Cervical Spine Trauma

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ACR Education Center 2025

Learning Objectives

- Consider how to image spinal trauma
- Review basic cervical spine anatomy introducing the concept of stability
- Create an approach for CT interpretation
- Discuss the advantages of obtaining MR
- Illustrate the CT and MR appearance of various spine injuries i.e., a case-based approach

Who Should We Image?

- The National Emergency X-Radiography Utilization Study (NEXUS) Criteria for Cervical Spine Imaging
  - Focal neurologic deficit
  - Midline spinal tenderness
  - Altered level of consciousness
  - Intoxication
  - Distracting injury

How Should We Image? CT

- The ACR panel concluded that thin-section CT, and not radiography, is the primary screening study in adults.
- The panel recommended that sagital and coronal multiplanar reconstruction be performed for all studies to improve identification and characterization of fractures and subluxations.

ACR Appropriateness Criteria 2012 update

Advanced Imaging: CT

- Dual energy CT can differentiate acute/subacute fractures from chronic injuries by measuring water content.
- Photon counting CT generates images at multiple (not just two) energies.
  - The utility of this technique in the evaluation of acute spine trauma is currently under investigation.

If CT Shows Traumatic Injury

- Let the treating physician decide if MR is needed to plan patient care
- MR is useful for determining stability because it can evaluate ligaments
- Cord injury and neurologic outcome may not correlate with CT findings

Indications for Spine MR, CT WNL

- Progressive neurologic deficit
- Incomplete neurologic deficit
- Obtunded/unreliable patient
- “Potential medical, social, economic, and medicolegal consequences of missed injuries”

Munera F et al. Radiology 263: 645-660 (2012)

MR of Obtunded Pt, CT WNL

- Unrecognized spine injury
  - Disability
  - Death
- Prolonged spinal immobilization
  - Complications
  - Increased health care cost
- Incidence of unstable injuries is very low
  - Need for MR is still controversial

Spine Trauma: MR Protocol

- CT is best for fracture
- MR best for cord injury and ligamentous injury
- T2 weighted STIR useful for ligamentous injuries and cord edema
- T2* gradient echo (GRE) useful for cord hemorrhage

Sundgren et al. Neuroimag. Clinics NA 17:73-85 (2007)

MR of Ligamentous Injury

MRI demonstrates lesions in the ligaments; many of these are clinically insignificant. There are not established criteria for distinguishing significant abnormalities on MRI. In the absence of proven guidelines, many use through-and-through tears of ligaments as indicating definite mechanical failure, with high signal on T2-weighted images, considered ambiguous.

ACR Appropriateness Criteria

Anatomy: Occiput & Atlas

- Five C-C ligaments
  - 1) tectorial membrane
  - 2) cruciform ligament
  - 3) apical ligament
  - 4) atlanto-occipital ligament
  - 5) anterior longitudinal ligament

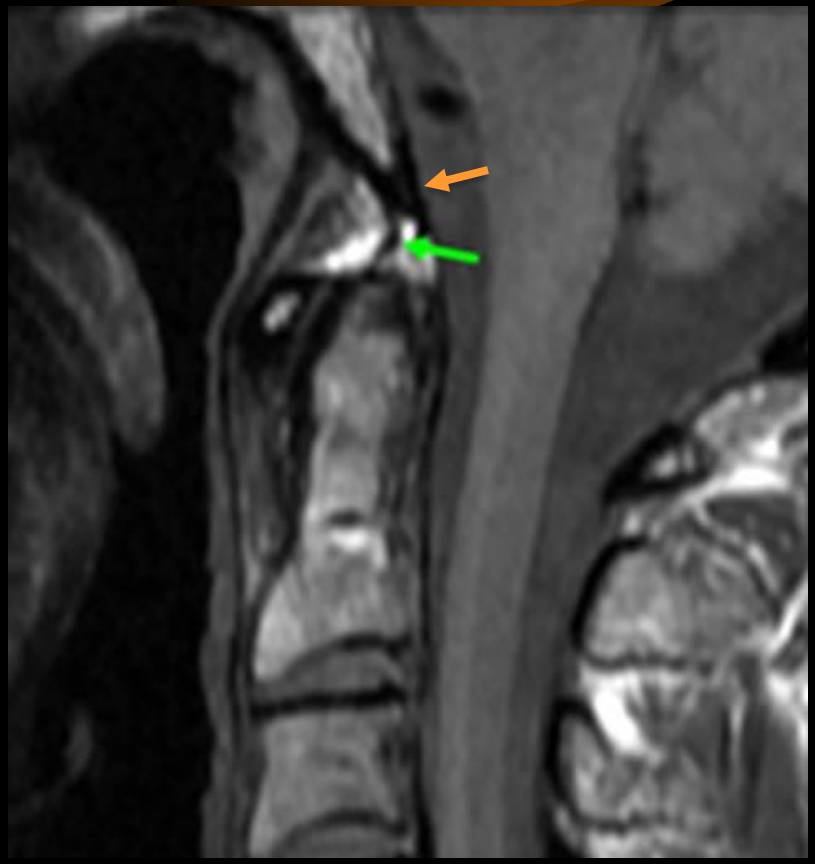
CT Anatomy: Occiput & Atlas

- Four C-C ligaments
  - 1) tectorial membrane & cruciform ligament
  - 2) apical ligament
  - 3) atlanto-occipital ligament
  - 4) anterior longitudinal ligament

Lustrin, Elizabeth et. al. RadioGraphics (2003)

MR Anatomy: Occiput & Atlas

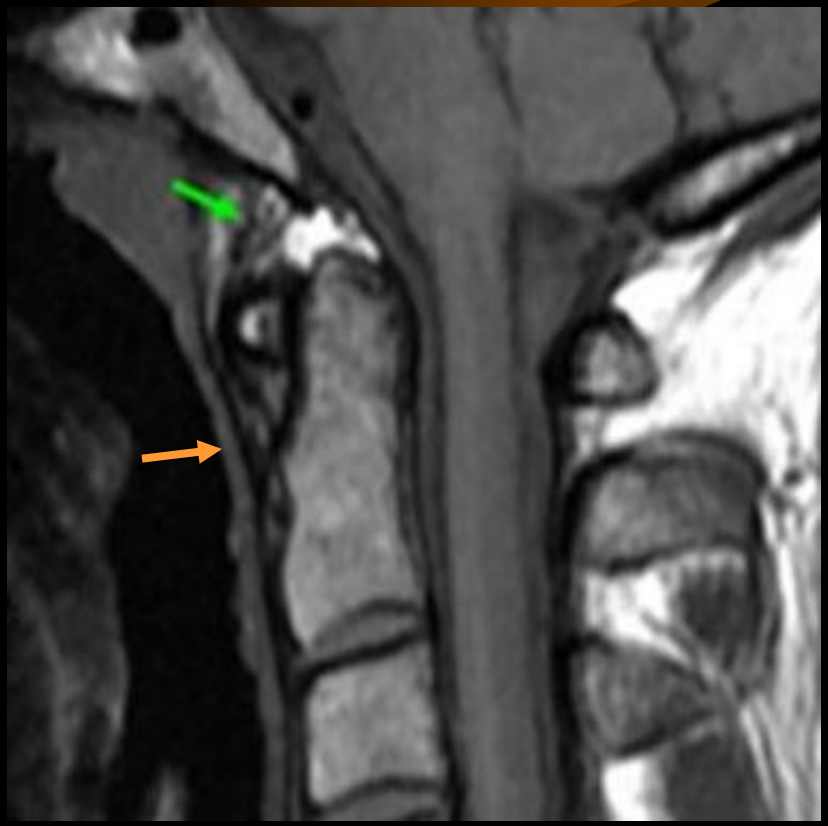
- Four C-C ligaments
  - 1) tectorial membrane & cruciform ligament
  - 2) apical ligament
    - seen in 60% of normals
  - 3) atlanto-occipital ligament
  - 4) anterior longitudinal ligament



Vassion et al, J. Biomedical Science & Engineering (2012)

MR Anatomy: Occiput & Atlas

- Four C-C ligaments
  - 1) tectorial membrane & cruciform ligament
  - 2) apical ligament
  - 3) atlanto-occipital ligament
    - Seen in 96% of normals
  - 4) anterior longitudinal ligament



Vassion et al, J. Biomedical Science & Engineering (2012)

Stability: Occiput & Atlas (C1)

Occipital condyle to atlas = 1-2 mm

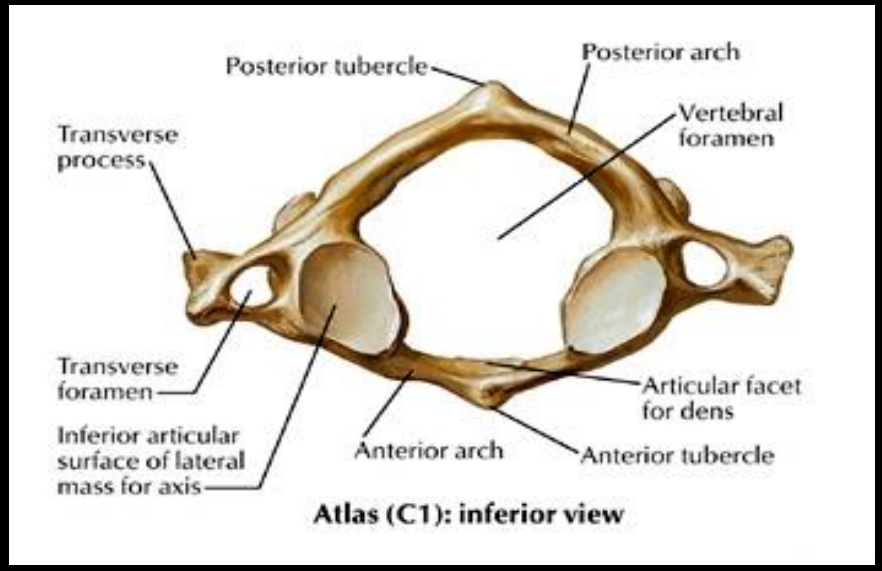
T2 hyperintensity / disruption of ligaments

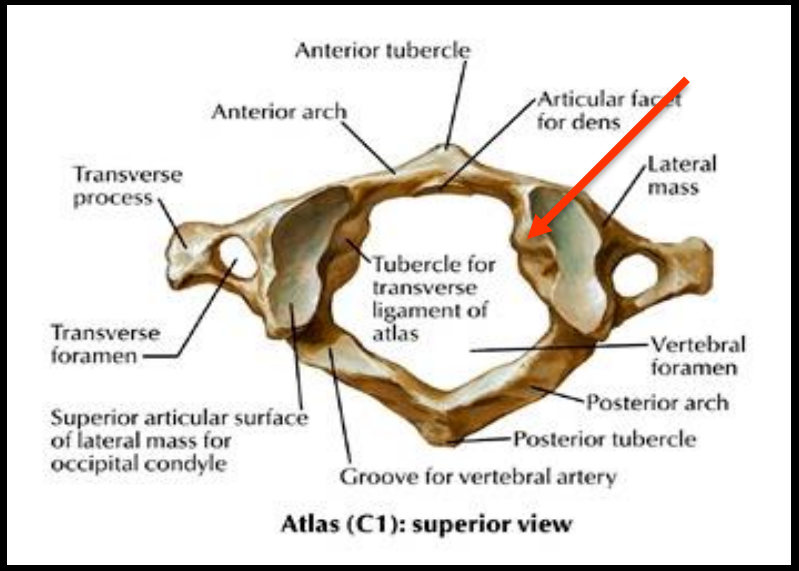
- Tectorial membrane & cruciform ligament
- Apical ligament
  - seen in only 60% of normals !
- Atlanto-occipital ligament
- Anterior longitudinal ligament

Chang W et al. AJR 192:52-58 (2009)

Anatomy: C1

- “Ring” of C1
- C1-C2 articulation is stabilized by transverse ligament attached to tubercle

