

Imaging of Spinal Trauma and Spinal Cord Injury: Cervical Spine



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Thurs Dec 02 8:30-10 AM

RSNA 2004

RC617 Room

OUTLINE

- Conceptual Framework
- Normal Anatomy
- Families of Injuries
- Pitfalls
- Normal Variants
- Emphasis on DX

Cervical Spine Trauma Imaging

WHO?

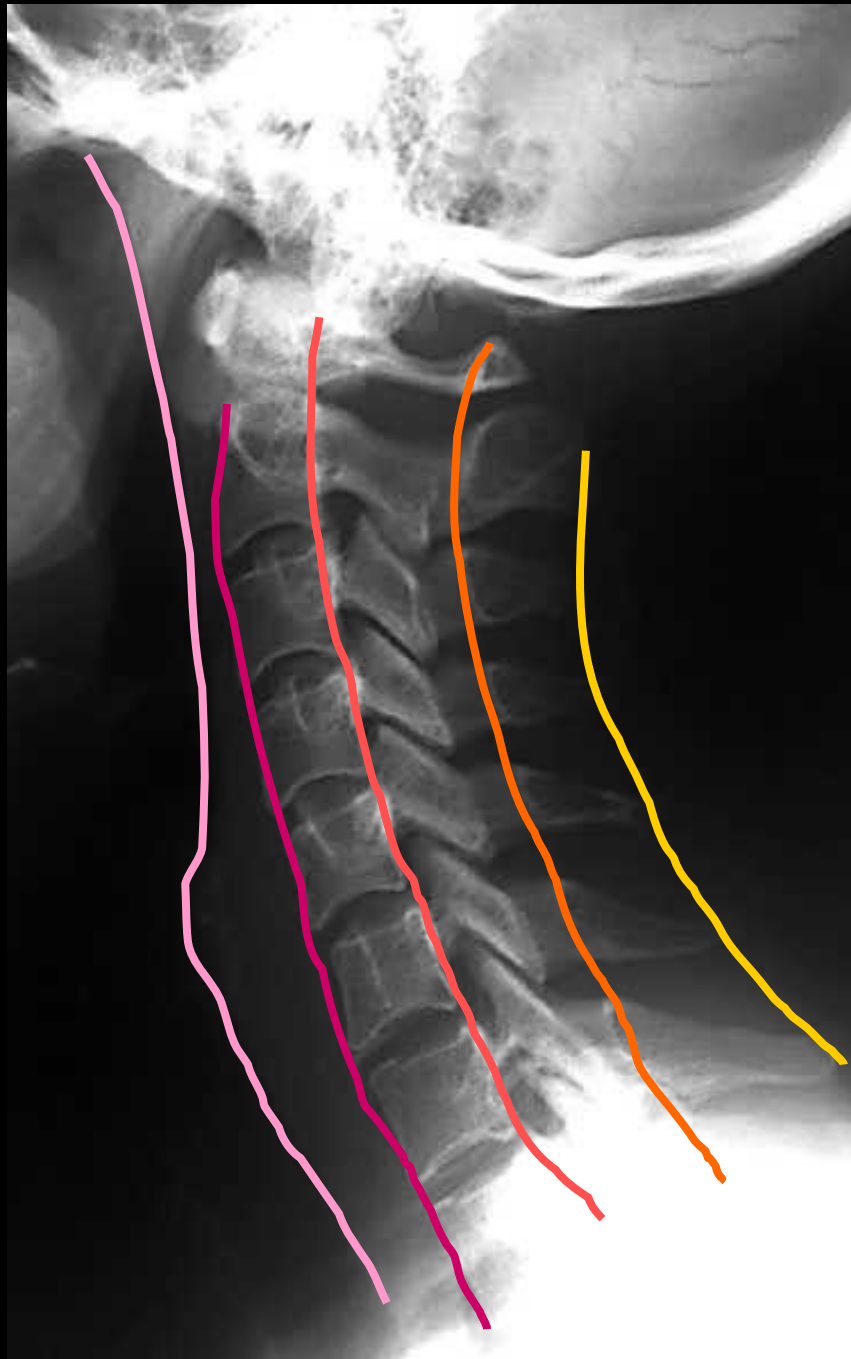
HOW?

WHY?



Lateral

- The axis "ring"
- Intervertebral disc (IVD)
- Facet joint parallelism
- Interspinous distance
- Atlanto-dental interval <3mm
- Prevertebral ST
 - C2 < 7mm, <5mm(peds)
 - C6 < 22mm
 - At C4-C7 < $\frac{3}{4}$ Vert Body
- Essential to evaluate to the C7-T1 level (Swimmers view)



Lateral

- THE FIVE LINES

- Anterior prevertebral soft tissues
- Anterior vertebral body line
- Posterior vertebral body line
- Spinolaminar line
- Spinous process line

The Axis Ring



Anterior arc = junction
cortex C2 body and
pedicle

Upper arc = junction
dens and body

Posterior arc = posterior
cortex C2 body

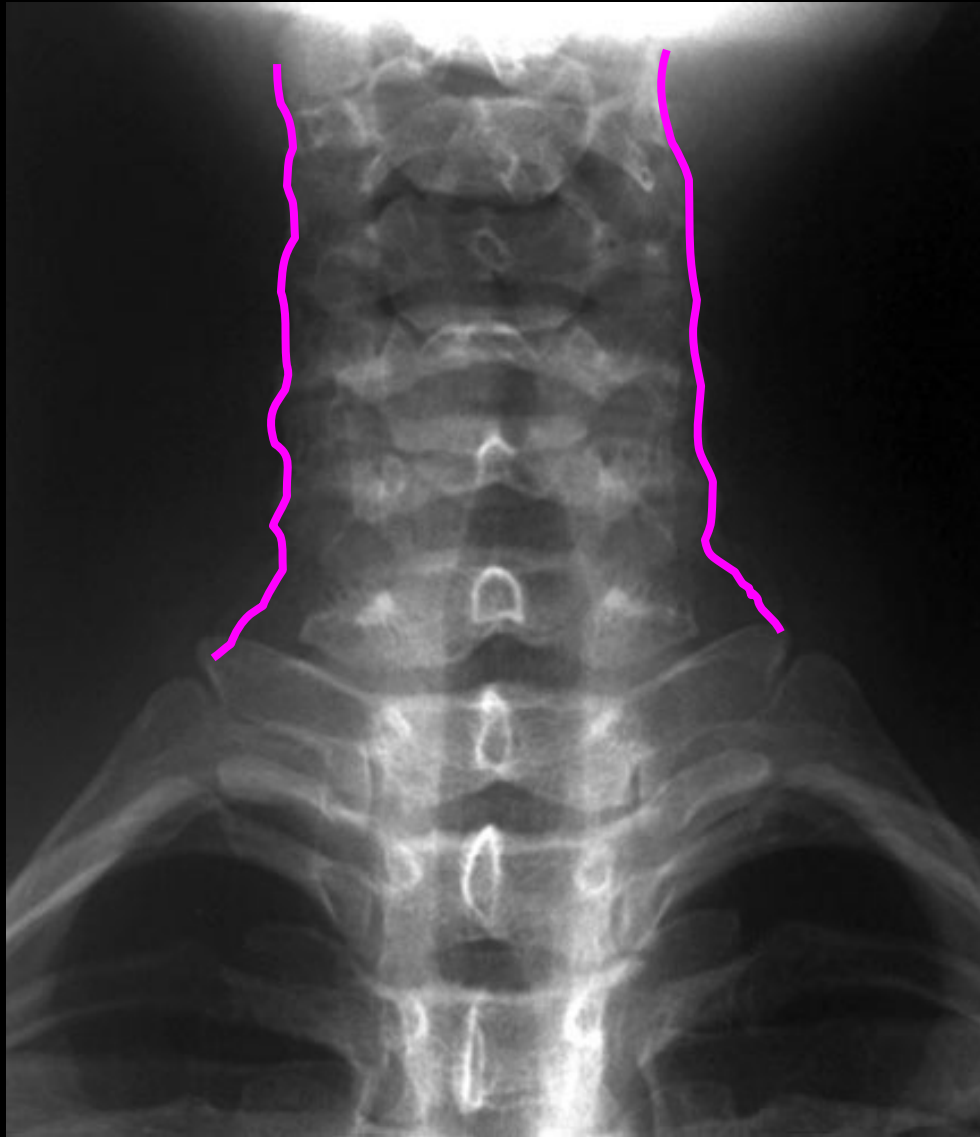
Inferior apex =
transverse process C2



Oblique View

- Neuroforaminal Encroachment
- Contralateral pedicle
- Vertebral body morphology
- Laminae appear as "shingles on a roof"
- Trauma Obliques
 - supine imaging → can appear distorted

AP View

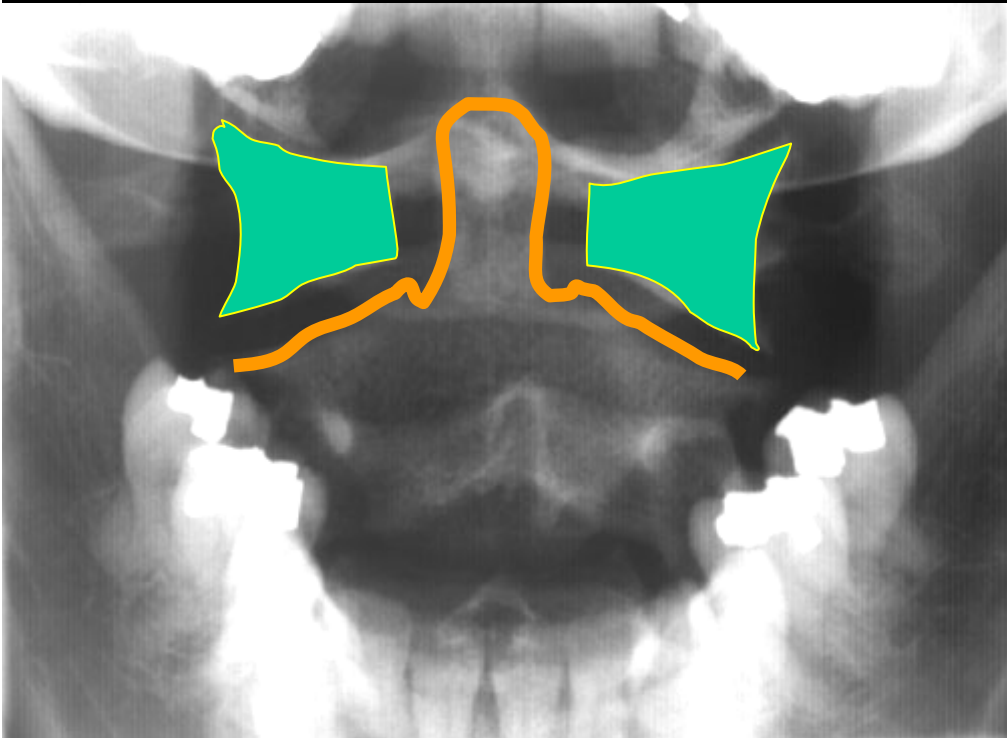


- Visualizes C3 to upper thoracic VB
- Alignment of the spinous processes
 - Bifid may not align
- Smooth alignment of the lateral margins of the articular masses
- Uncovertebral joints
- VB morphology

Bifid Spinous Process



AP Odontoid View



- Atlantooccipital joint
- Atlantoaxial joint
- Odontoid morphology
- Odontoid process position
- Alignment of C1 lateral masses & C2
- Rotation/head tilt - narrowing occurs on side opposite of head movement

C-spine Injuries

Mechanism

- Vector of forces causing injury
- Classification system

Mechanism

- Hyperflexion
- Hyperflexion/Rotation
- Vertical Compression
- Hyperextension
- Hyperextension/Rotation
- Lateral Flexion
- Others

Classification of Acute Cervical Injuries

HYPERFLEXION:

Anterior subluxation (hyperflexion sprain)
Bilateral interfacetal dislocation (BID)
Simple wedge (compression) fracture
Clay Shoveler's (coal shoveler's) fracture
Flexion teardrop fracture

HYPERFLEXION/ROTATION

Unilateral interfacetal dislocation (UID)

HYPEREXTENSION:

Hyperextension dislocation
Avulsion fracture of the anterior arch of the atlas
Fracture of the posterior arch of atlas
Extension teardrop fracture
Laminar fracture
Traumatic spondylolisthesis ("hangman's" fracture)
Hyperextension fracture-dislocation

HYPEREXTENSION/ROTATION

Pillar fracture
Pedicolaminar fracture-separation

VERTICAL COMPRESSION:

Jefferson bursting fracture, C1
Burst (bursting, dispersion, axial loading) fracture, lower cervical spine

LATERAL FLEXION:

Unilateral occipital condylar fracture
Unilateral fracture, lateral mass, C1
Uncinate process fracture
Transverse process fracture

