can be assessed by the ADI

# Atlantoaxial Anteroposterior Dislocation

Dynamic cervical radiographs → to evaluate atlantoaxial stability with spontaneous reducible dislocation.

MRI → to assess soft tissues, joints, and the spinal cord.

Classification of AAD:

- Type I : Dynamic reduction on radiographs (instability).
- TypeII : Reducible dislocation after skeletal traction under general anesthesia.
- Type III : Irreducible dislocation after skeletal traction under general anesthesia.
- Type IV : Bony dislocation (C1–C2 bony fusion).

# Pathomechanism

Cervical flexion combined with axial loading

the anterior and superior margin of the vertebral bodies is weakened and may wedge

⬆ Forces

a fracture line may appear in the coronal plane.

A triangular anterior fragment is separated from the vertebral body

## Teardrop Fractures

# Distraction Injuries

After exaggerated cervical hyperextension:

- Tensile failure of the anterior column progressively occurs.
- Ligamentous disruptions first take place, beginning with the anterior longitudinal ligament → progressing posteriorly → affect the intervertebral disc and posterior longitudinal ligament.
- Posterior subluxation of the cranial vertebra over the caudal one may appear transiently as distraction increases and be combined with ligamentous and disc injuries.
- Widened anterior disc space resulting from anterior longitudinal ligament and anterior annulus disruption, spinous processes fractures, and avulsion fractures of the anterior body.

# Distraction Injuries

## Imaging features:

- Posterior dislocation is transient → hyperextension-dislocation injuries produce minimal imaging features on plain radiographs or CT.

- Indirect sign:
  - ❖ Diffuse prevertebral soft tissue swelling.
  - ❖ Degree of retrolisthesis.

- Unrestrained hyperextension followed by flexion → Whiplash injuries.
  - ❖ High-energy trauma, MRI: limited and nonspecific imaging findings.
  - ❖ Low grade acute, MRI: poor diagnostic accuracy,

# Distraction Injuries

**Imaging features:**

Severe cervical osteoarthritis and ankylosing spondylitis → weaken the cervical spine.

Only subtle injuries can be visible on plain radiographs

**undergo CT + MRI**
if there are clinically or radiologically suspected discoligamentous or spinal cord injuries