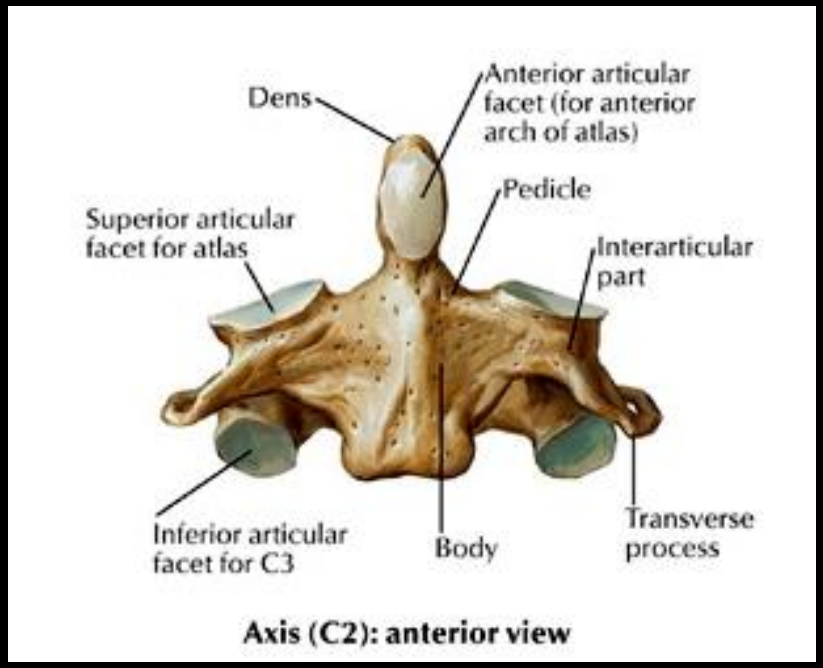


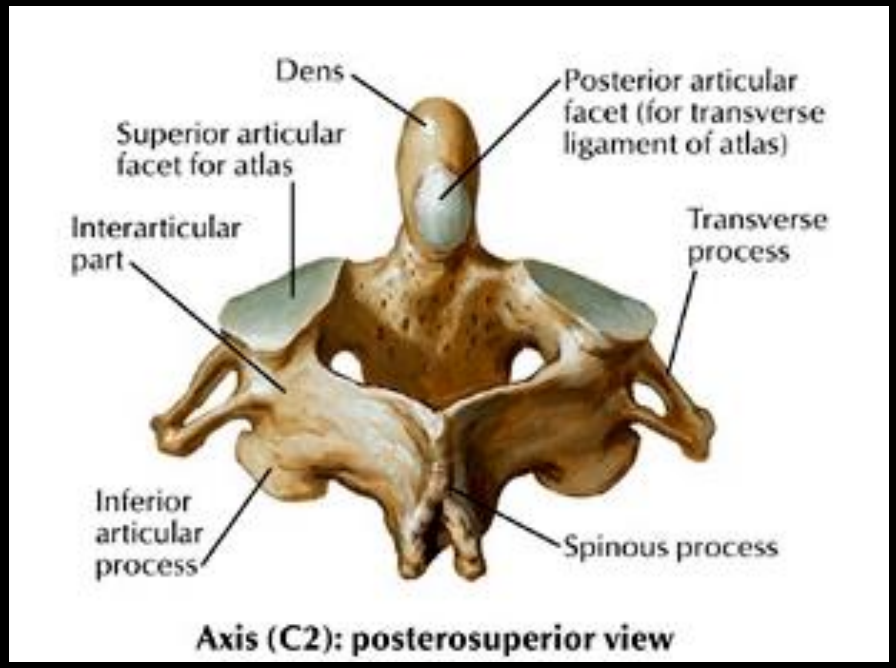


Netter FH. Atlas of Human Anatomy

Anatomy: C2

- C1-C2 Stabilized by transverse ligament





Netter FH. Atlas of Human Anatomy

Anatomy: C1

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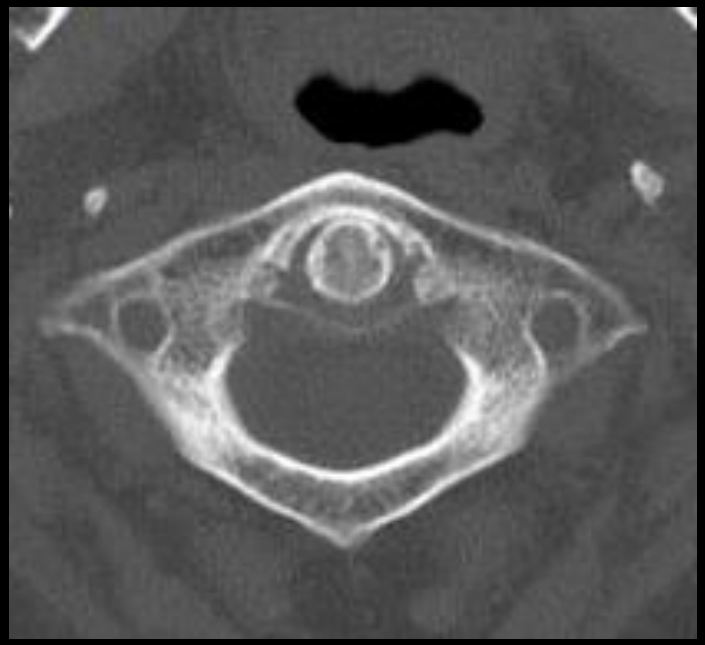
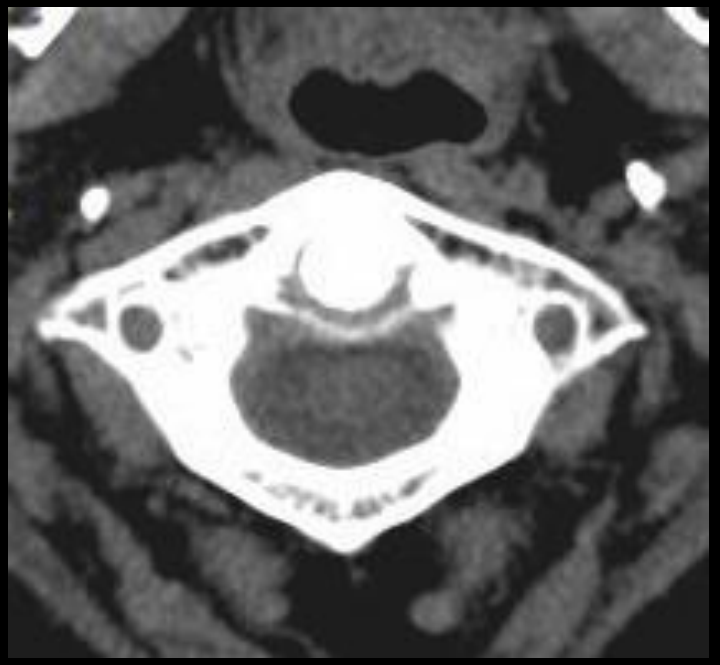
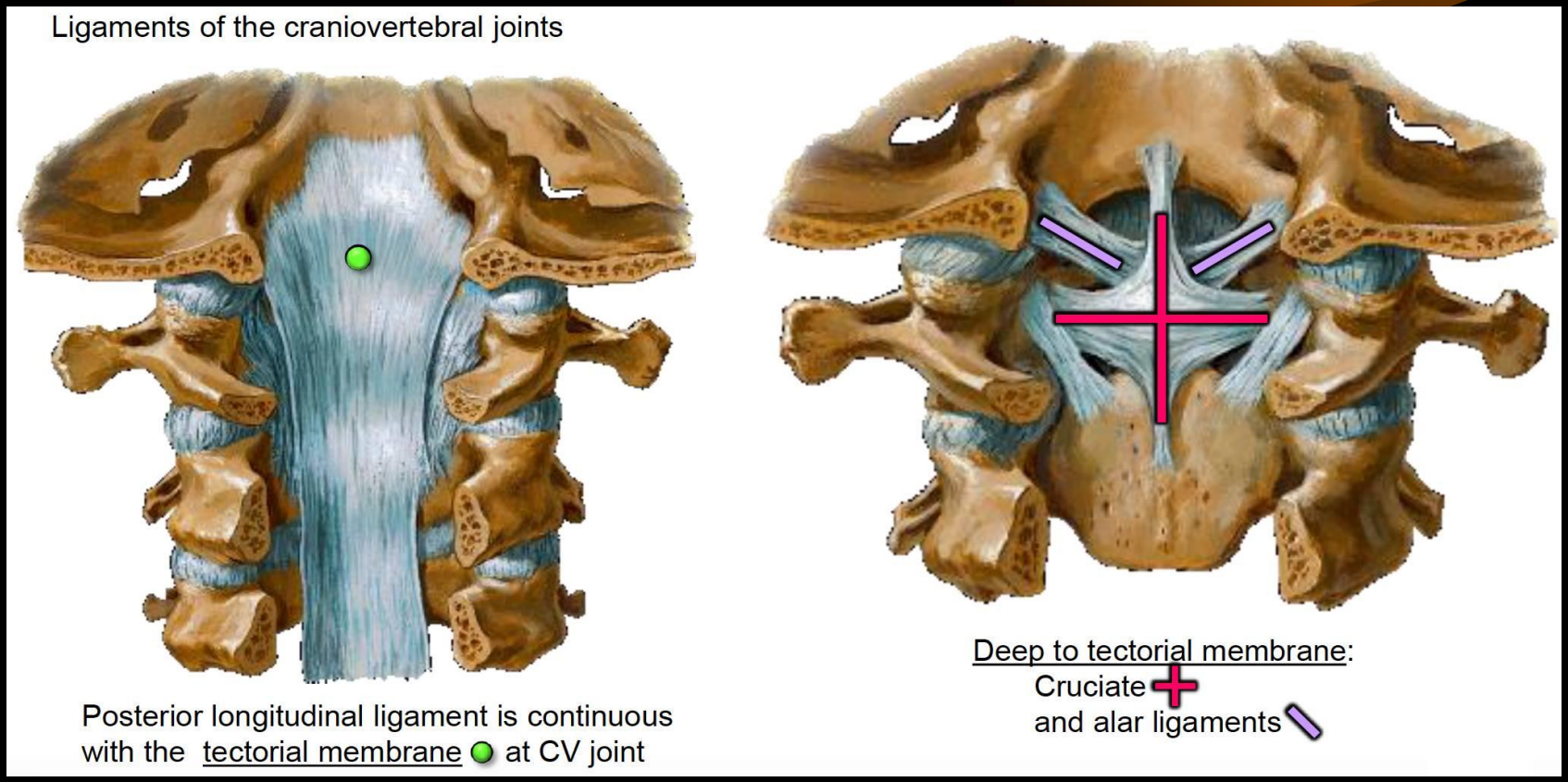




Anatomy: Atlas (C1) & Axis (C2)



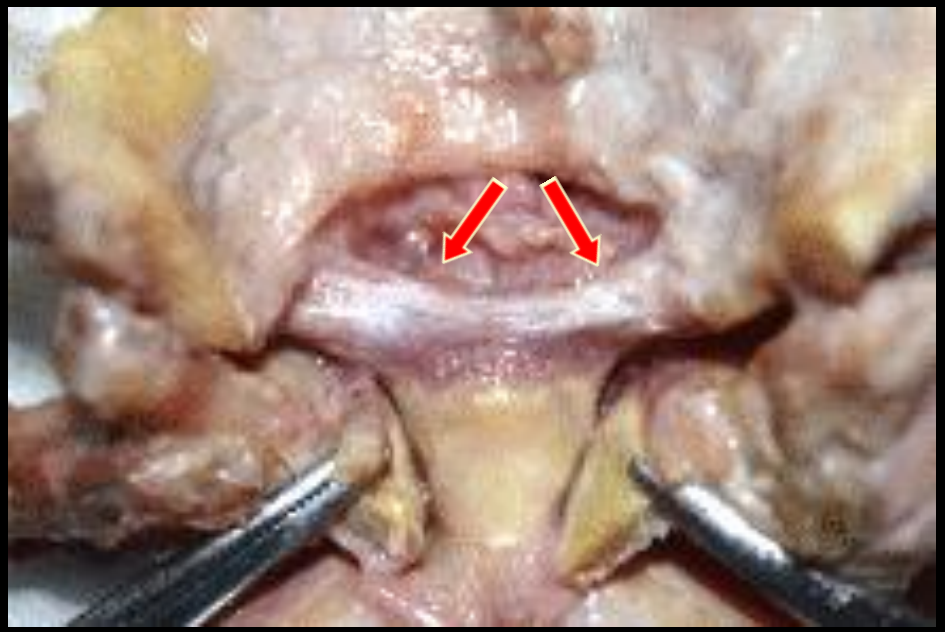
Netter FH. Atlas of Human Anatomy

Cruciform (Cruciate) Ligament

The transverse ligament is attached on either side to a small tubercle of the atlas. As it crosses the odontoid process, a small fasciculus (crus superius) projects upward, and another (crus inferius) downward, from the posterior fibers of the transverse ligament. The former is attached to the basion of the occipital bone, in close relation with the tectorial membrane; the latter is fixed to the posterior surface of the axis; hence, the whole ligament is named the cruciform ligament.

Alar Ligaments

The paired alar ligaments are attached on either side of the dens and project laterally and superiorly to attach to the medial aspect of the ipsilateral occipital condyle.