OTHER:

Occipitoatlantal dissociation
 Subluxation
 Dislocation
Odontoid fractures
Torticollis (atlantoaxial rotary displacement or fixation)
Atlantoaxial rotary dissociation
 Subluxation
 Dislocation

Harris and Mirvis

Hyperflexion Injuries

1. Hyperflexion Sprain (Anterior Subluxation)
2. Bilateral Interfacetal Dislocation
3. Simple Wedge Compression fracture
4. Clay Shoveler's fracture
5. Flexion Teardrop fracture

Distraction of posterior elements and compression of the anterior column

Anterior Subluxation (HyperFlexion Sprain)

- Classic "whiplash" injury
 - abrupt deceleration <30mph
 - rear ending a stopped car
- Posterior ligament complex injury
- Posterior anulus fibrosis & disc can be disrupted
- **STABLE, Initially**
 - 21-50% incidence of delayed instability

Anterior Subluxation: Hyperflexion Sprain



- Abrupt focal hyperkyphotic angulation at level injury
- Interspinous and interlaminar spaces widened ("fanning")
- Partial uncovering and loss of congruity of facets
- Increased distance from displaced vertebral body and superior facets
- Disc widened posteriorly and narrowed anteriorly
- Anterior translation (inconstant)

Hyperflexion Sprain: MRI



Bilateral Interfacetal Dislocation (BID)

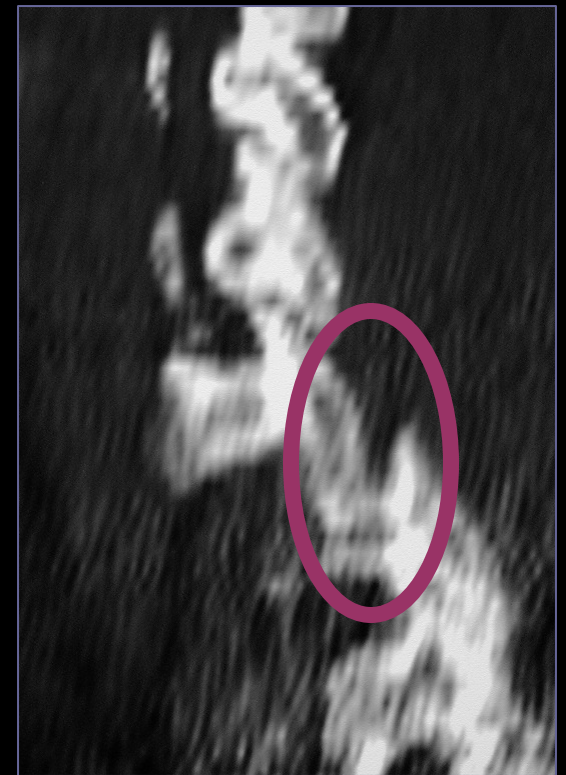
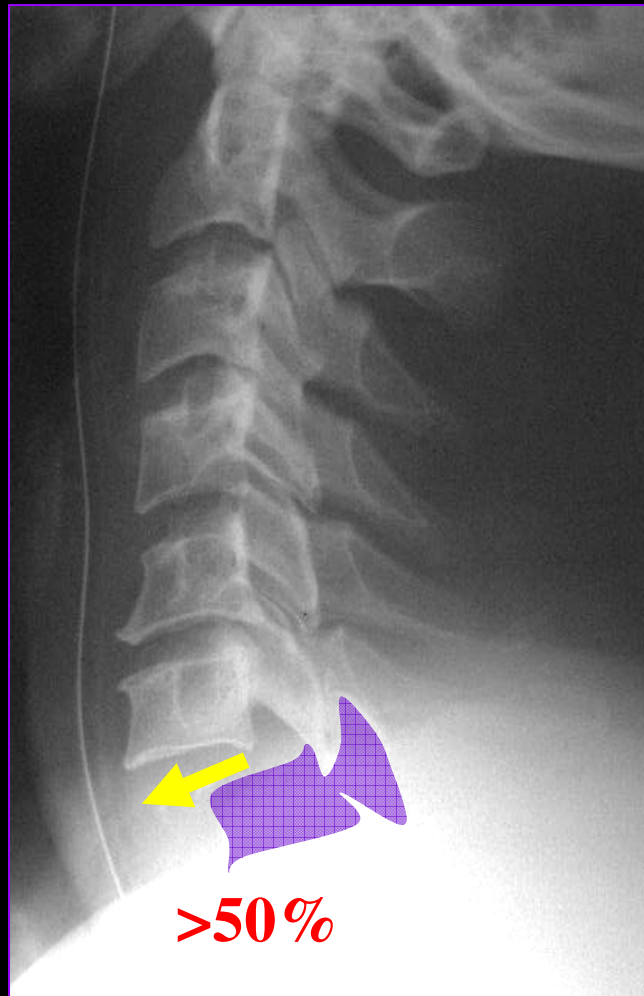
- Soft tissue injury
- Disrupted ALL, PLL, Intervertebral disc and post ligament complex
- Articular masses pass superiorly and anteriorly
- High risk of cord damage
- UNSTABLE

Bilateral Interfacetal Dislocation

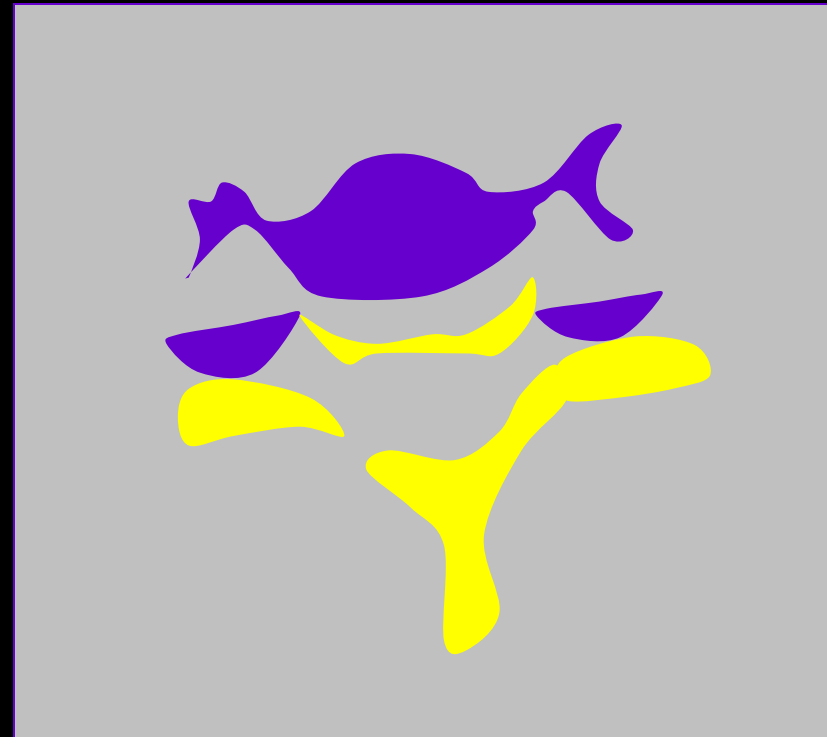
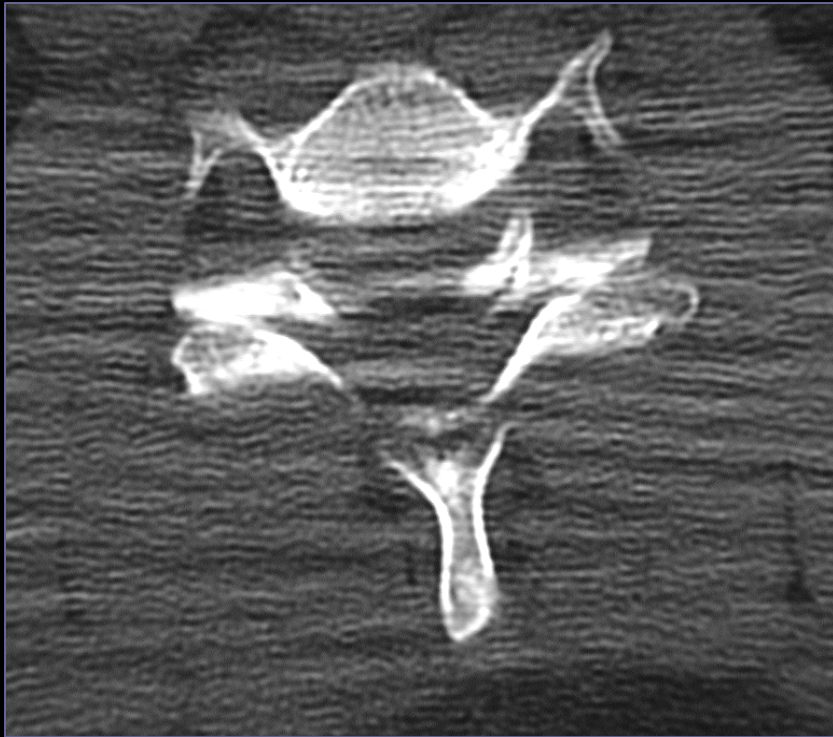


- Anteriorly dislocated VB at least 50% (if complete dislocation)
- Incomplete dislocation
 - <1/2 sublux
 - perched facets
- Impaction fracture fragments small → not clinically significant
- Increased spinous process distance on AP view at level of injury

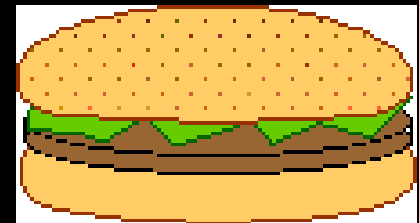
Bilateral Interfacetal Dislocation



Bilateral Interfacetal Dislocation



Inverted Hamburger Bun Sign

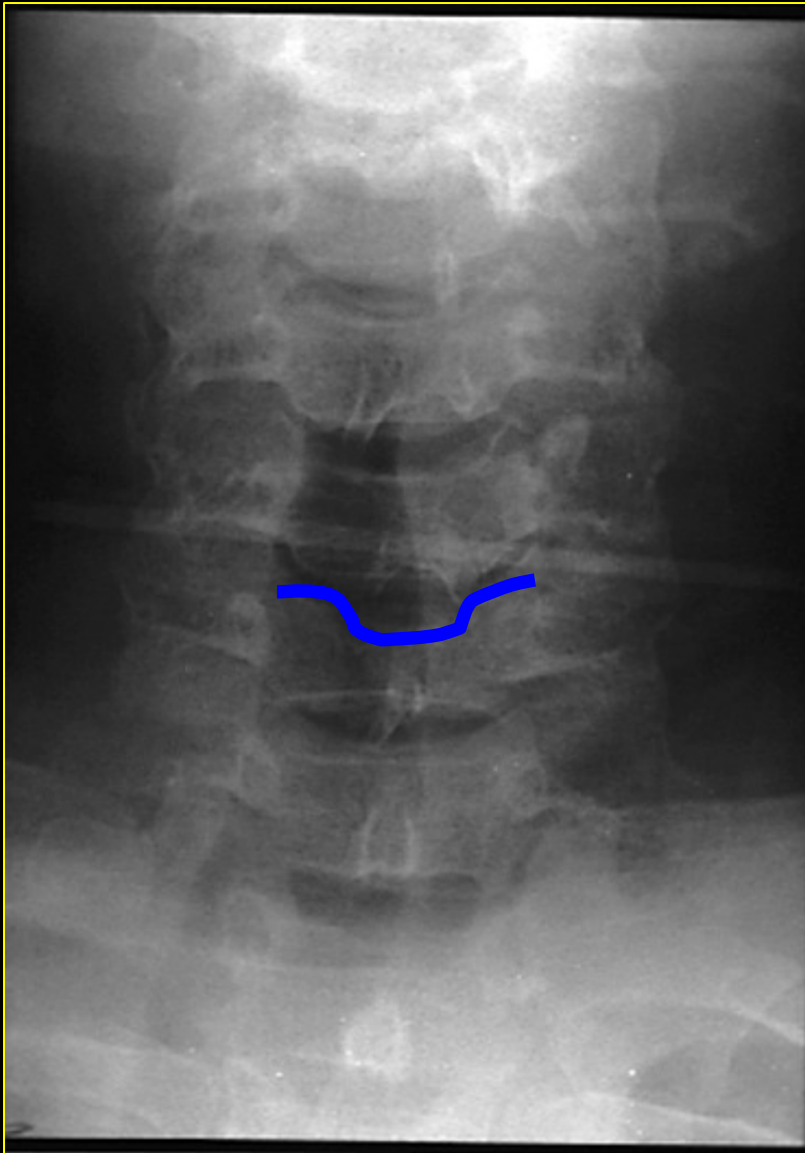




Simple Wedge Compression

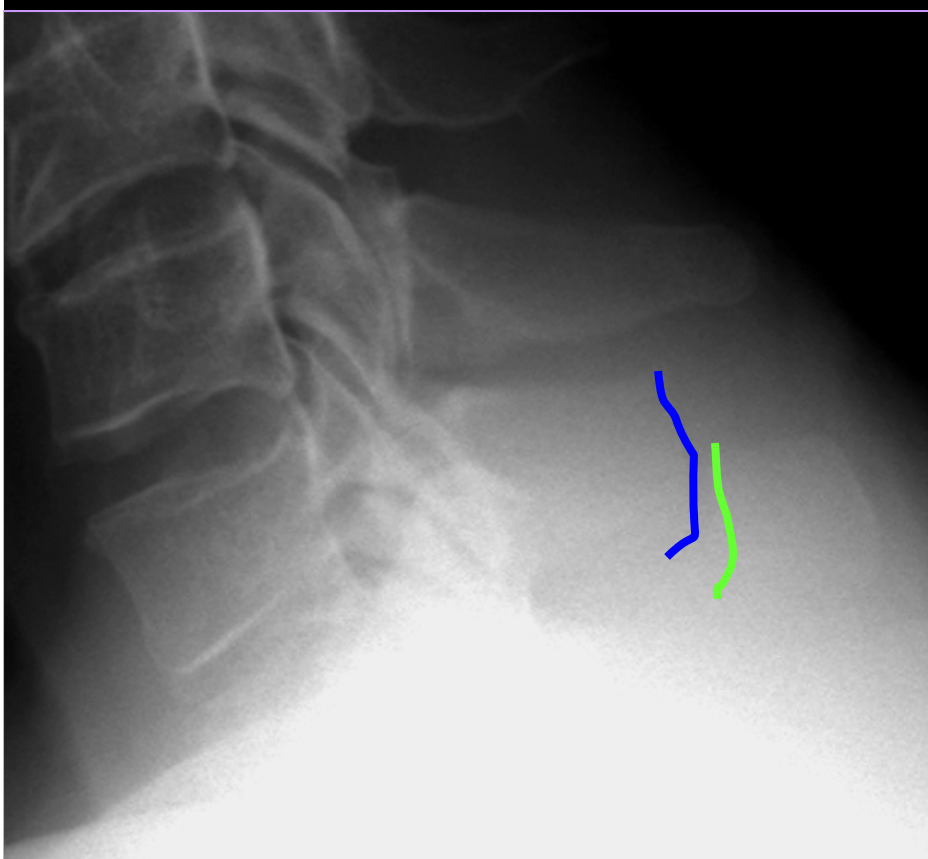
- Mid to lower cervical spine
- Impacted superior endplate
- No vertical fracture
- ALL and disc intact
- initially STABLE, however: delayed instability if post ligament complex is injured and does not heal

Wedge Compression

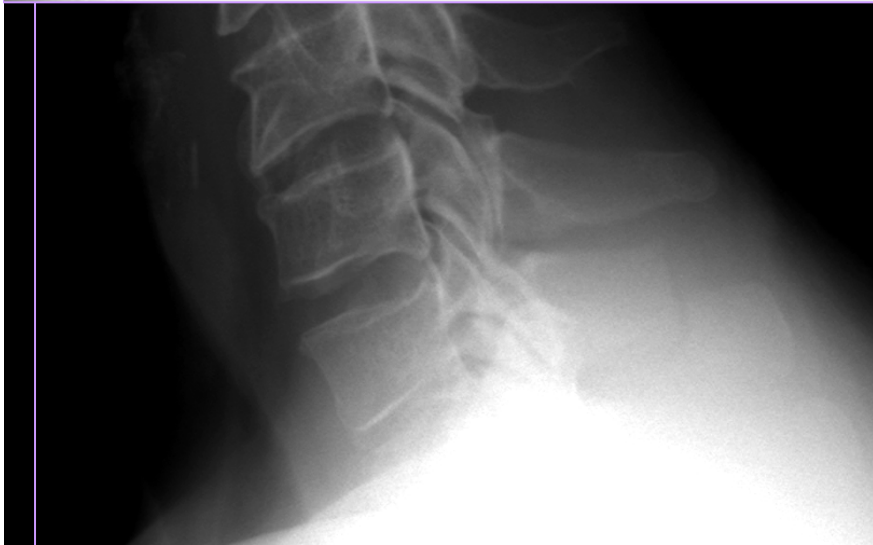


- Decreased anterior VB height
- Possible "fanning" if posterior ligament complex disrupted
- Increased density of superior endplate from impaction
- Angulation of anterior cortical margin of vertebral body

Clay Shoveler's FX



- Forced flexion head and upper cervical spine
- Opposed action of interspinous and supraspinous ligaments
- Oblique avulsion fracture spinous process C7, C6 or T1
- STABLE



Flexion Teardrop Fracture

- Most devastating c-spine injury compatible with life
- Severe flexion with disruption of all ligaments and disc + VB FX
- UNSTABLE

Acute anterior cord syndrome

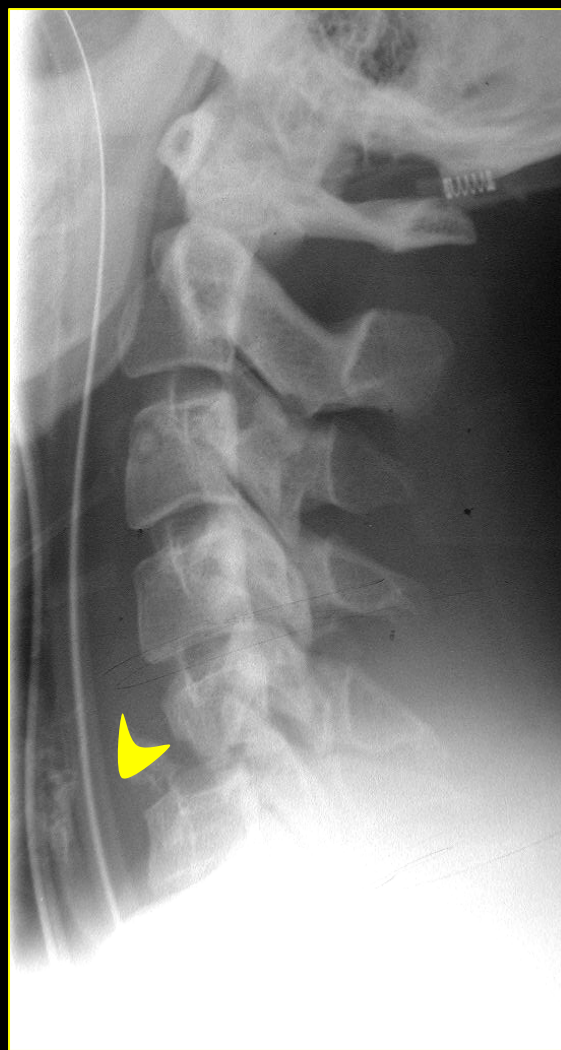
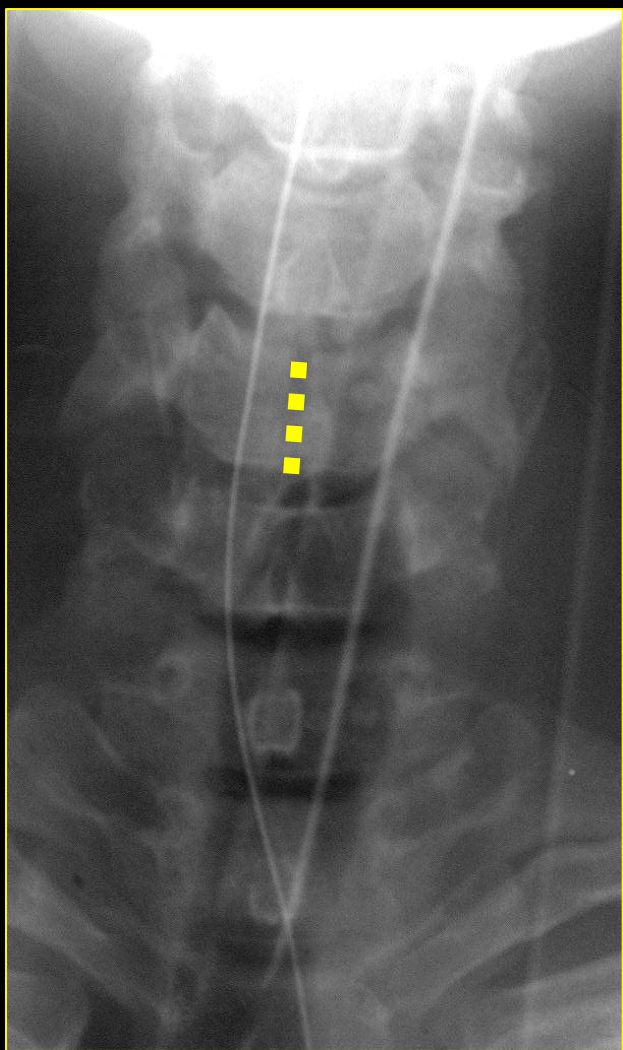
1. Complete paralysis
2. Hypesthesia and hypalgesia to level injury
3. Preservation touch, motion, position and vibration sense

Flexion Teardrop Fracture



- Large triangular fragment of the ant/inf endplate
- Posterior VB → into canal
- Inferior VB rotates and appears shorter in AP dimension
- Facet sublaxed/dislocated
- "fanning" with severe flexion of c-spine
 - Kyphotic deformity at and above level fracture
- Prevertebral STS