Iwanaga J et al. World Neurosurgery 107:1012-1015 (2017)

Stability: Atlas (C1) & Axis (C2)

C1–C2 distance = 2-3 mm

Pre-dental space < 2-3 mm

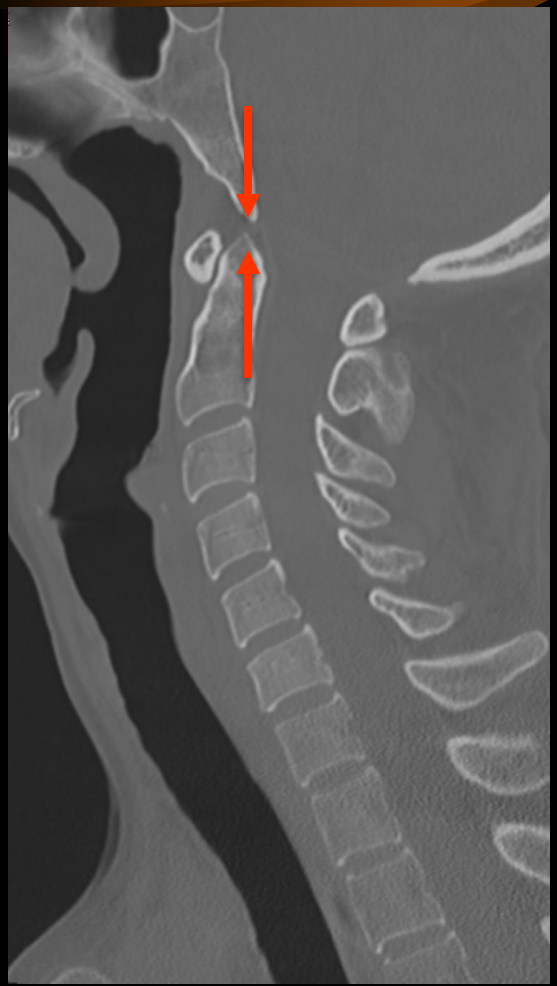
T2 hyperintensity / disruption of ligaments

- Transverse ligament
  - Seen in 93% of normals
- Anterior longitudinal ligament
- Posterior longitudinal ligament
- Interspinous ligament

Chang W et al. AJR 192:52-58 (2009)

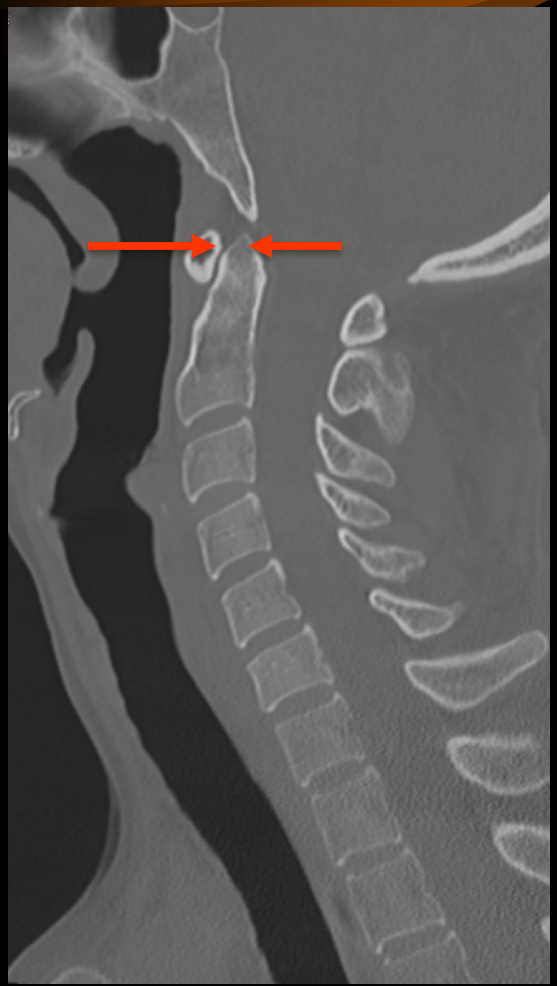
Midline Sagittal CT

- Start with the midline sagittal CT at a bone window
- Basion-dens interval should be less than 8.5-9.5 mm



Midline Sagittal CT

- Predental space should be less than 2.0-3.0 mm
- Predental space should be parallel
  - No “V sign”



Midline Sagittal CT

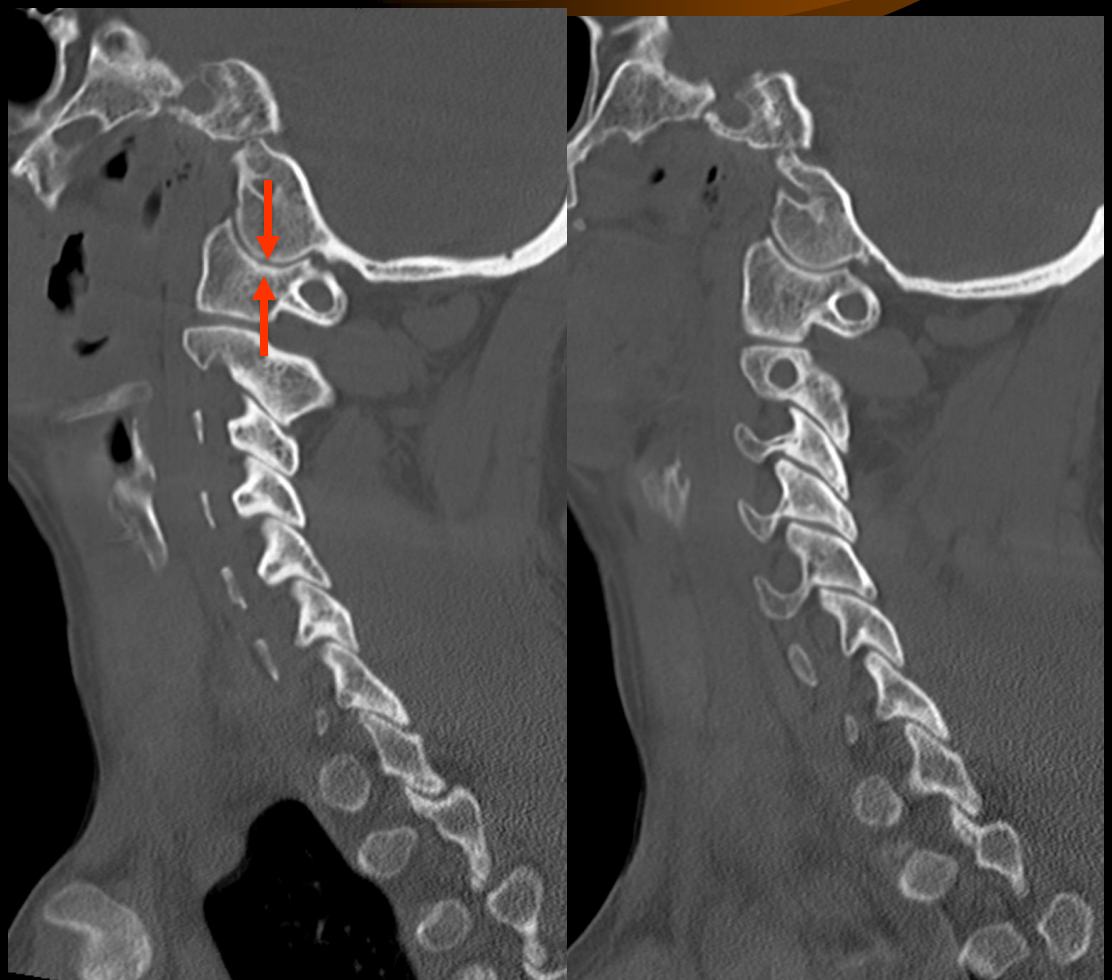
- Anterior vertebral bodies and posterior vertebral bodies should align
  - Within 1-2 mm if DJD
- Spino-laminar line should be a smooth curve
  - No “fanning” of spinous processes

Midline Sagittal CT

- Go to the soft tissue (abdominal) window
- Confirm the integrity of the tectorial membrane
- Look for hematomas within the spinal canal

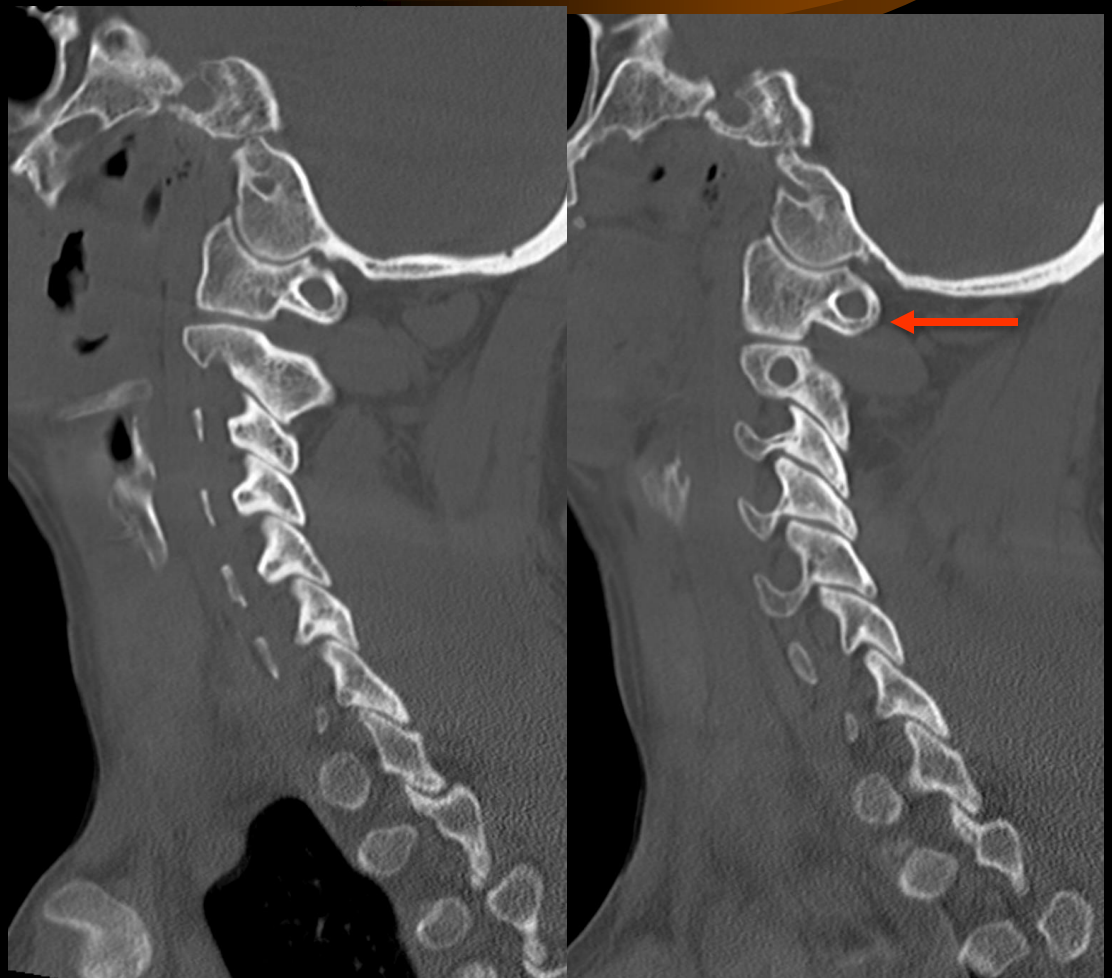
Off Midline Sagittal CT

- Congruity of the occipital condyle with the lateral mass of C1
- Should lie 1-2 mm apart



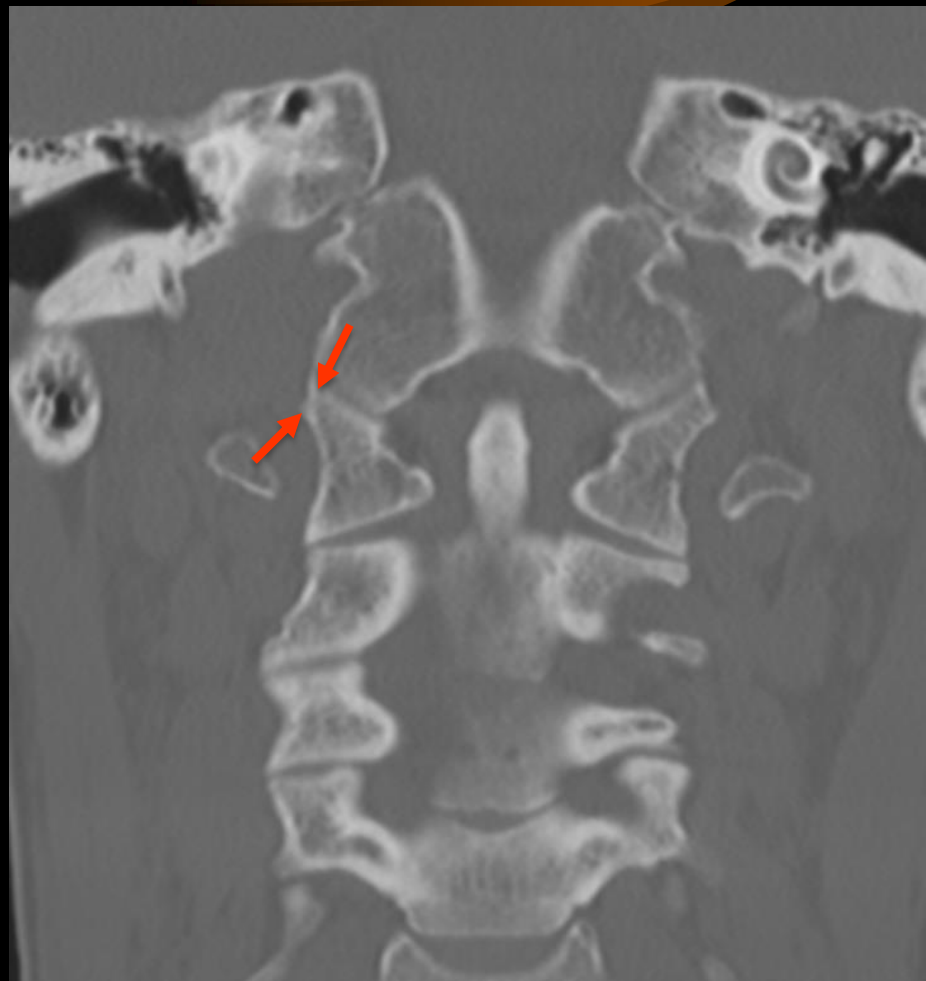
Off Midline Sagittal CT

- Assess facet joints for imbrication
  - No jump
  - No perch
- Note arcuate foramen