Flexion Teardrop Fracture



Flexion Teardrop Fracture

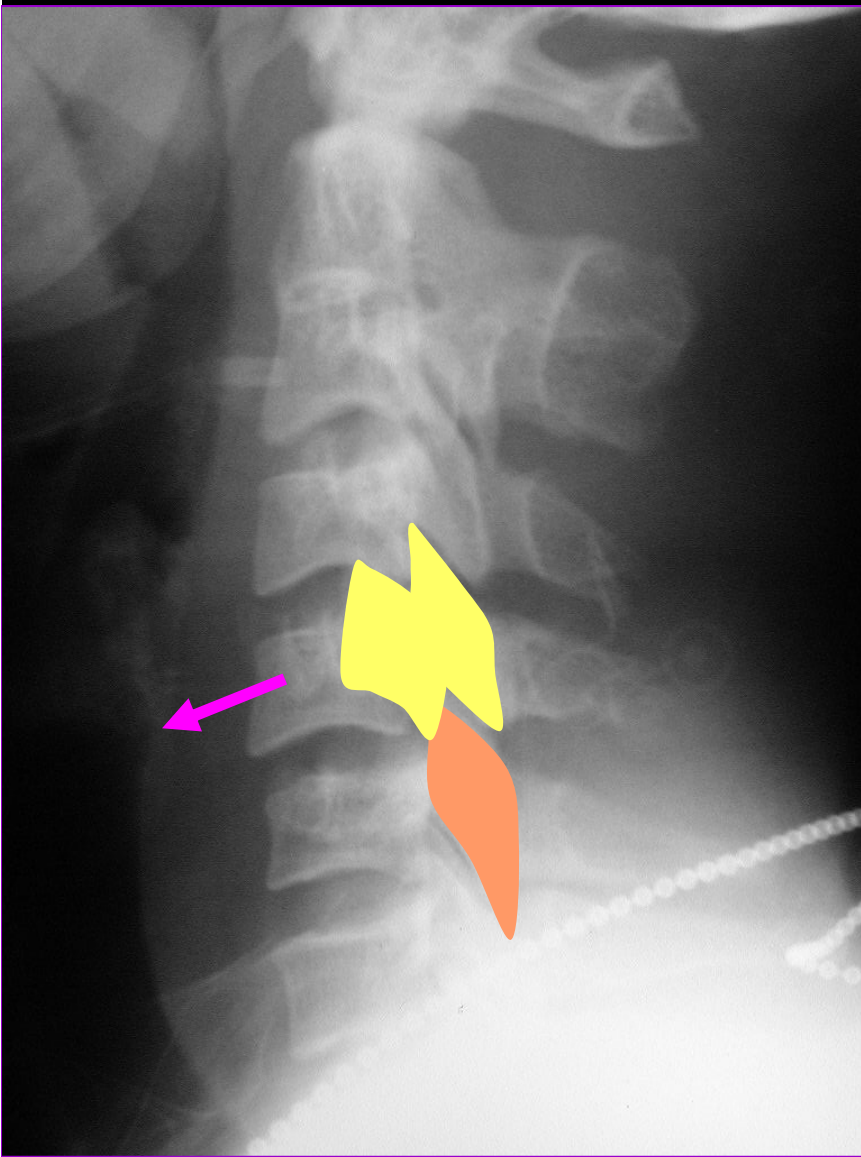


Hyperflexion Injury with Rotation

1. Unilateral Interfacetal Dislocation

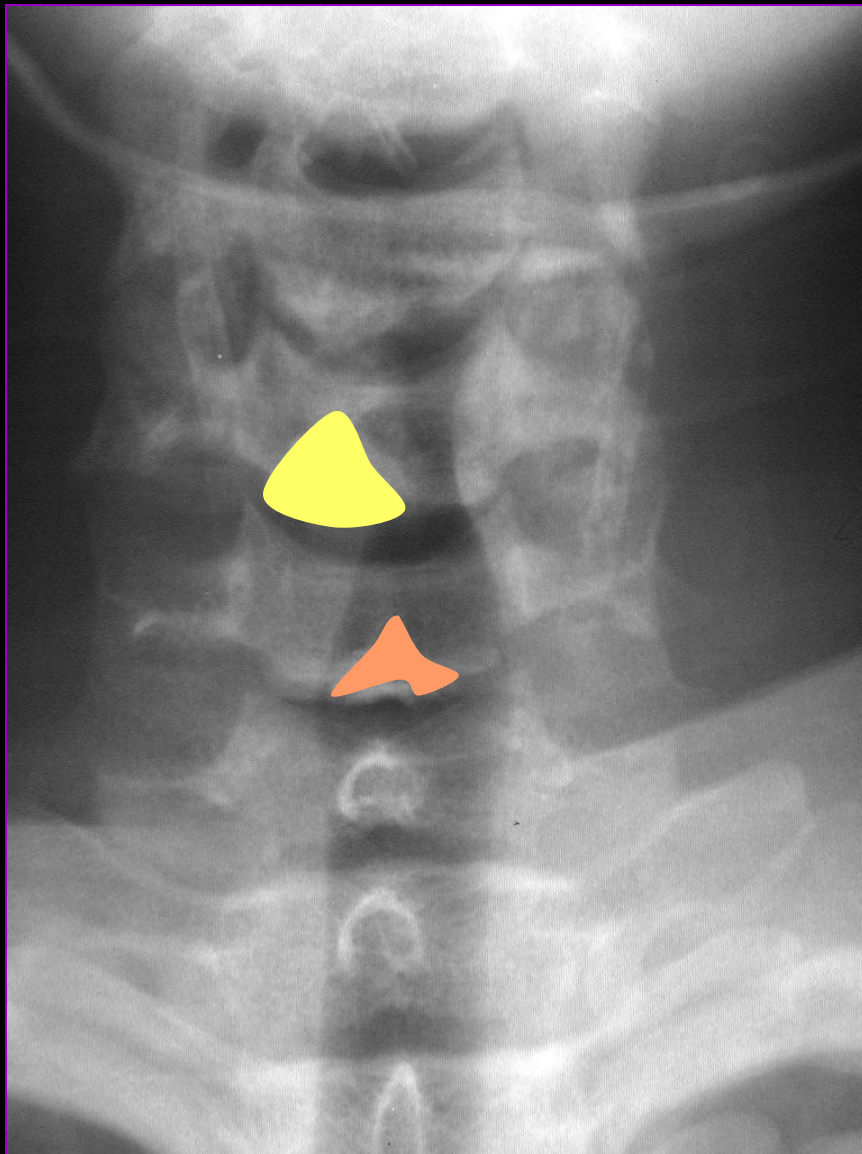
- Dislocation of facet joint opposite that of the direction of rotation
- Posterior ligament complex and articular joint capsule are disrupted
- ALL, disc and PLL intact
- Most common at C5-6, C6-7
- Impaction fractures tip of either articular mass (up to 70%)
- STABLE, unless FX isolates articular process

Unilateral Interfacetal Dislocation



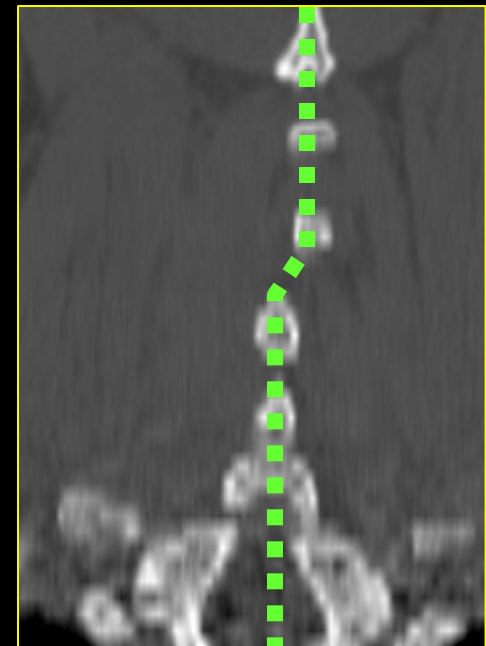
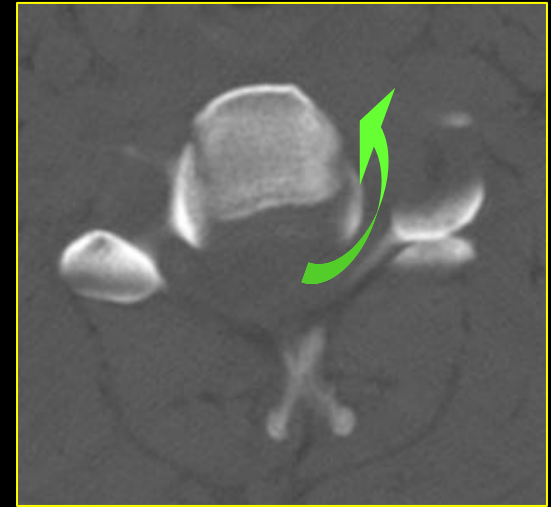
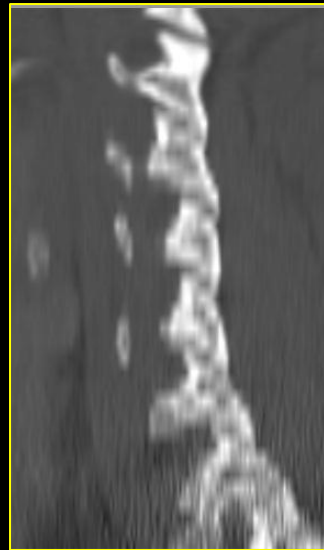
- "fanning"
- "laminar space" abrupt increase
- VB anterior sublux $< 1/2$ AP dimension but > 3 mm
- Lack of superimposition of articular masses at level of injury and superiorly
 - "Bowtie Sign"
- Reduced distance spinolaminar line to posterior cortex articular pillars

Unilateral Interfacetal Dislocation

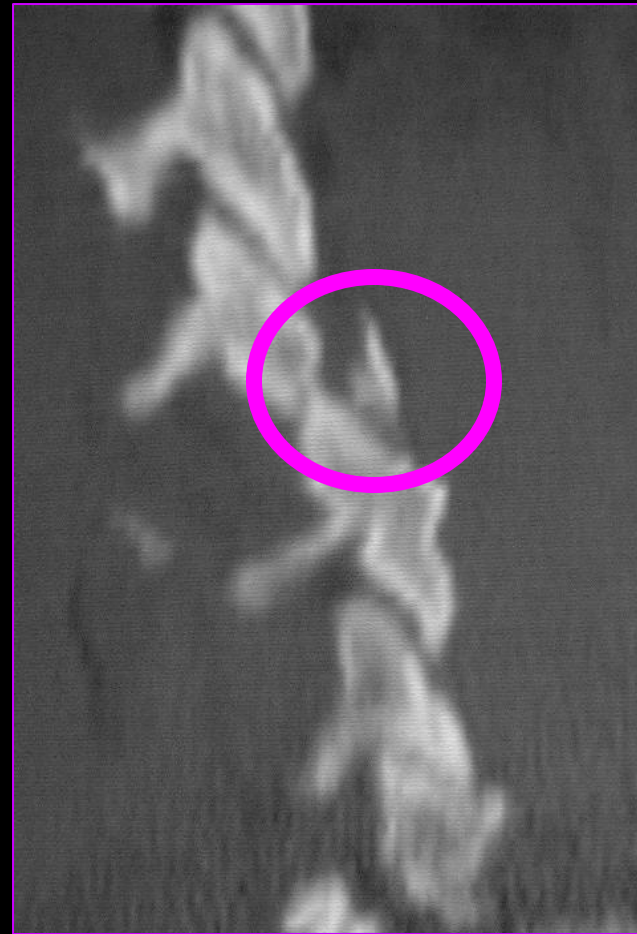


- AP view
 - rotation of spinous process
 - Spinous processes displaced to affected side on AP
- Oblique view
 - loss of "shingle on roof"

Unilateral Interfacetal Dislocation

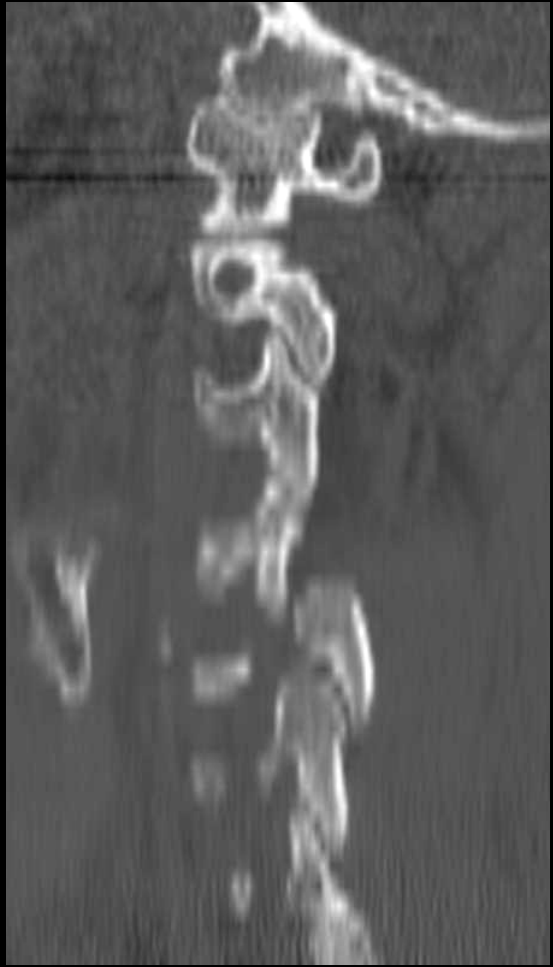
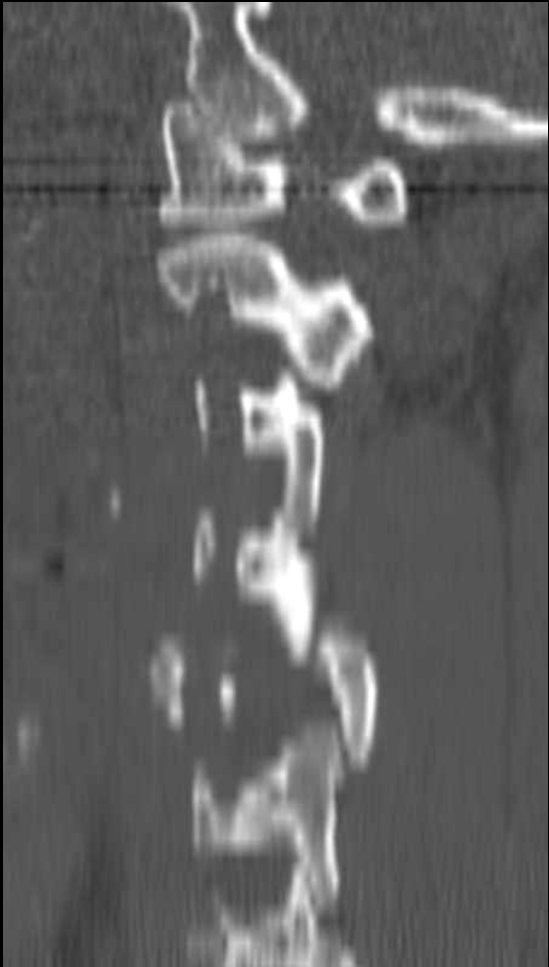