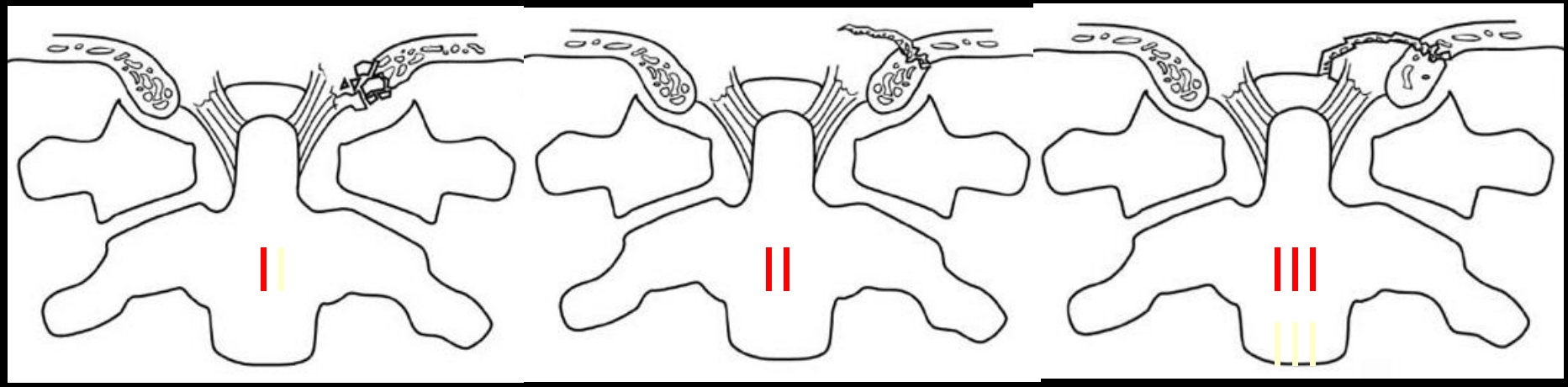
Coronal CT

- Distance from the occipital condyle to the lateral mass of C1 should be 1-2 mm
- Assess for occipital condyle fracture



Occipital Condyle Fractures

- Type I is stable
- Type II is stable; may need vascular assessment
- Type III is potentially unstable



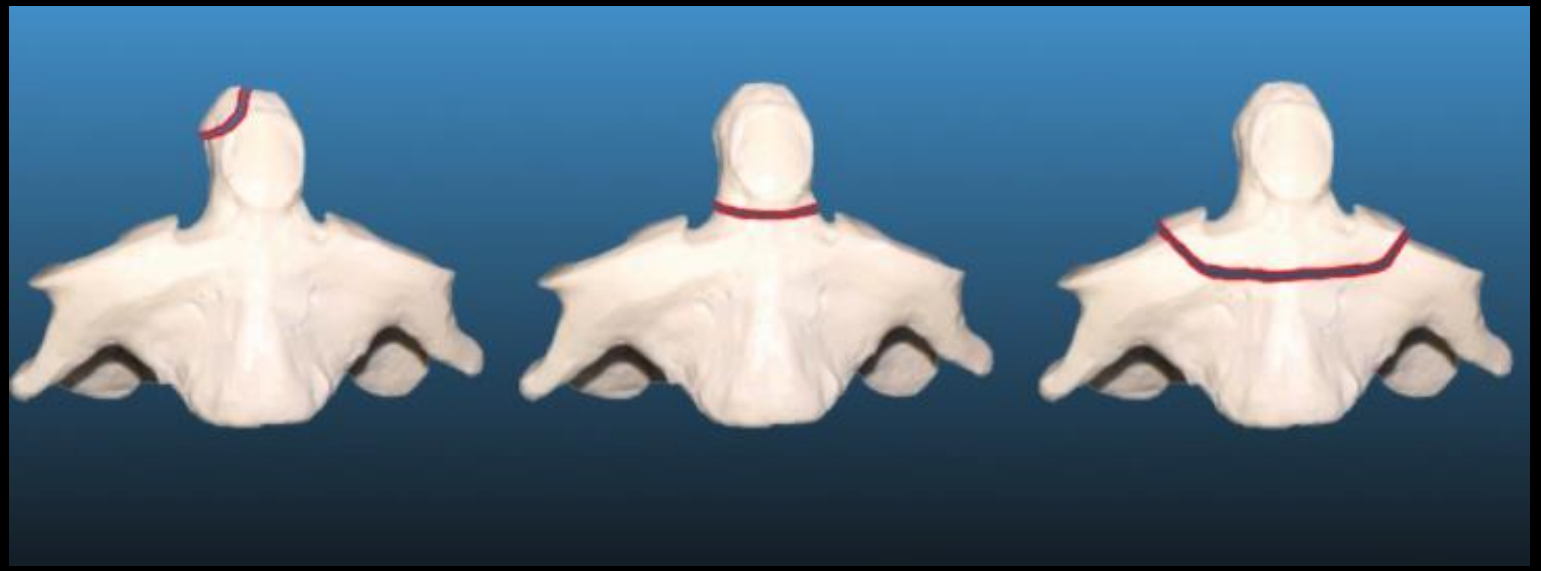
Karam YR et al. Neurosurgery 66:A56-A59 (2010)

Coronal CT

- Distance from C1 to C2 should be 2-3 mm
- Lateral masses of C1 and C2 should be aligned
- Assess dens fracture

Dens Fractures

- Type I, Type II, Type III



Axial CT

- Assess the transverse foramina
  - Possible vertebral artery injury
- Assess the facet joints
  - “Hamburger sign”

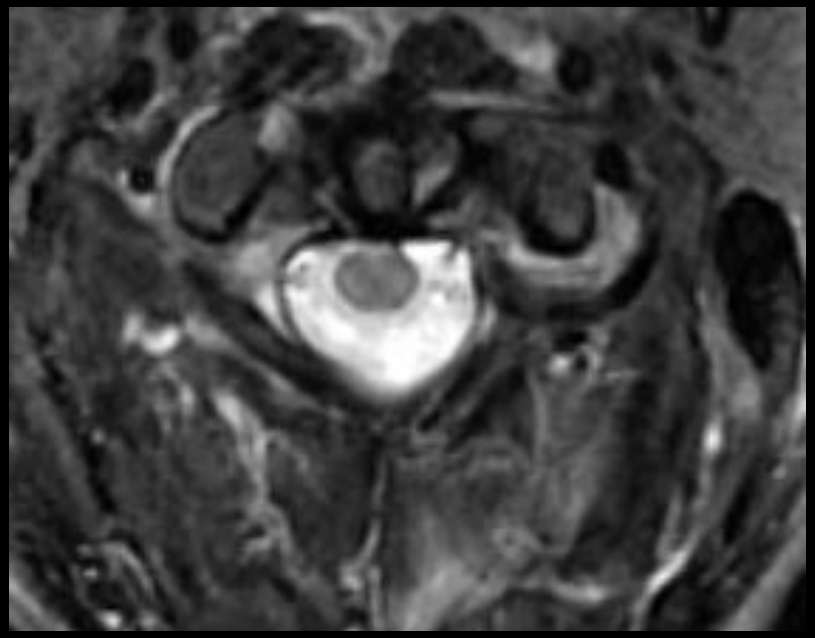
Jefferson Fracture: CT

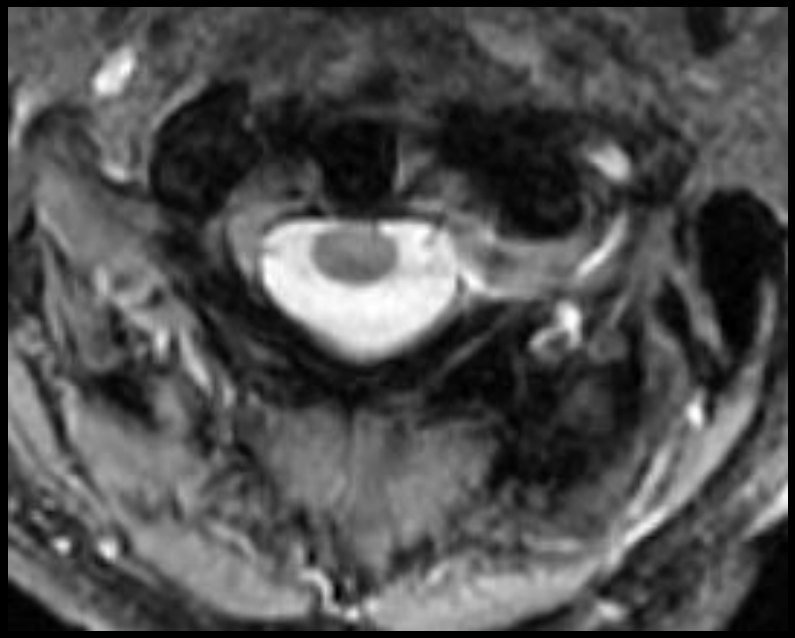
Jefferson Fracture: STIR

- Prevertebral edema
- Intact cord
- Edema within the interspinous ligament

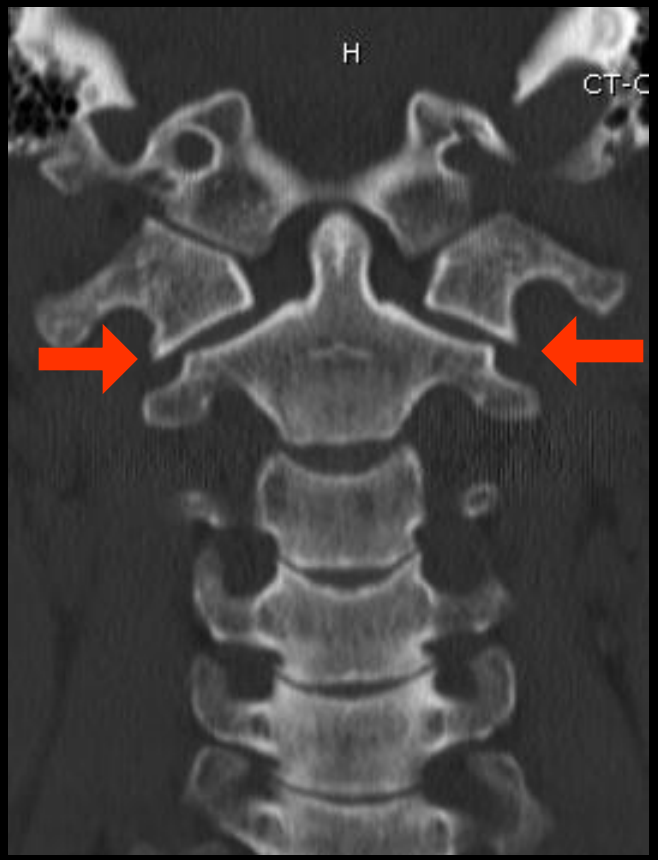
Jefferson Fracture: T2 & GRE

Intact transverse ligament



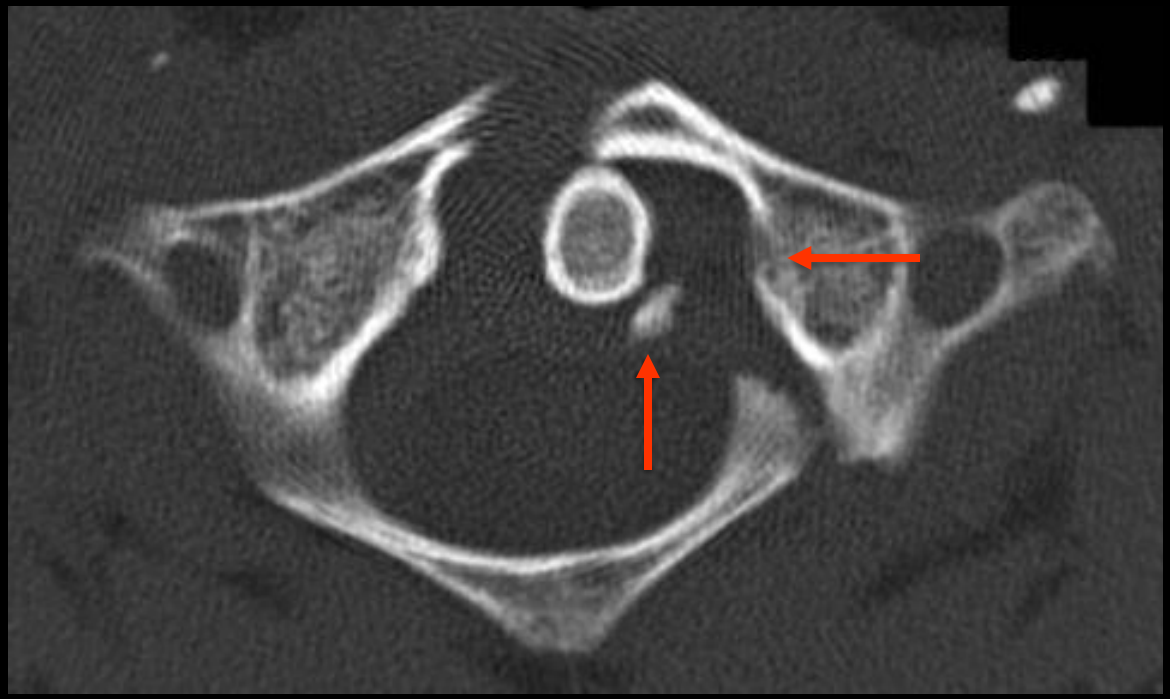


Jefferson Fracture: CT



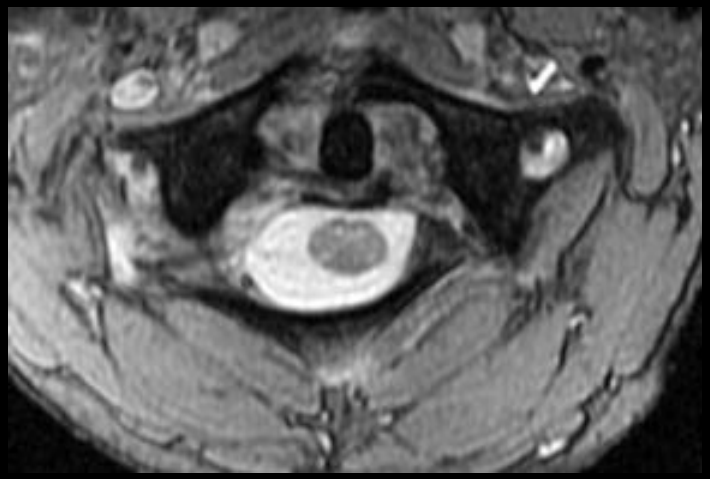
Jefferson Fracture: CT

Avulsed left tubercle?