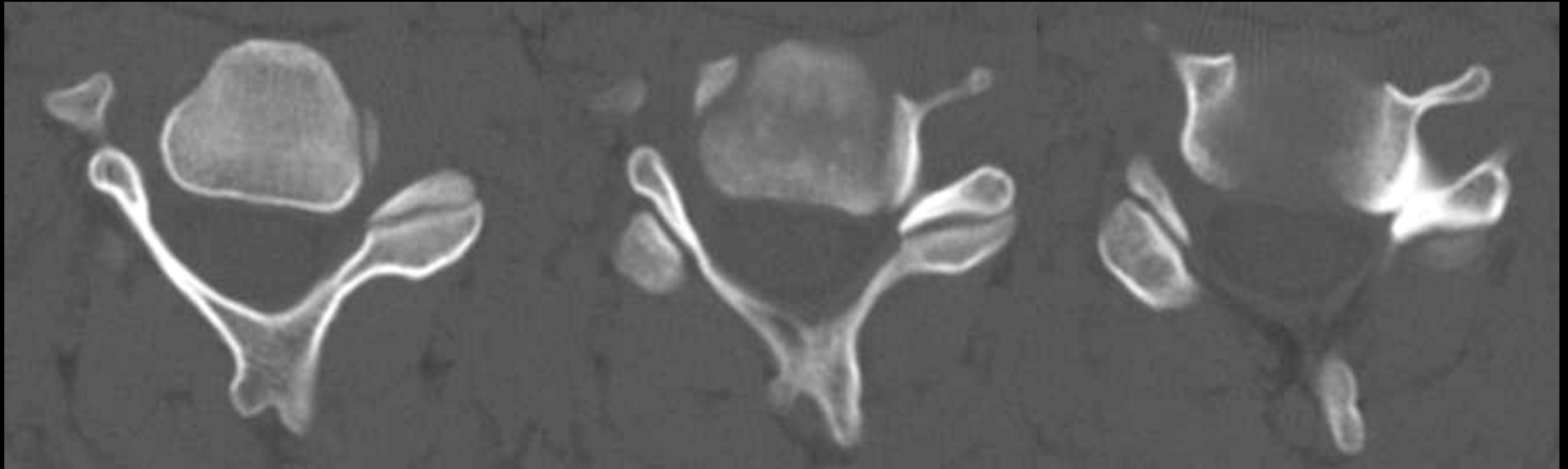
Unilateral Interfacetal Dislocation



Unilateral Interfacetal Dislocation







Congenital Pedicle Absence

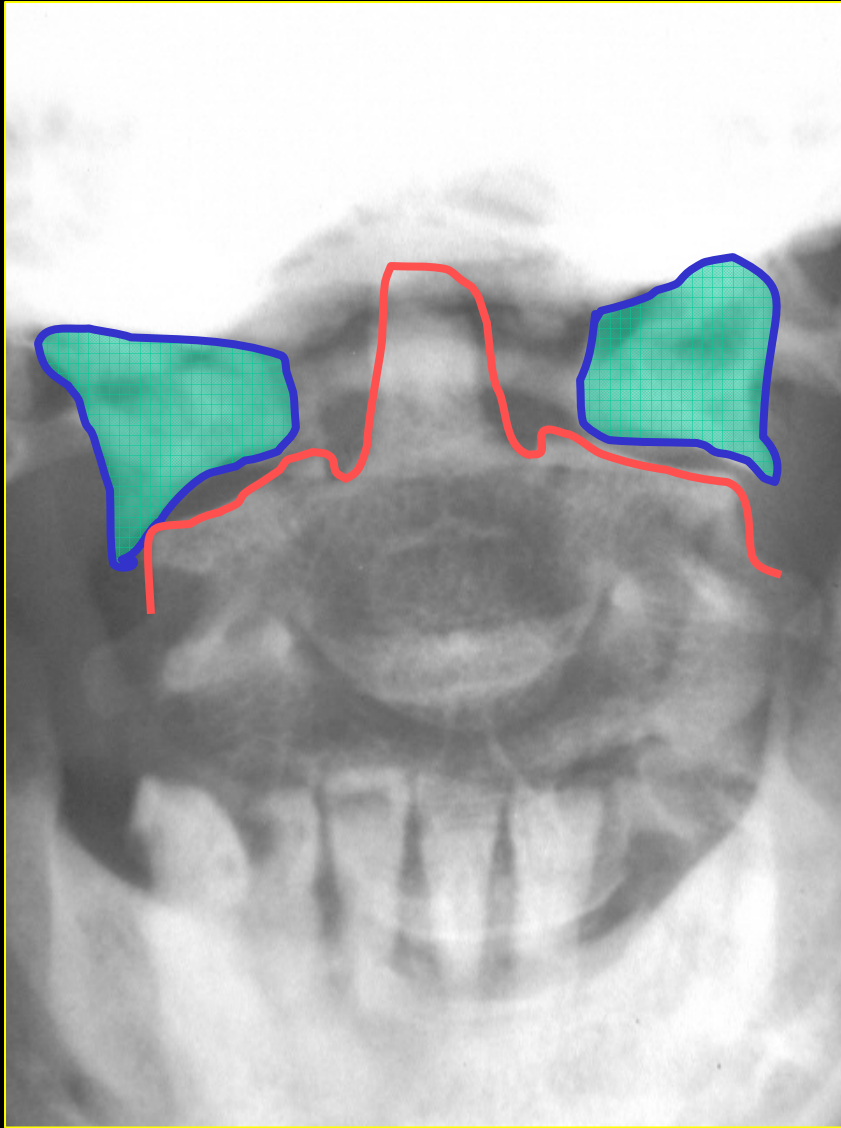
Vertical Compression (Axial Load)

- Force delivered to top of skull through the occipital condyles to the cervical spine at the instant that the cervical spine is straight
- Injury Patterns
 1. Jefferson fracture
 2. Burst fracture

Jefferson Fracture

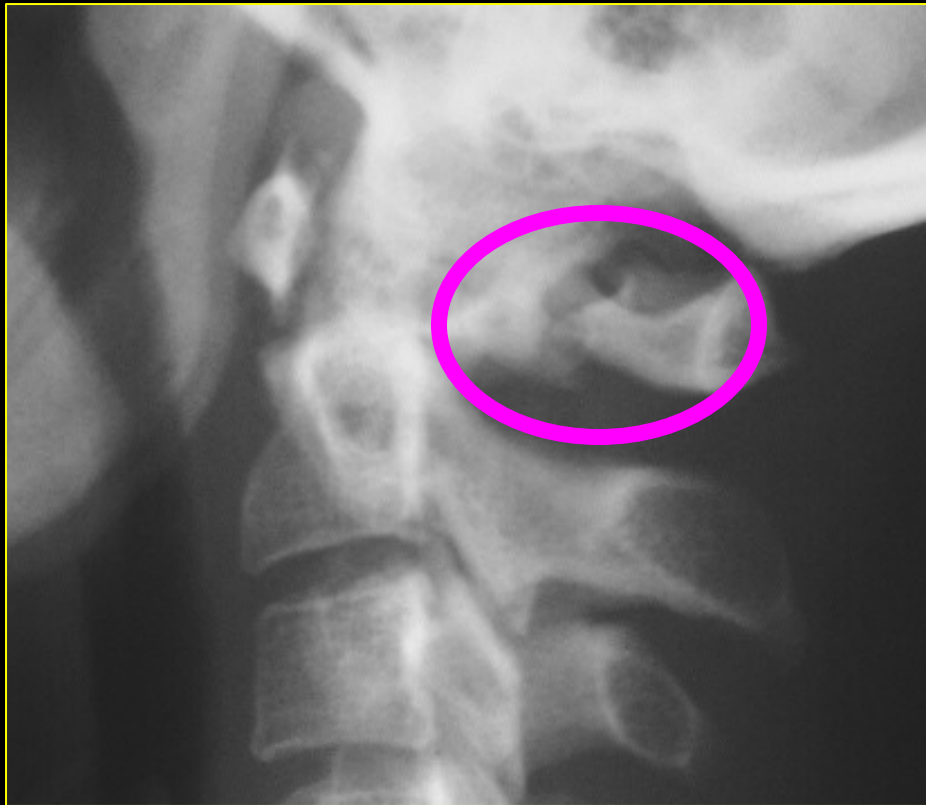
- Splitting of C1 ring with fracture of both the anterior and posterior arch
 - may result from a single break in each arch (anterior and posterior)
 - bilateral or unilateral
- Centripetal displacement fragments
- 50% → associated fractures
 - 33% = axis fractures
- no neurologic deficit
- Transverse atlantal ligament intact or not
- UNSTABLE

Jefferson FX: Odontoid view



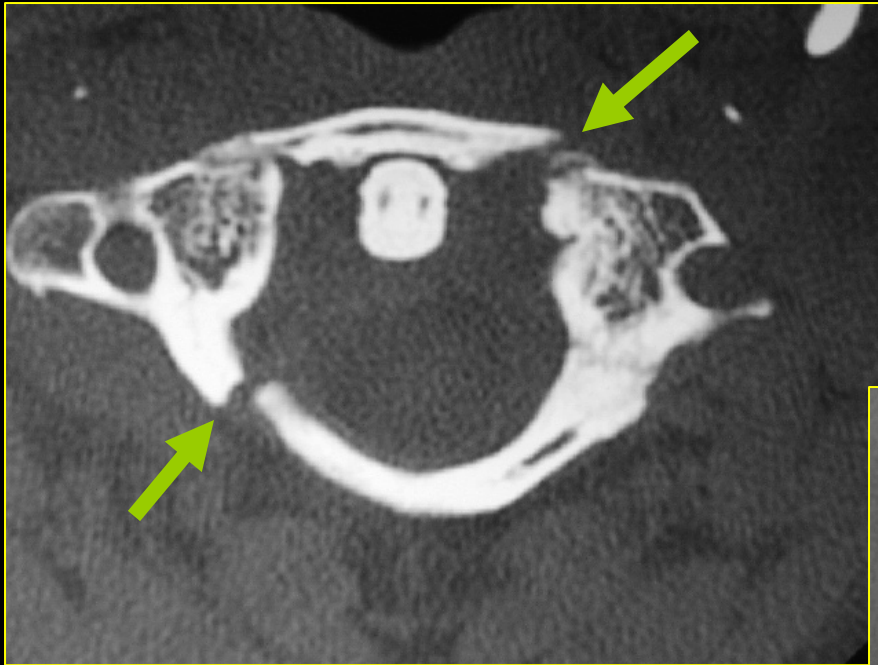
- offset lateral articular masses of C1 relative superior facets C2
 - bilateral or unilateral
- DDX: developmental pseudospread
- Total offset of the two sides <7mm, stable
- Total offset of the two sides >7mm, unstable (ruptured transverse lig.)

Jefferson FX: Lateral view



- prevertebral STS
- atlanto-dental interval $>4\text{mm}$, possible rupture transverse ligament
- Posterior arch FX

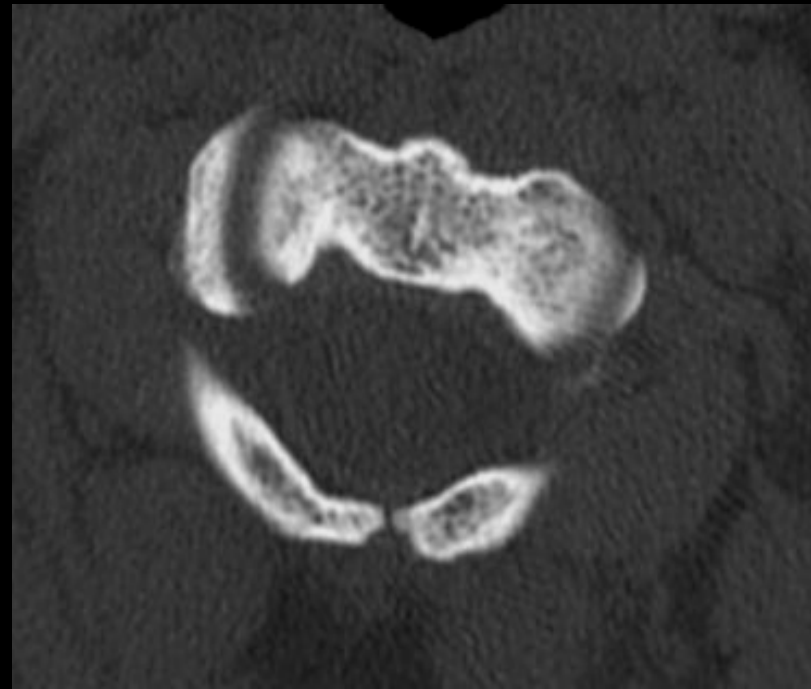
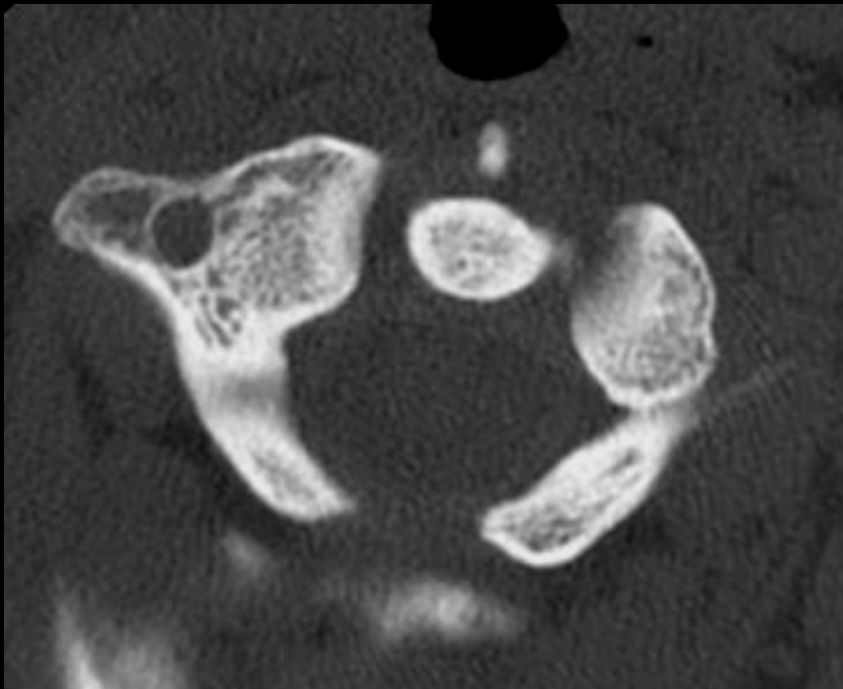
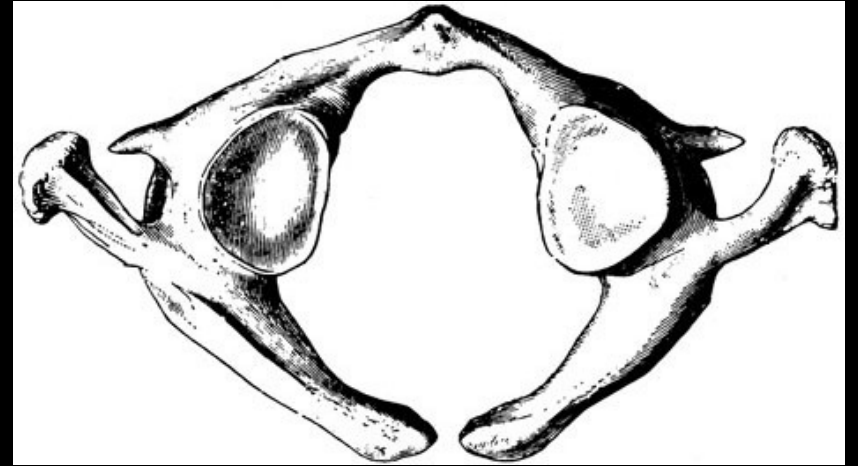
Jefferson Fracture



Jefferson FX:



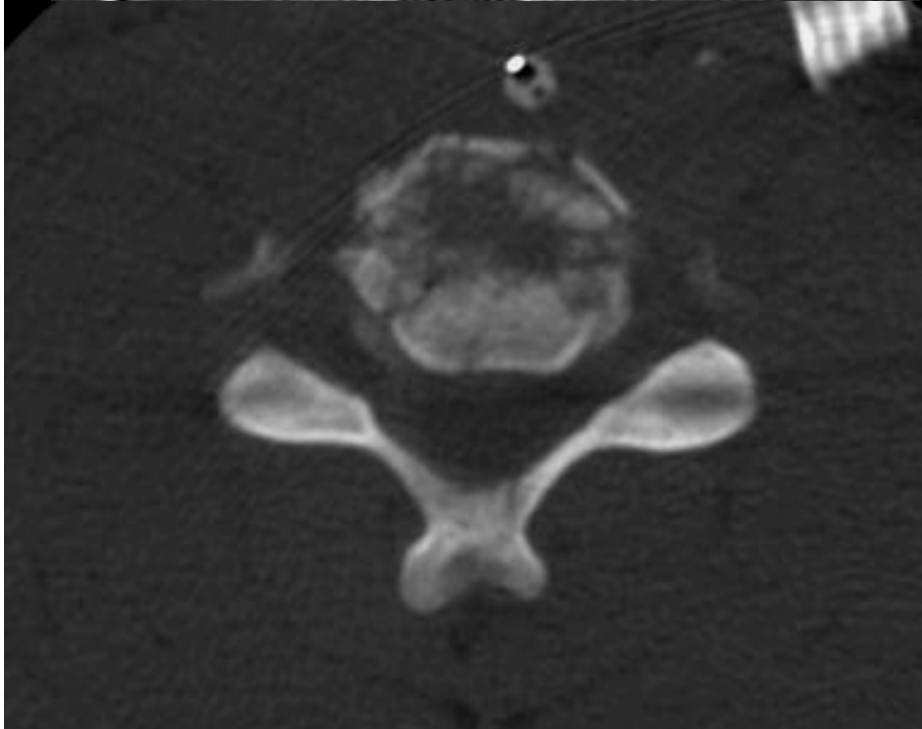
Incomplete Fusion C1 Posterior Arch



Burst Fracture

- C3-C7
- Theory - compressed disc bulges into inferior endplate causing VB to explode from the inside
- Usually with injury to spinal canal
- ALL, disc, posterior column intact
- STABLE

Burst Fracture



- Comminuted VB FX with retropulsion of posterior fragments
- Vertical FXs (best on AP view)
- Loss of lordosis
- Posterior column remains intact
- CT - evaluate fracture fragments
- MRI - evaluate cord, disc and ligaments

Hyperextension Injuries

1. Hangman's fracture
2. Hyperextension dislocation
3. Anterior arch avulsion of the Atlas
4. Posterior arch fracture of the Atlas
5. Extension teardrop fracture
6. Laminar fracture

Hangman's Fracture

- 4-7% of all cervical FXs and/or dislocations
- Most frequent FX in fatal traffic accidents (Alker)
- Clinical cases result from hyperextension
- Neurologic involvement is rare
- Predictive factors for neurologic injury:
 - Type II and III
 - Locked facets
 - Involvement transverse foramina with osseous fragment:
 - Dissection
 - Embolization

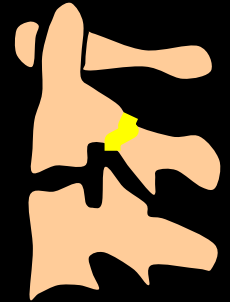
Hangman's Fracture



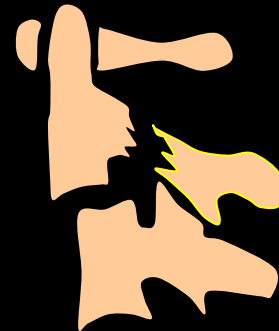
- Traumatic Spondylolisthesis of the Axis
- Bilateral fracture of the pars interarticularis or isthmus and / or adjacent articular processes
- From posterior superior to anterior inferior

Effendi et al. & Levine and Edwards:

Type I (65%): hair-line fracture, C2-3 disc normal



Type II (28%): displaced C2, Δ C2-3 disc, ligament lesions (instability), C3 anterosuperior compression fracture



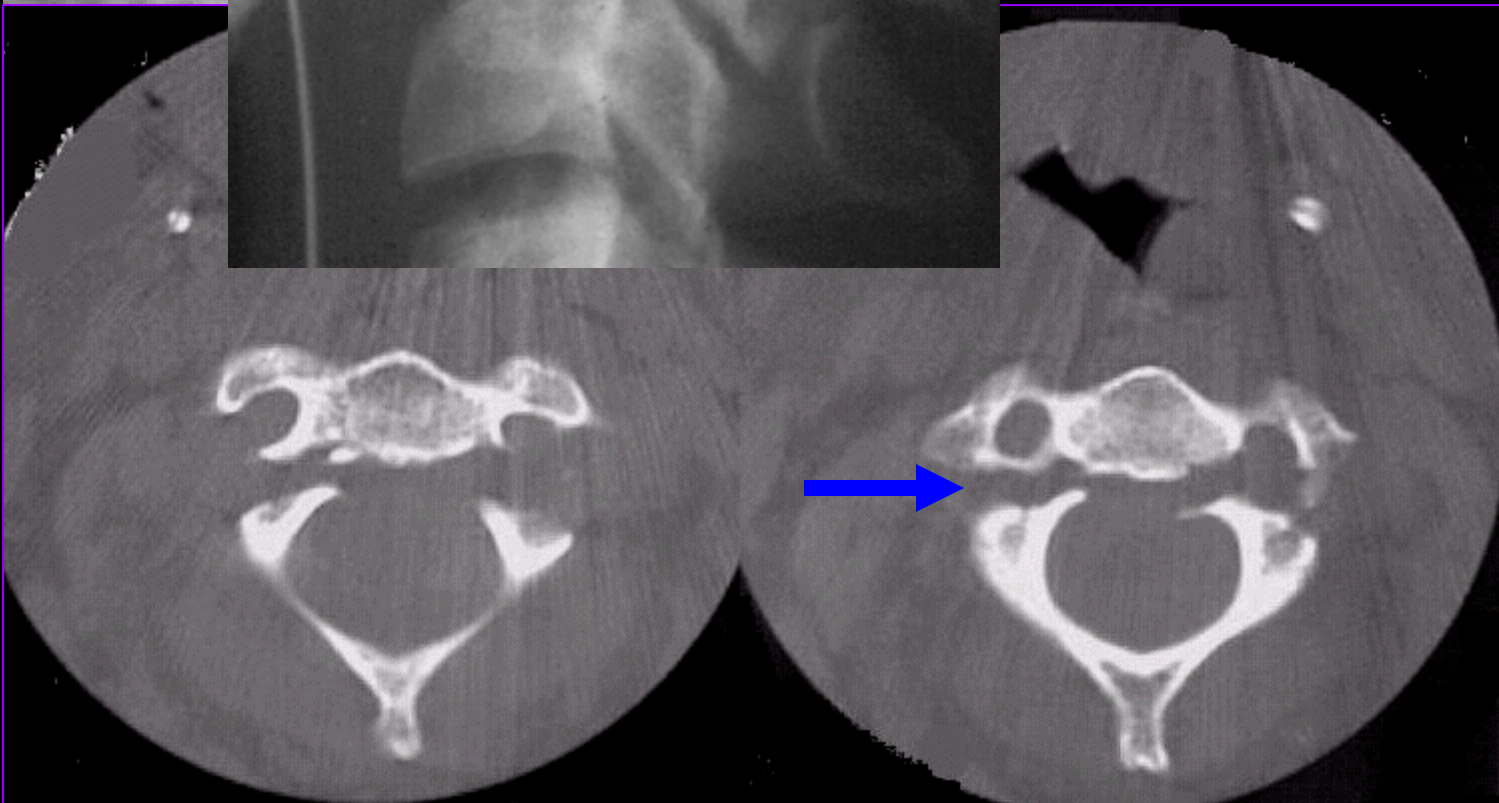
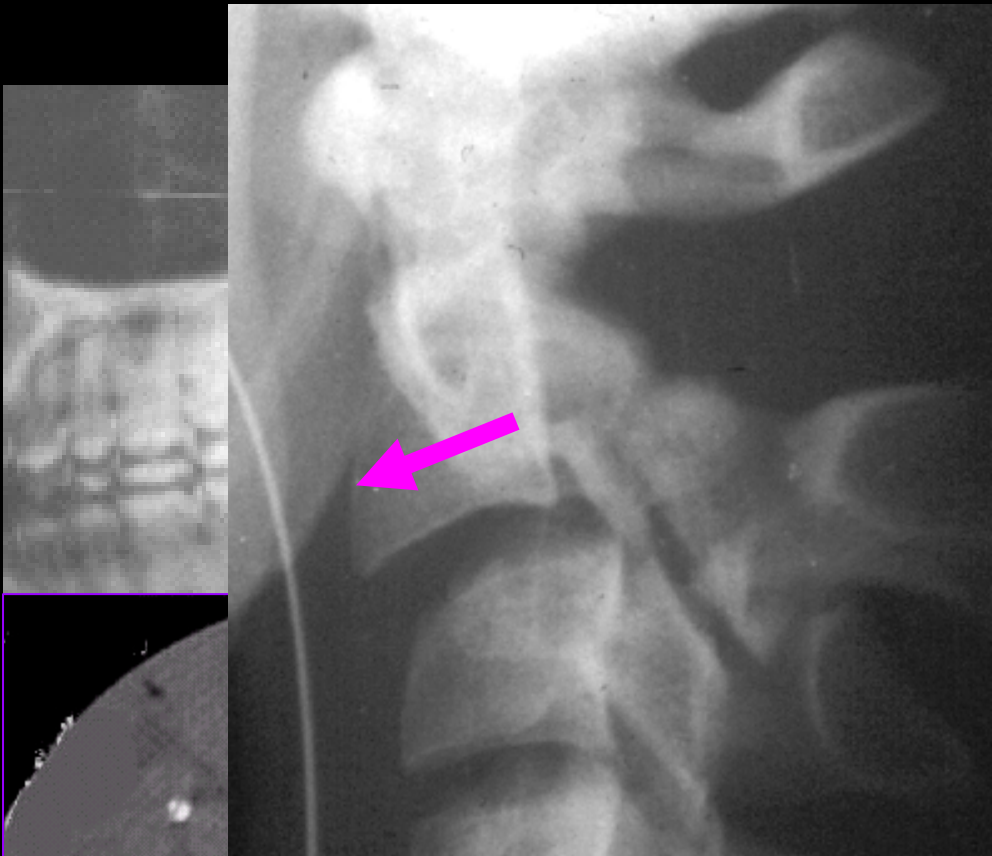
Type III (7%): displaced C2, C2-3 BID (severe instability)