Jefferson Fracture: GRE

Injury to the transverse ligament

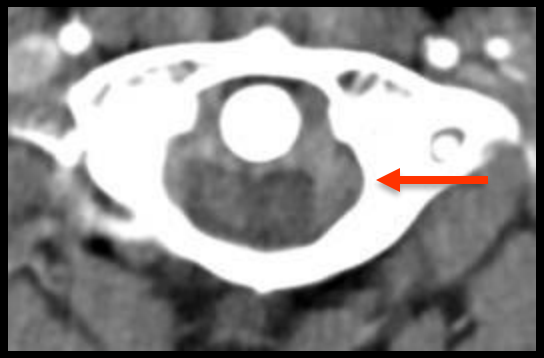


Wrestling Injury: CT

Widened pre dental space with a “V sign”

Injured transverse ligament?

Epidural hematoma?

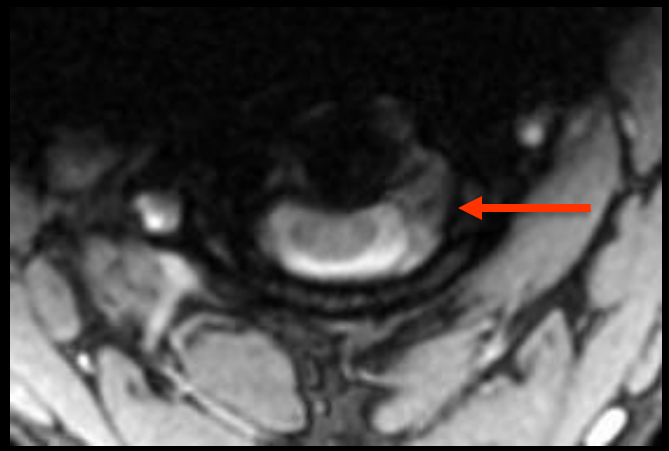


Wrestling Injury: MR

Interspinous ligament injury

Transverse ligament disruption

Epidural hematoma



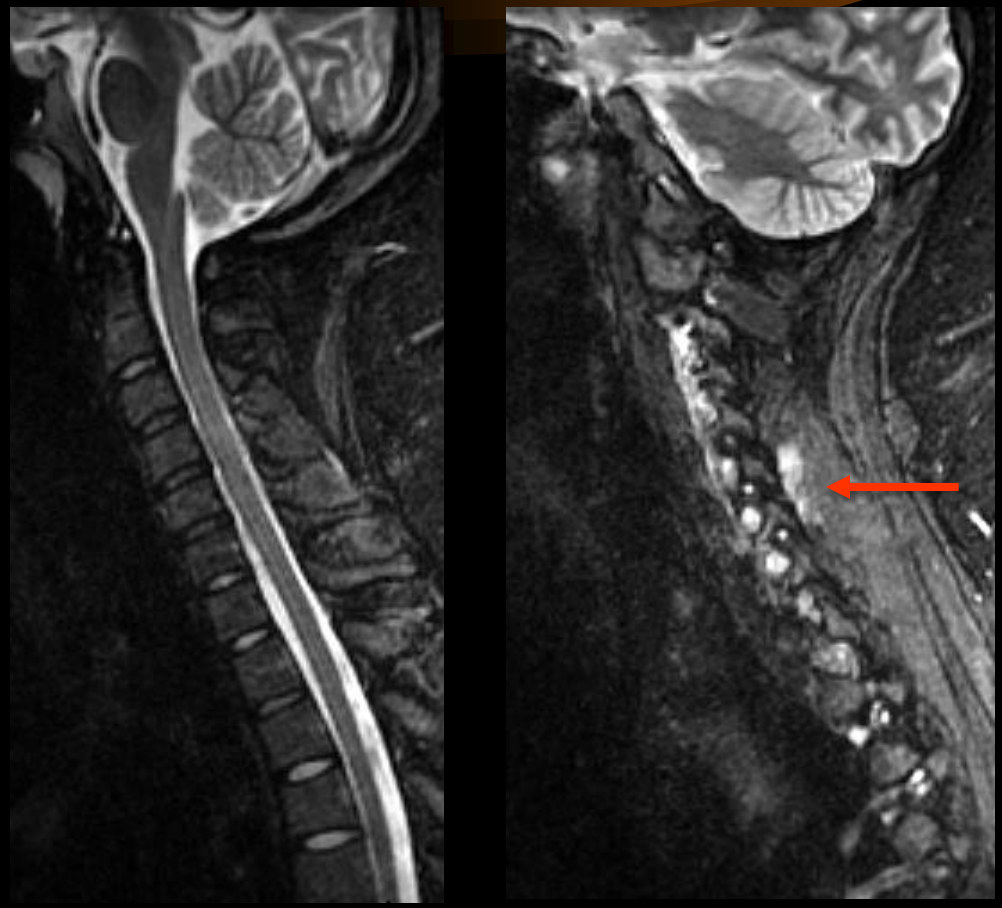
“Midline Tenderness”: CT

No fracture, loss of lordosis

“Midline Tenderness”: STIR

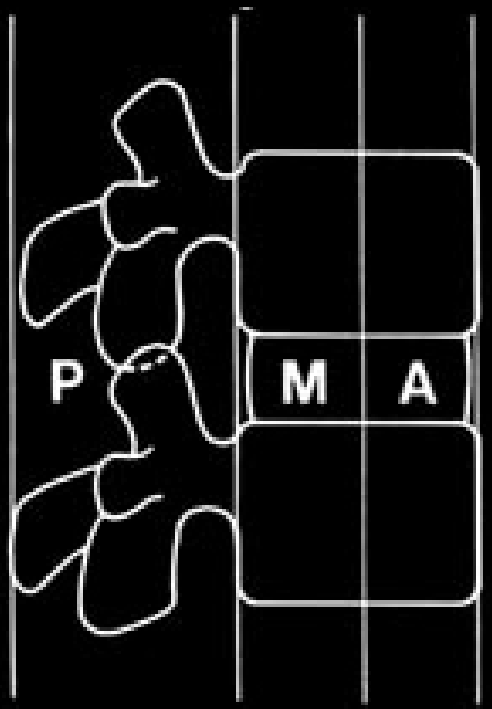
Ligaments are intact “black line”

Small perispinal muscular injury



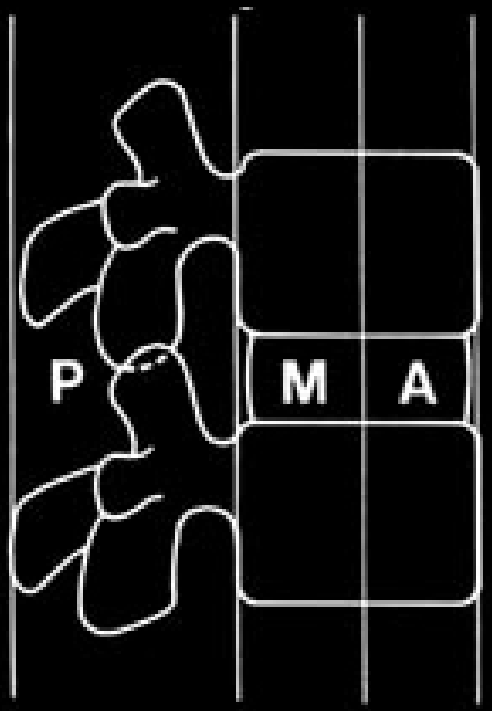
Three Column Model

- Anterior column
  - Anterior vertebral body
  - Anterior disc annulus
  - Anterior longitudinal ligament (ALL)



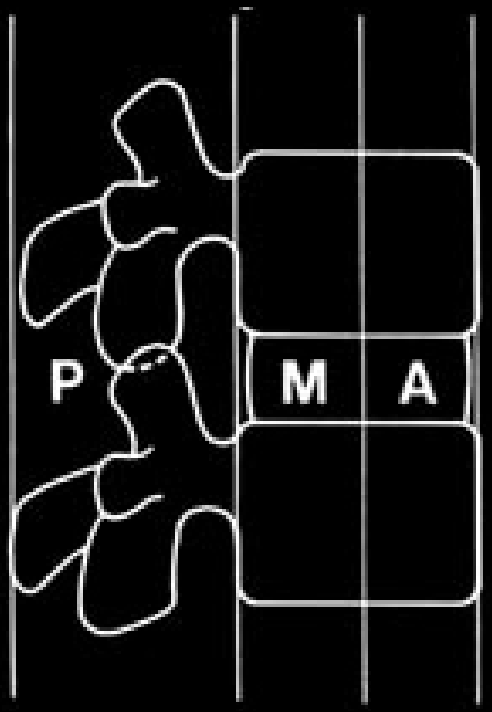
Three Column Model

- Middle column
  - Posterior vertebral body
  - Posterior disc annulus
  - Posterior longitudinal ligament (PLL)



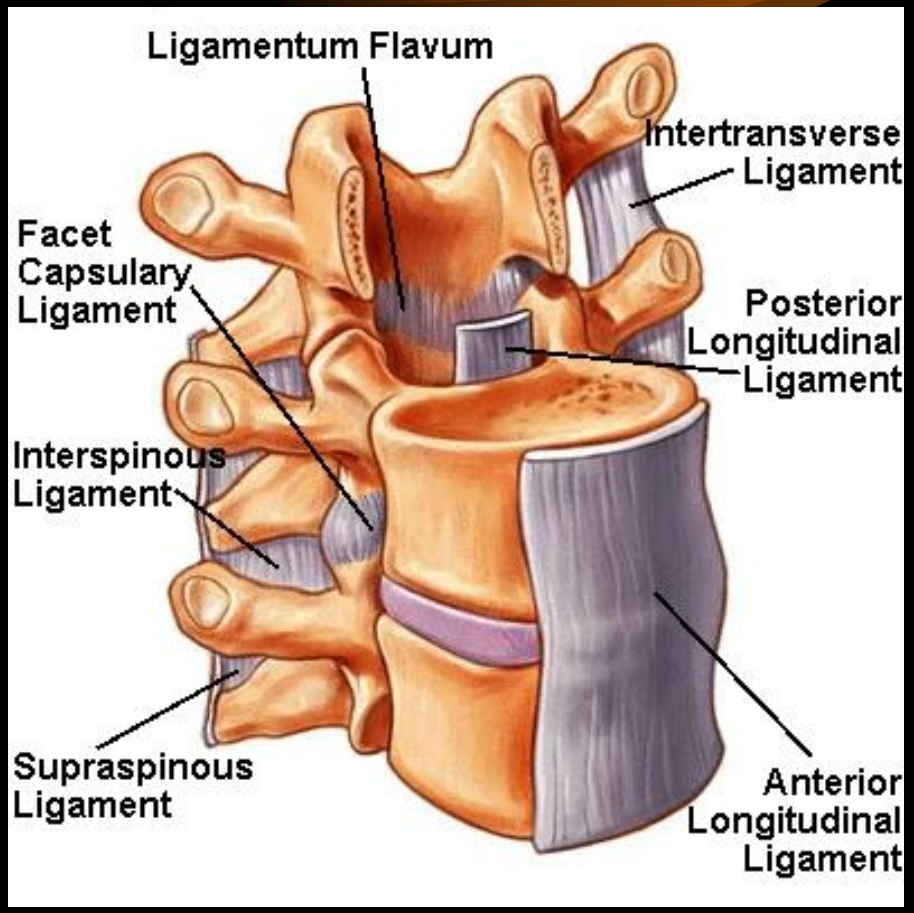
Three Column Model

- Posterior column
  - Pedicles
  - Facet joints
  - Laminae
  - Ligamentum flavum
  - Spinous processes
  - Interspinous ligament



Ligaments

- Posterior ligamentous complex (PLC) = ligamentum flavum + interspinous ligament



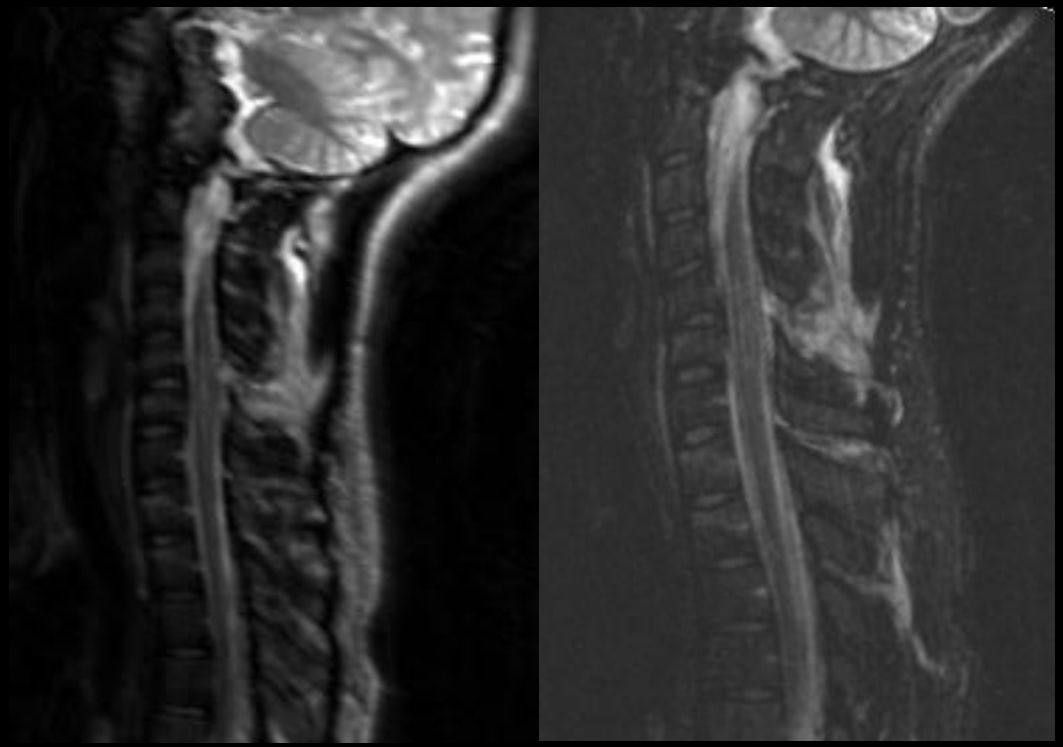
Birdwell, Keith. Health Central (2019)

Flexion Injury: 1 of 4

- Suspect injury of the posterior ligamentous complex
- Widened interspinous distance

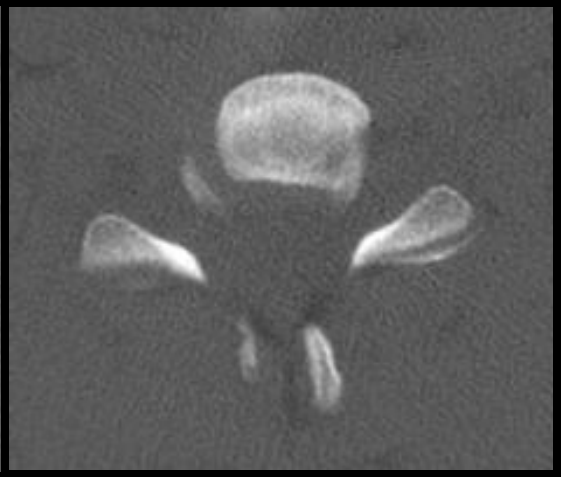
Flexion Injury: T2 & STIR

- Injury of the posterior ligamentous complex (PLC)
- Multilevel cord edema



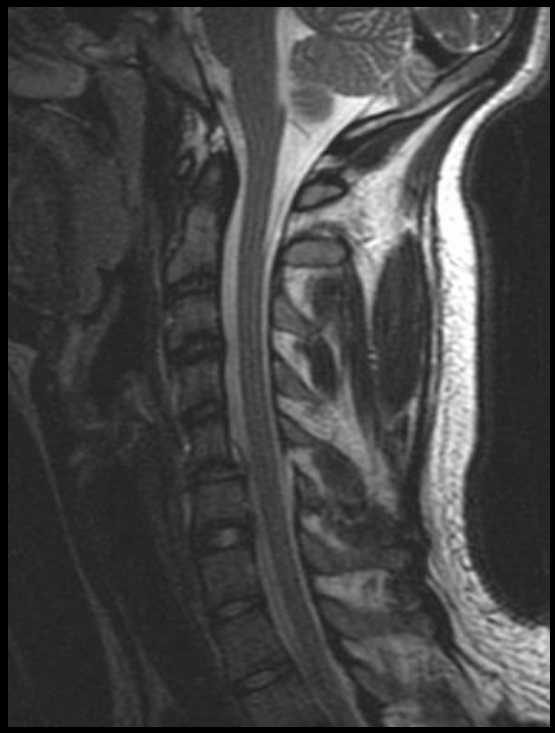
Flexion Injury: 2 of 4

- Hyperflexion and anterior subluxation
- Stable vs. unstable



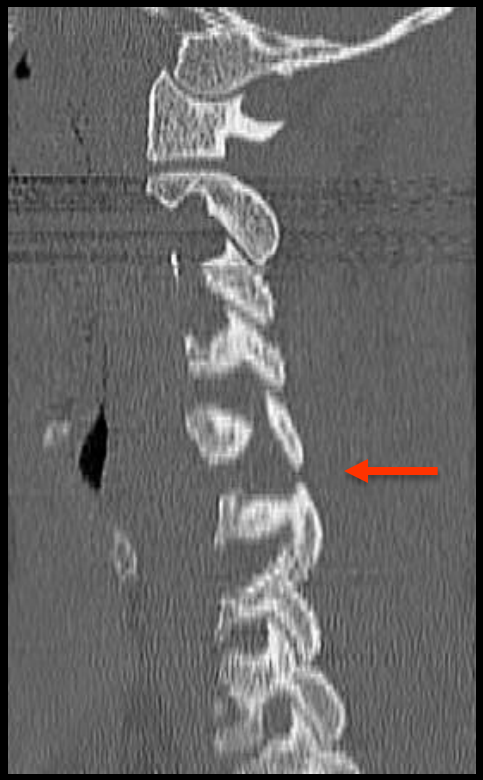
Flexion Injury: STIR & T2

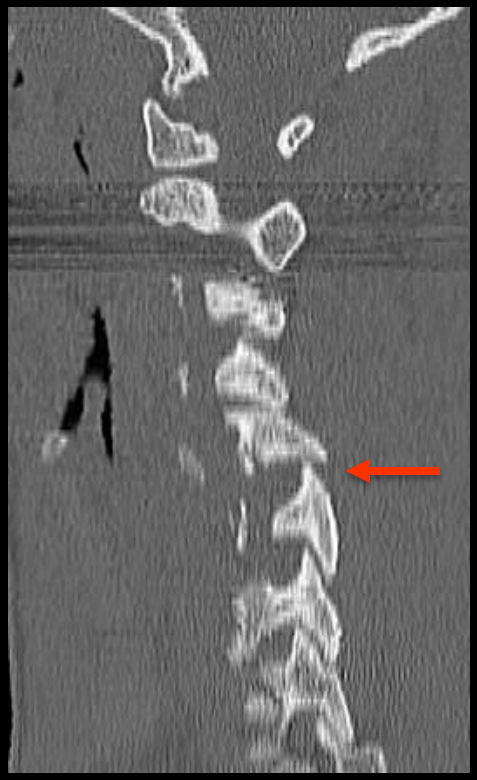
- STIR and FSE T2 show PLL & PLC disruption & normal cord



Flexion Injury: 3 of 4

- Anterior subluxation, bilateral perched facets





Flexion Injury : STIR

- STIR shows abnormal cord signal consistent with edema at one level
- Bilateral facet disruptions are strongly associated with cord injury

Flexion Injury : GRE

- GRE shows no cord hemorrhage
- Intermediate prognosis

Bozzo A et al.
J. Neurotrauma 28:1401-1411 (2011)

Flexion Injury: 4 of 4

Flexion Injury:T2, STIR, GRE

Cord edema, ligament injury, no hemorrhage

ASIA Impairment Scale

- American Spinal Injury Association (ASIA)

- A = complete sensory & motor deficit
- B = sensory preserved, motor deficit
- C = incomplete > 50% motor deficit
- D = incomplete < 50% motor deficit
- E = normal sensory and motor

Cord Injury: MR Prediction

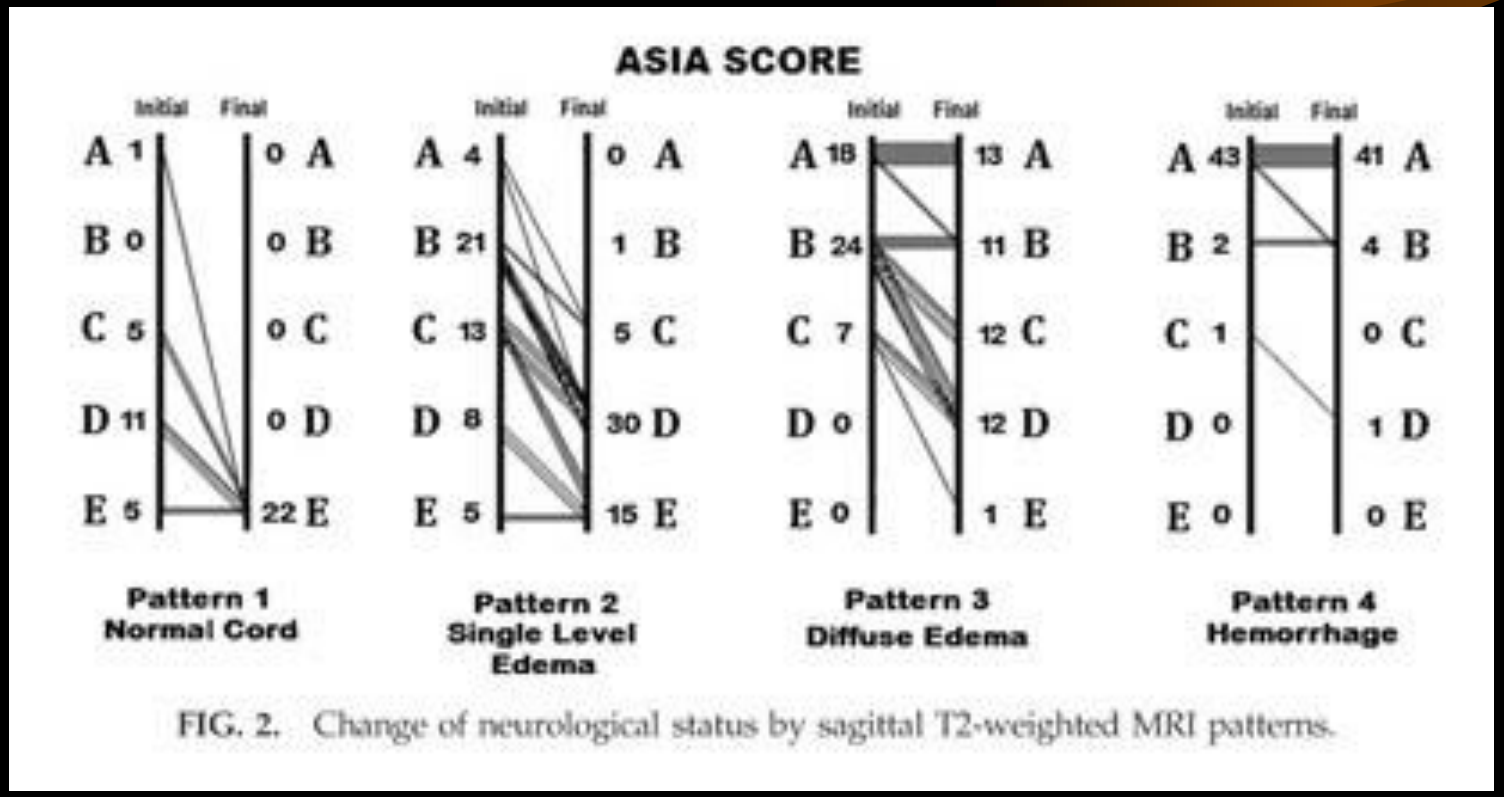


FIG. 2. Change of neurological status by sagittal T2-weighted MRI patterns.

Bozzo A et al. J. Neurotrauma 28:1401-1411 (2011)

Trauma: CT

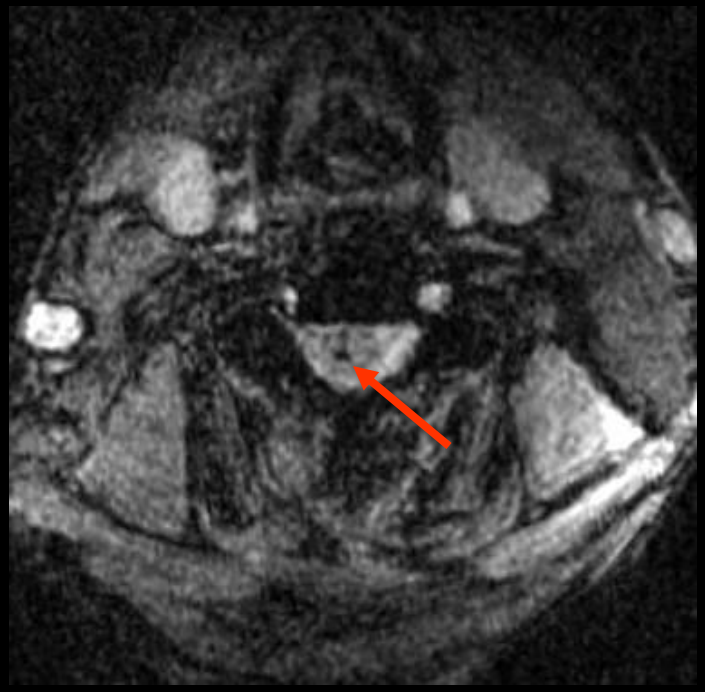
- Disruption at C4-C5 anterior osteophytes
- Acute vs. chronic
- Difficult to scan

Trauma: STIR

- Scan in body coil
- Disruption of anterior longitudinal ligament
- Acute injury

Trauma: GRE

- Cord hemorrhage
- Poor prognosis



Spine Trauma: CT

- No obvious fracture
- Prevertebral STS
- Abnormal neurologic exam

Spine Trauma: STIR & GRE

- No obvious fracture
- Cord swelling & edema
- Abnormal GRE signal

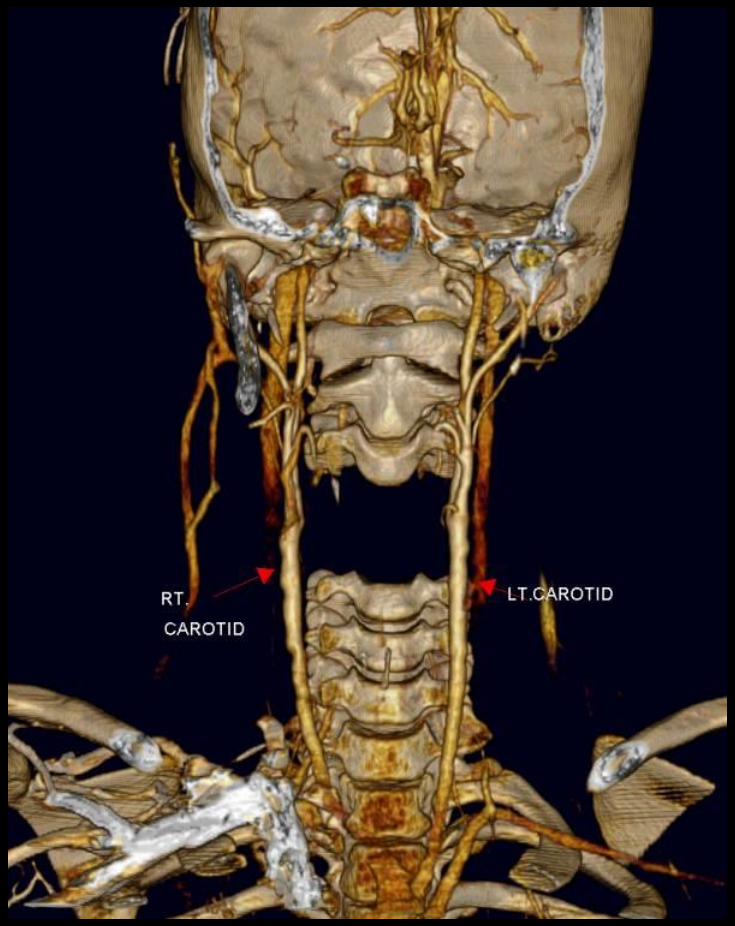
Spine Trauma: 6 months

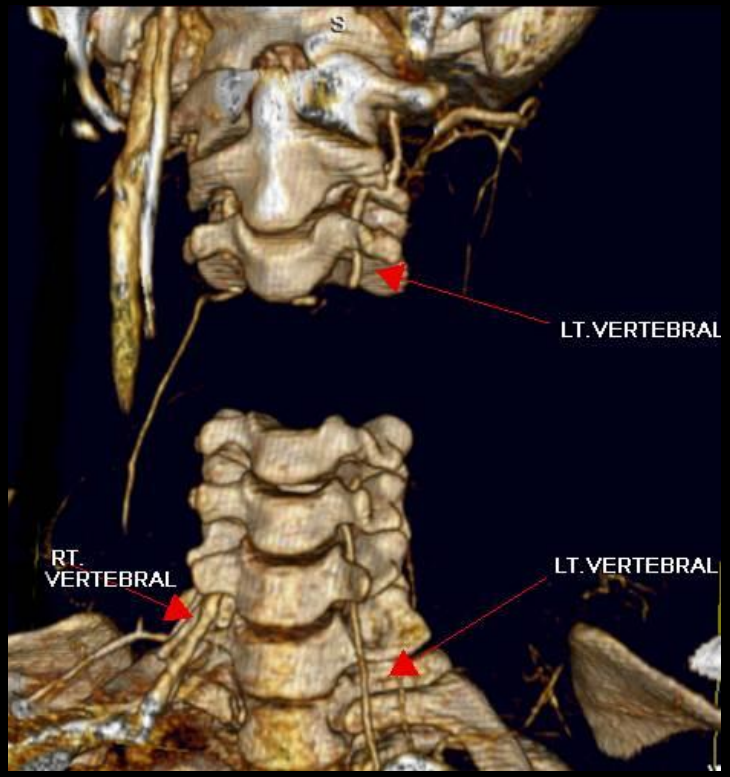
- Post op decompressive laminectomy
- T1 & T2 show cystic myelomalacia

Distraction Injury

- Three column injury: clearly unstable
- Need to evaluate neck vessels
- Need to evaluate the cord

Distraction Injury





Distraction Injury: GRE & STIR

Cord transection

Spine Trauma: CT

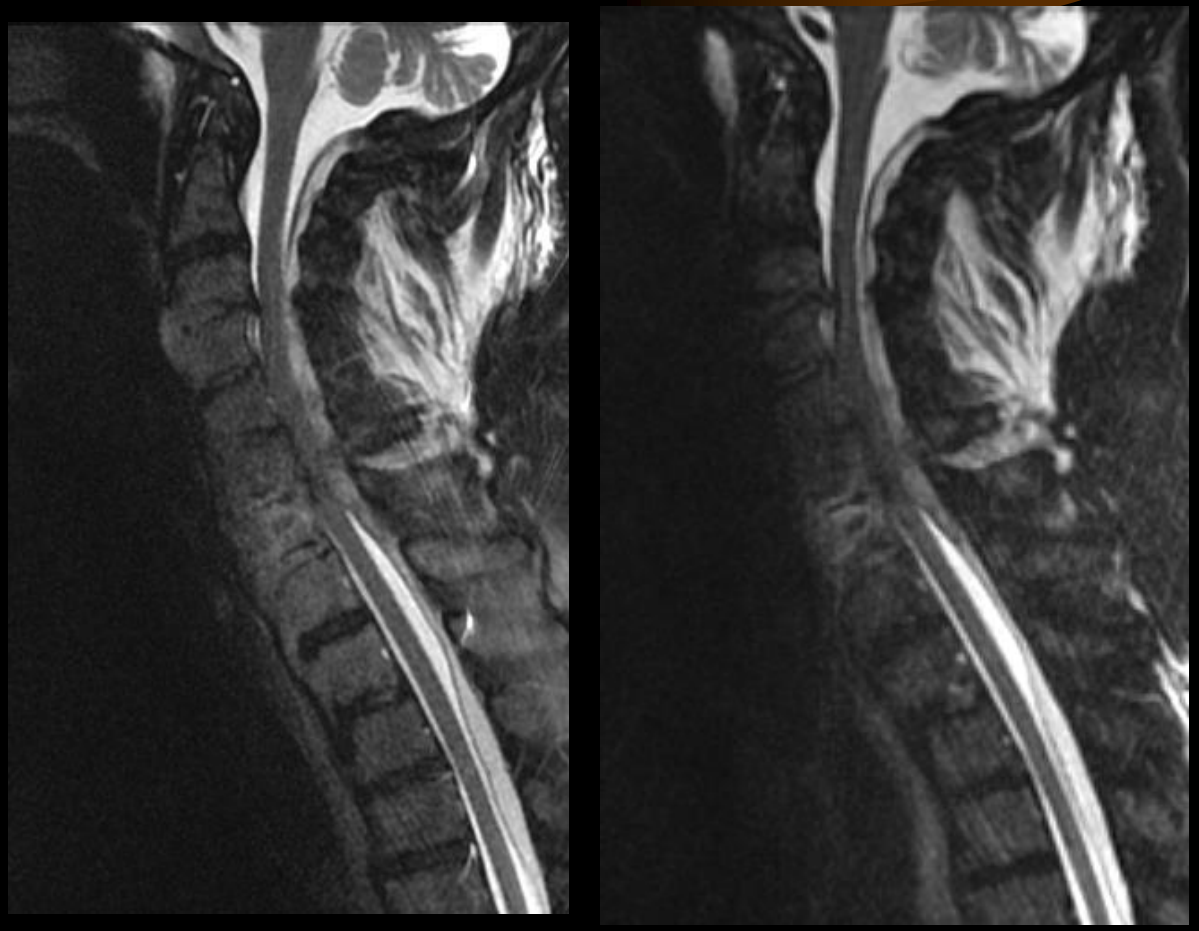
- DISH
- Fracture of C7?
- Acute vs chronic?
- Cord injury?

Spine Trauma: T2(FS), STIR

Cord is displaced anteriorly by EDH

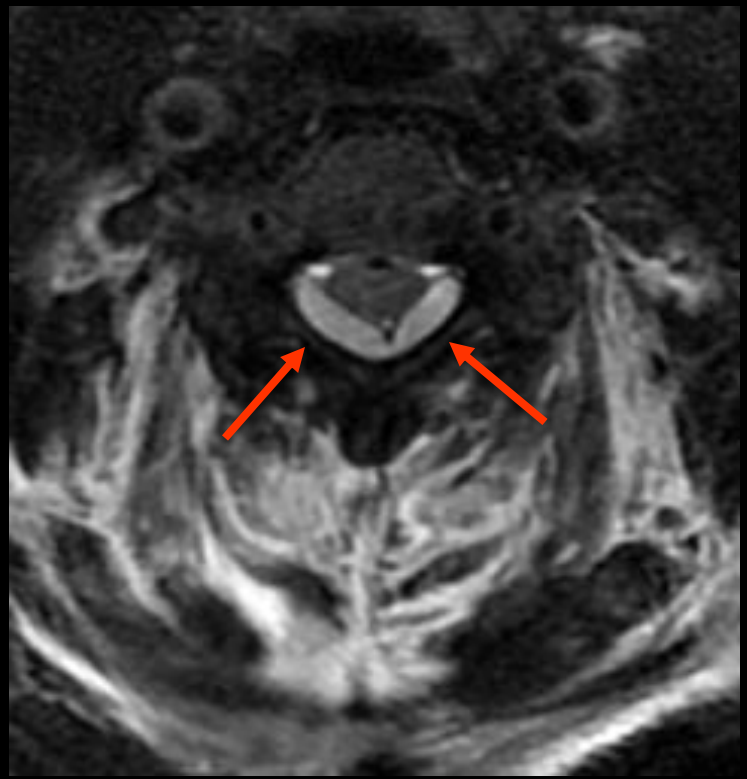
C7 fracture

PLC injury



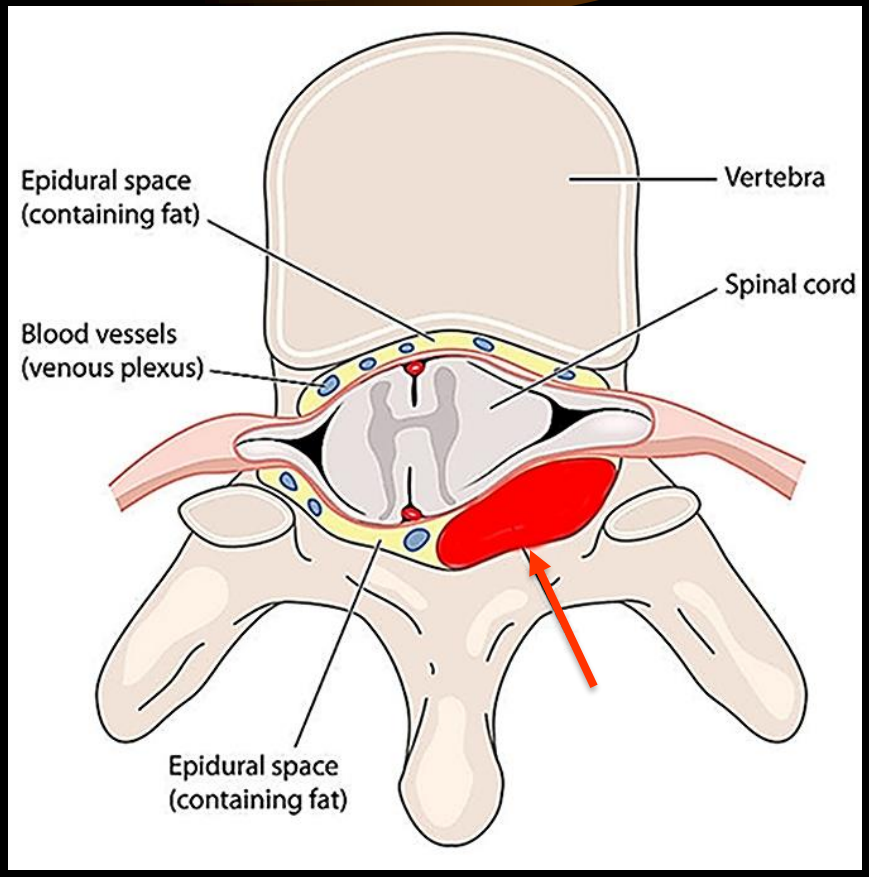
Spine Trauma: T2

- DISH
- Acute C7 fracture
- Cord displaced anteriorly by epidural hematoma (EDH)



Spinal Epidural Collection

- Epidural collection distorts the thecal sac and displaces the spinal cord.



Tetsuka S et al. JMA J 3:29-40 (2020)

Spine Trauma: CT

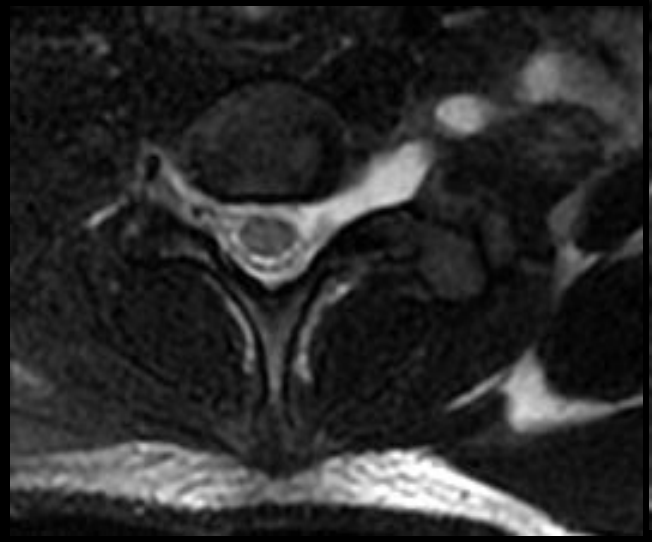
- Narrowing of C5-6 interspace?
- Young patient without obvious DJD
- Abnormal neurologic exam

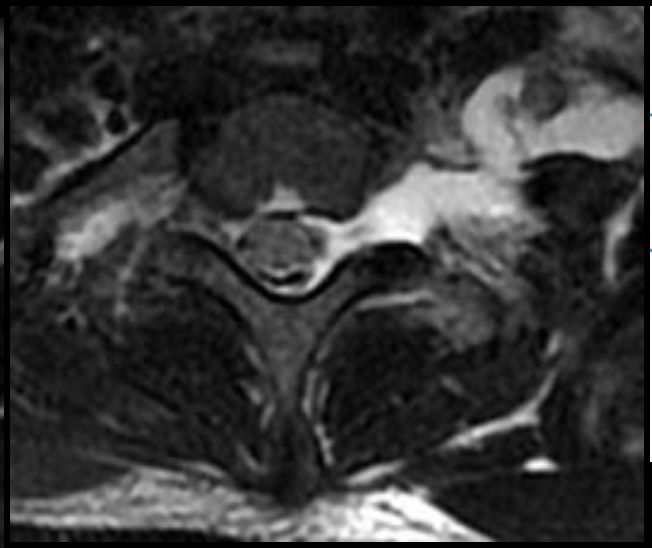
Spine Trauma: T2 & STIR

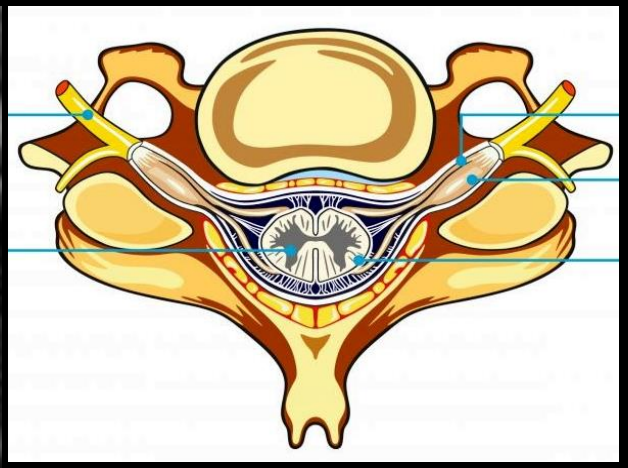
- C5-6 HNP
- No fracture
- Cord edema
- PLC injury

Cervical Traction Injury: T2

- Two level nerve root avulsions
- Tear of dural sleeve
- CSF leak



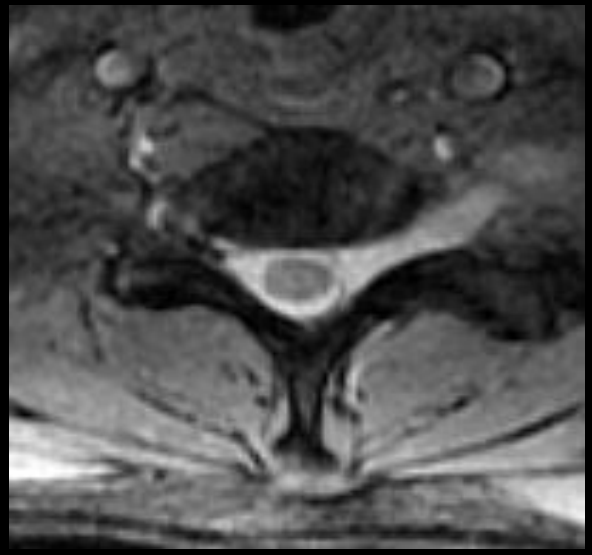


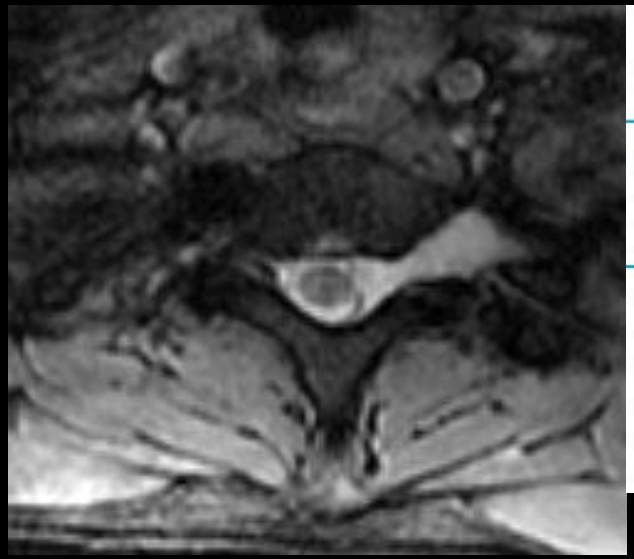


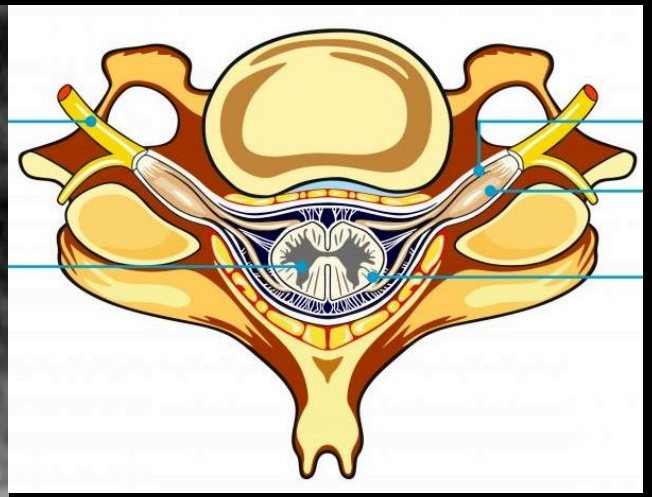
Medical News Today

Cervical Traction Injury: GRE

- Two level nerve root avulsions
- Tear of dural sleeve







Medical News Today

DTI of Cord Injury

- At the site of acute, non hemorrhagic cord injury, reduction in FA was strongly correlated with ASIA motor score.
- DTI of the spinal cord, including fiber tracking and FA measurements, are more technically challenging than similar measurements in the brain.

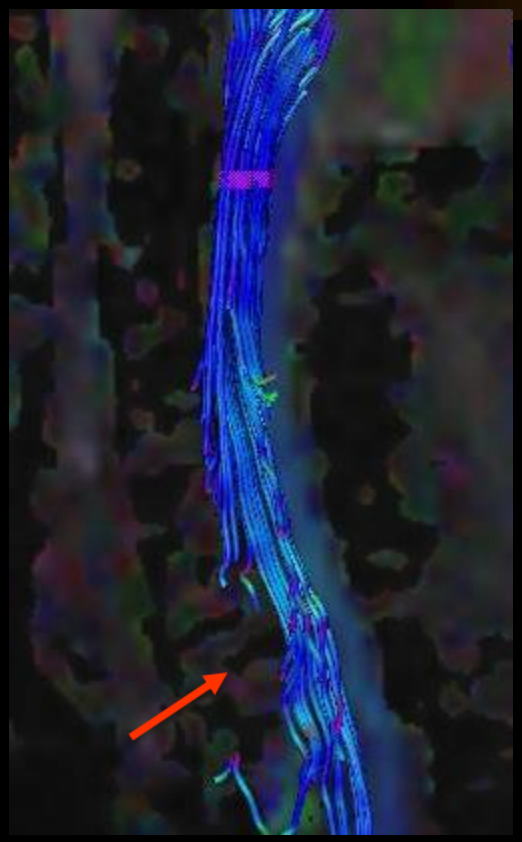
Cheran et al, J. Neurotrauma 2010
Kamble et al, Indian J. Radiol. Imaging 2011

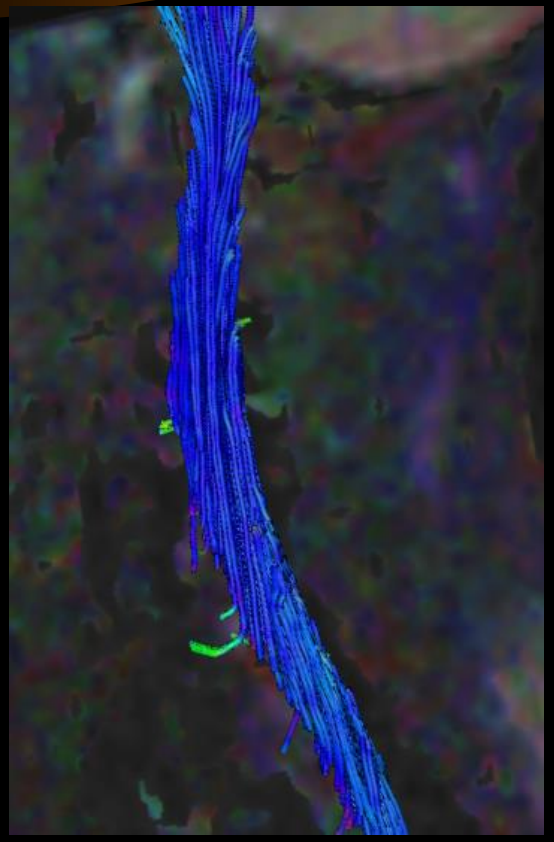
Cord Injury: STIR & GRE

- Injury of the posterior ligamentous complex (PLC)
- Cord edema
- Small cord hematoma
- Vertebral fxs

DTI: Fiber Tracking

- Cord injury patient with fiber tract disruption (red arrow) vs. normal





Learning Objectives

- Consider how to image spinal trauma
- Review basic cervical spine anatomy introducing the concept of stability
- Create an approach for CT interpretation
- Discuss the advantages of obtaining MR
- Illustrate the CT and MR appearance of various spine injuries i.e., a case-based approach

How to Image: MR Sequences

- Sagittal T2
  - Best for cord injury
- Sagittal STIR
  - Best for ligament/osseous injury
- Sagittal or Axial GRE
  - Best for cord hemorrhage

MR: Ligamentous Stability

- Prefer STIR or T2 (FS)
- Solid “black line” = intact
- Increased SI = injury
  - Not necessarily torn (sprain)
- Discontinuous structure = torn
  - Potentially unstable

Spine Trauma: MR Advantages

- Cord injury
  - Edema, hemorrhage, transection
- Epidural hematomas
- Ligamentous injury
- Fracture
  - CT is more sensitive
  - Differentiate remote from acute fx
- Disc extrusions (HNP)
- Nerve root avulsion

Thanks!