Hangman's Fracture Type I



Hangman's Fracture Type II



Hyperextension Dislocation

- Soft tissue injury with disruption of ALL, disc and PLL
- Posterior column severely lordotic
- Compression of cord anteriorly by VB and posteriorly by ligaments
- spontaneously reduction when force gone
- Paralyzed patient with "normal" C-spine
- Spondylosis a predisposing factor
- UNSTABLE

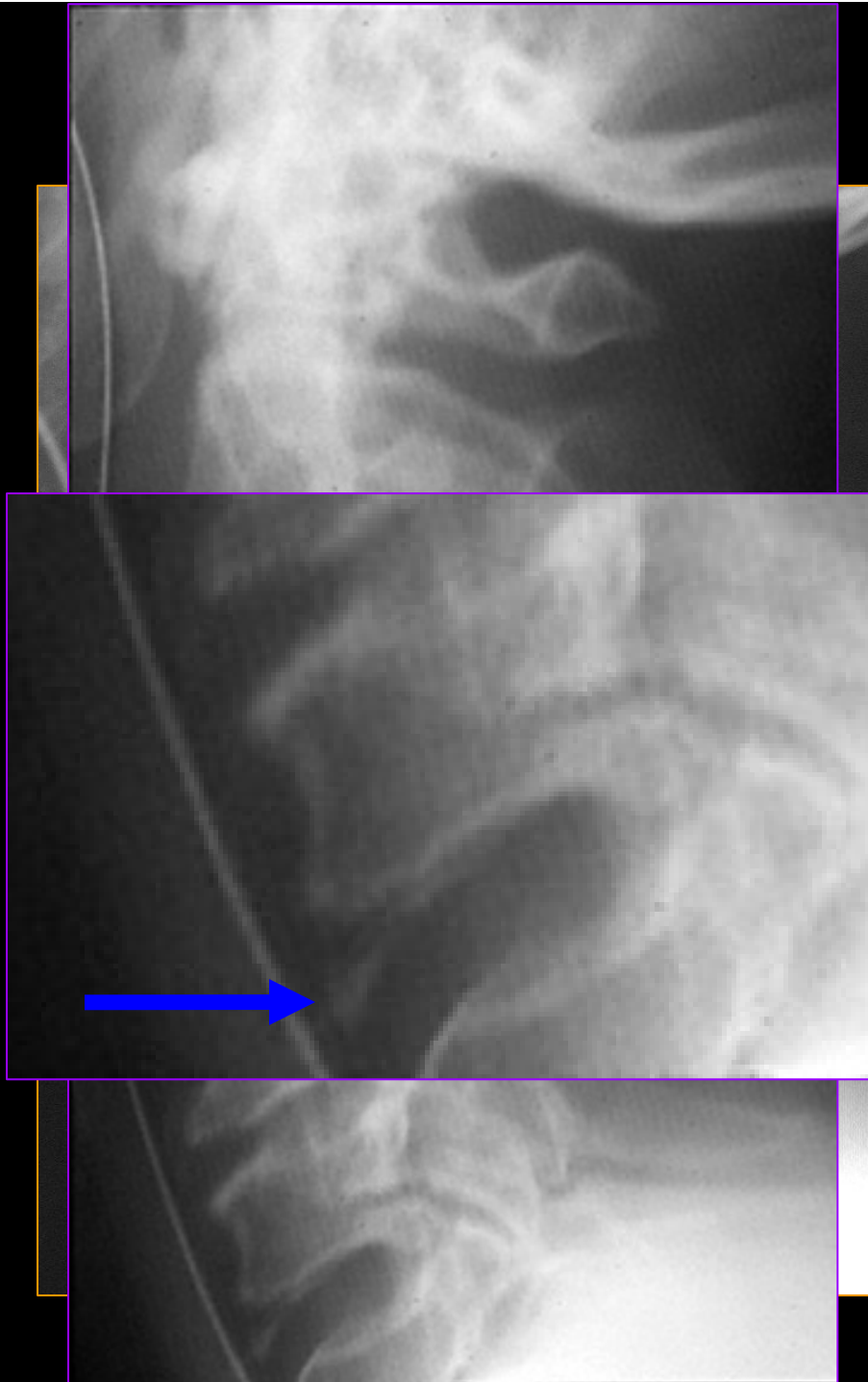
Hyperextension Dislocation

Triad:

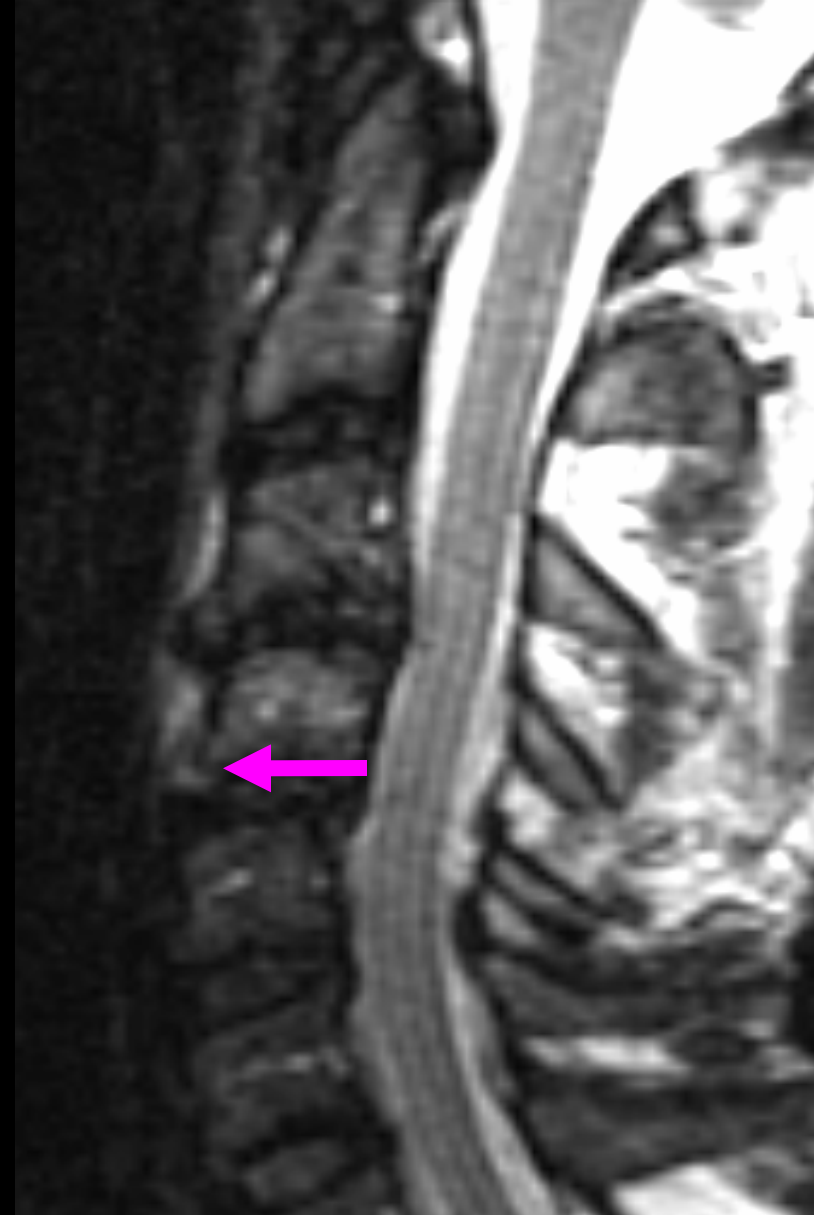
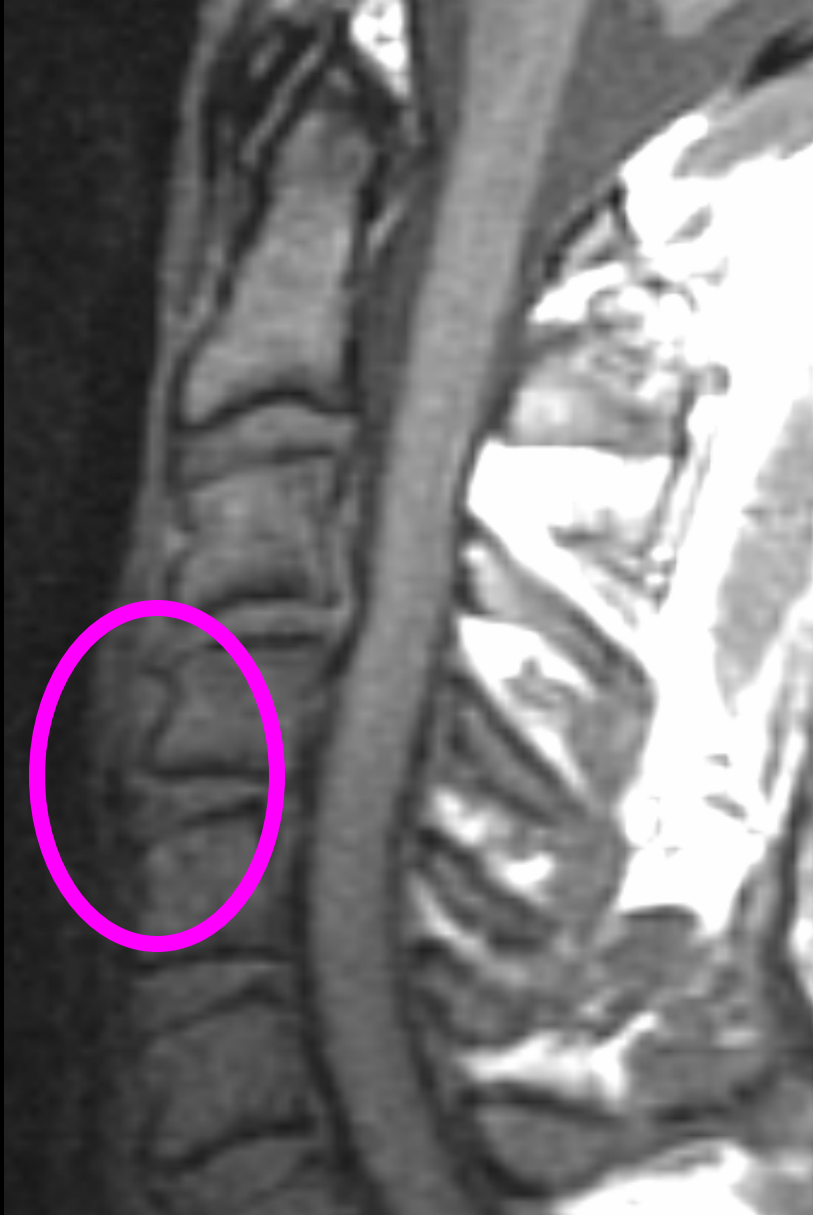
1. Facial injuries
2. Diffuse soft-tissue swelling with normally aligned vertebrae on lateral radiograph
3. *Acute Central Cervical Cord Syndrome*
hemorrhage into central cord → range of Sxs from upper extremity paralysis to quadriplegia (motor tracts to arms are located centrally)

Hyperextension Dislocation:

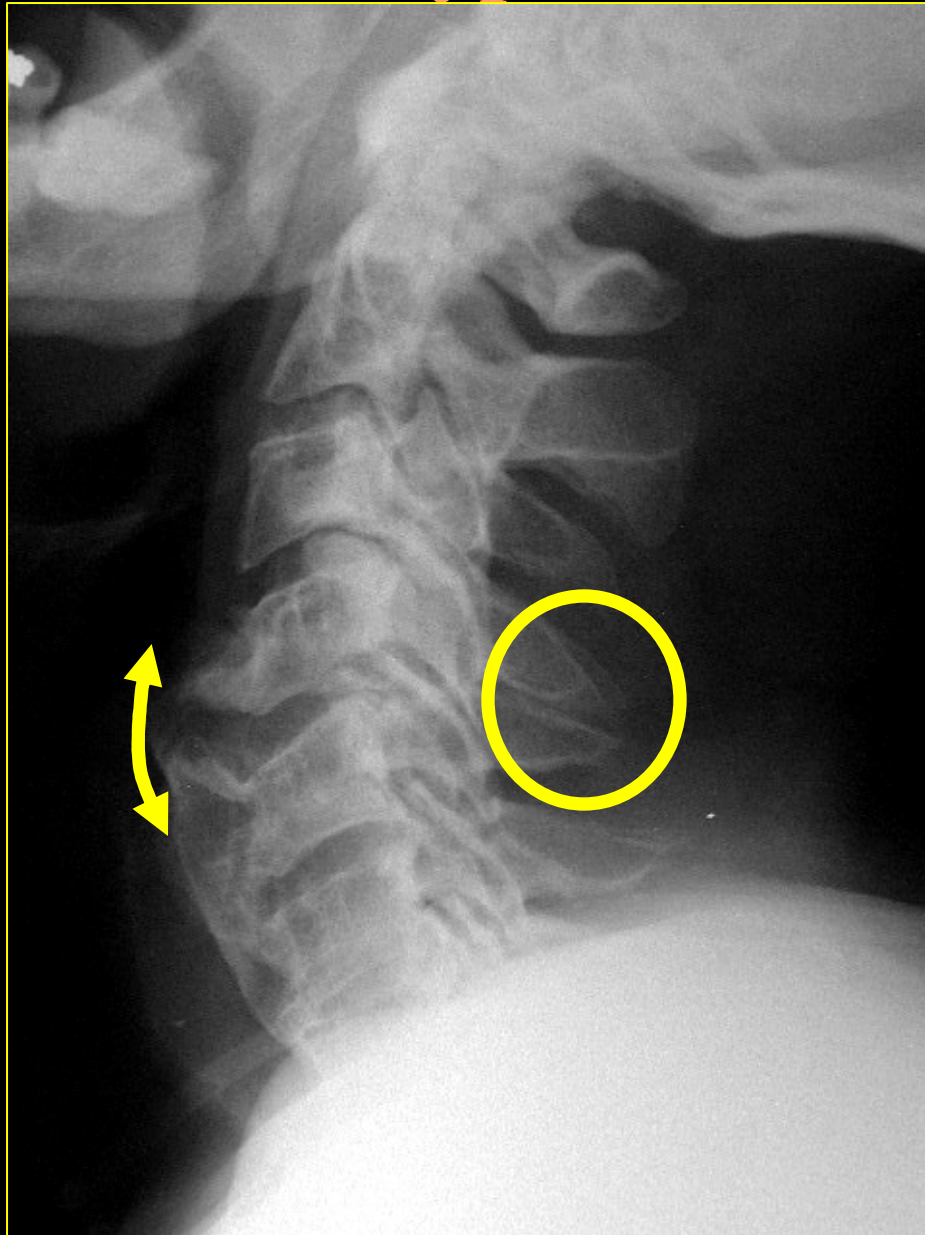
- Normal alignment (30%)
- Prevertebral STS
- 60% → thin, horizontal avulsion FX from anterior aspect inferior endplate (Sharpey Fiber attachment to ring apophysis)
Horizontal > vertical
- Vacuum phenomenon
- Widened IVD (uncommon)



Hyperextension Dislocation



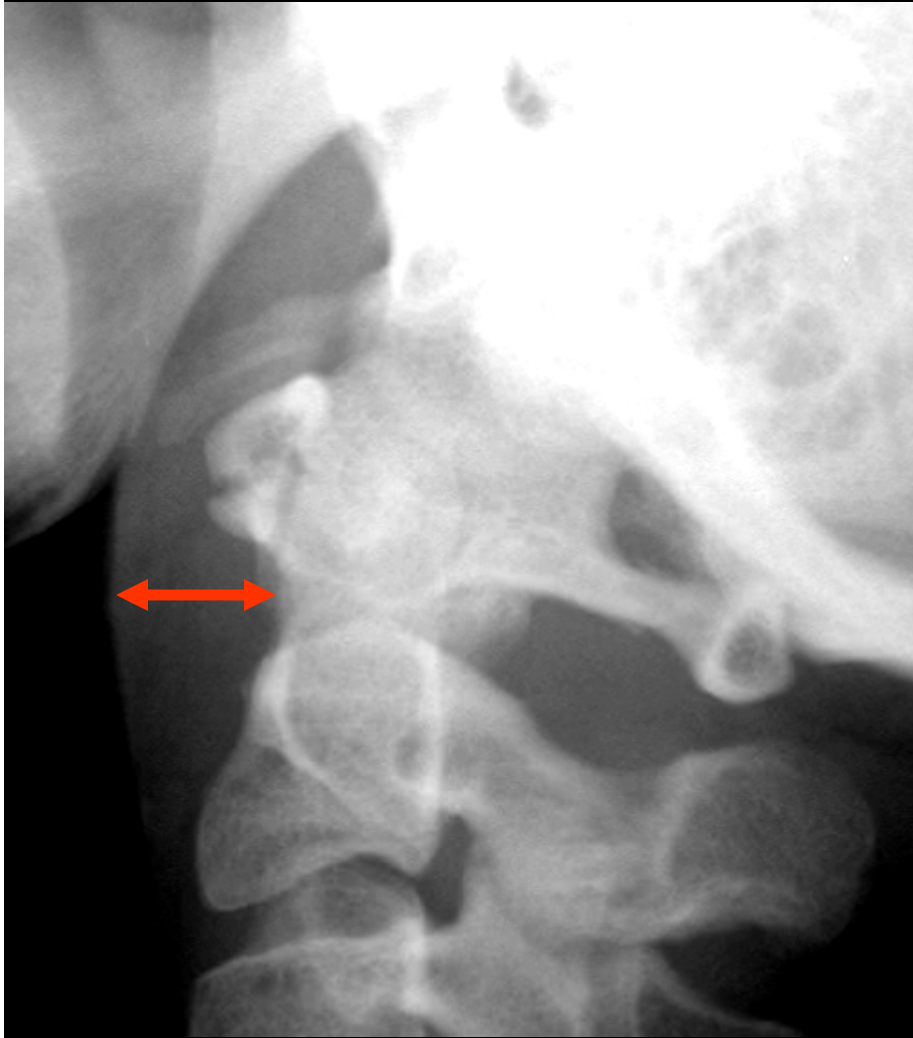
Hyperextension Dislocation



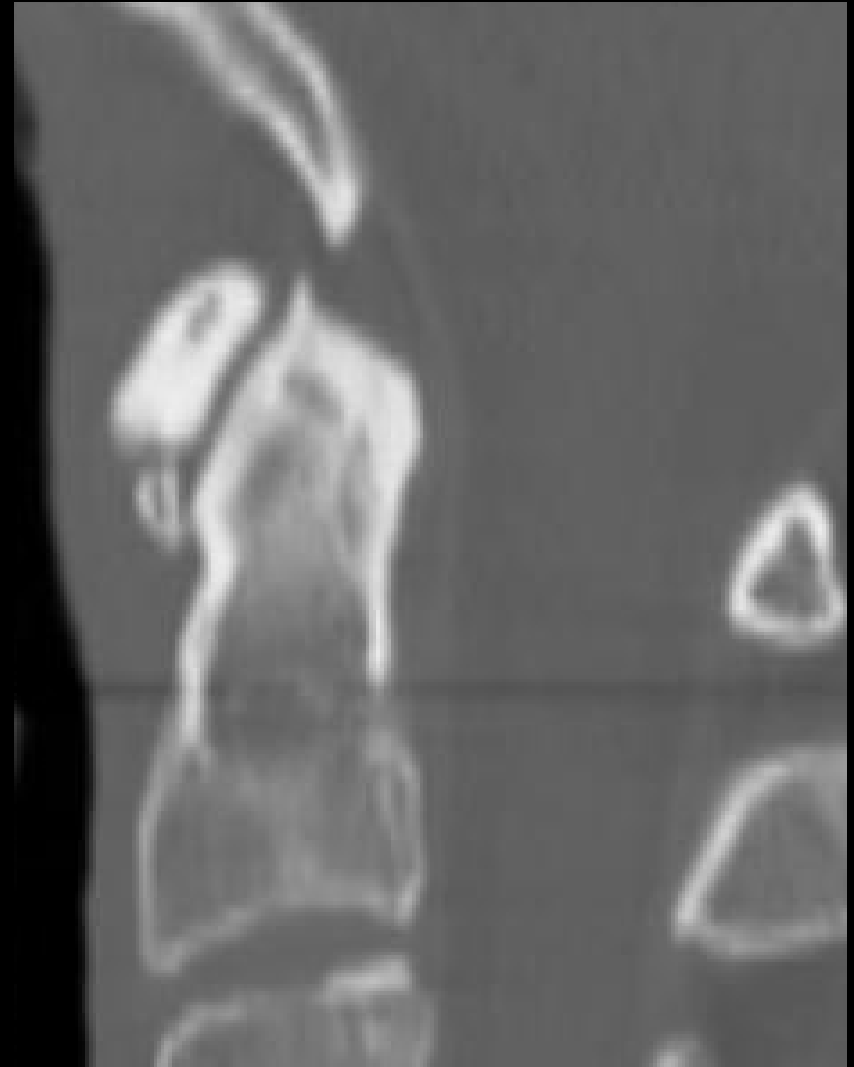


Atlas Anterior Arch Avulsion

- Hyperextension injury due to intact longus colli muscles and atlantoaxial ligaments
- Transverse FX mid or inferior arch
- Prevertebral STS
- Open mouth view - fracture line extends past lateral margin of the dens
- No neurological deficit
- STABLE

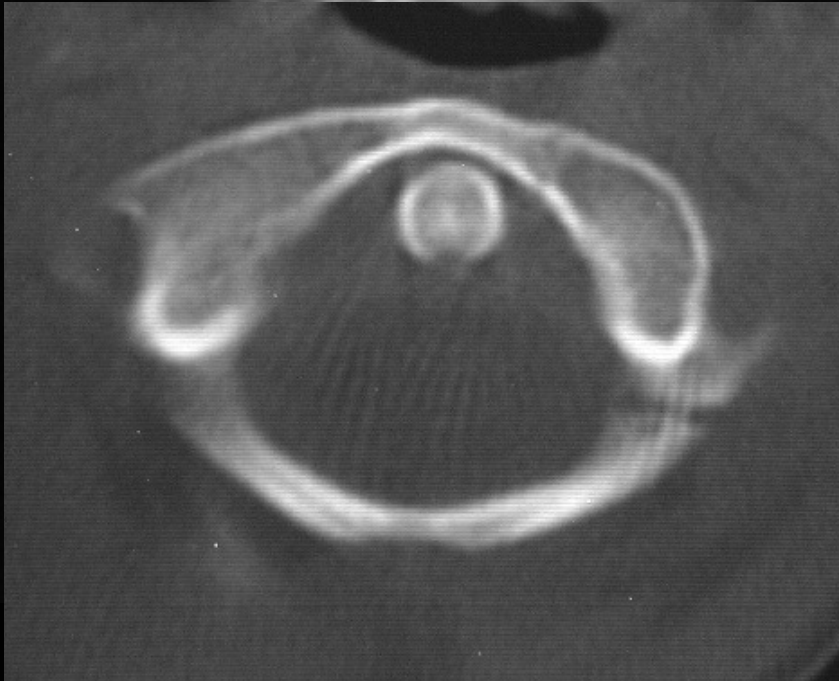
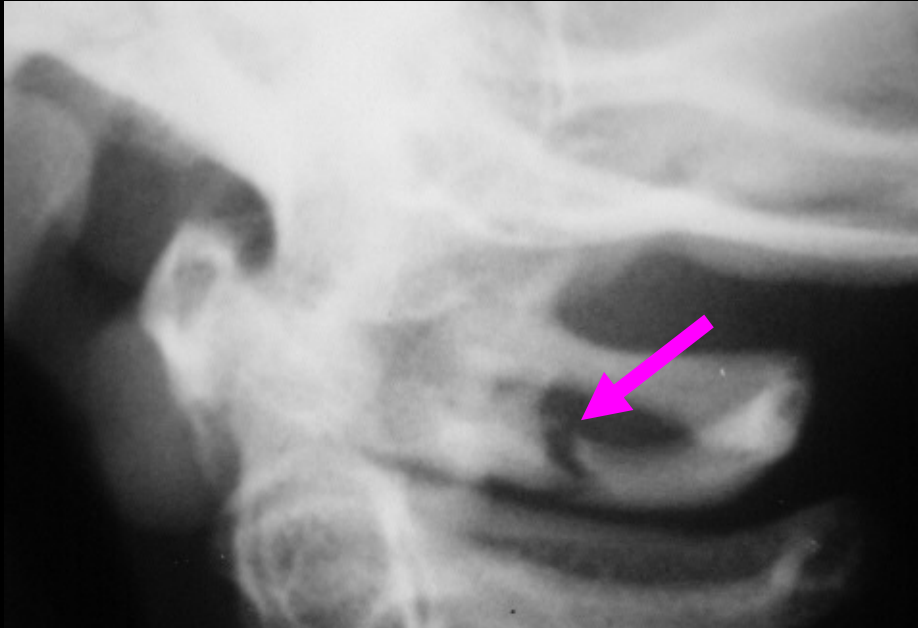


Arch FX



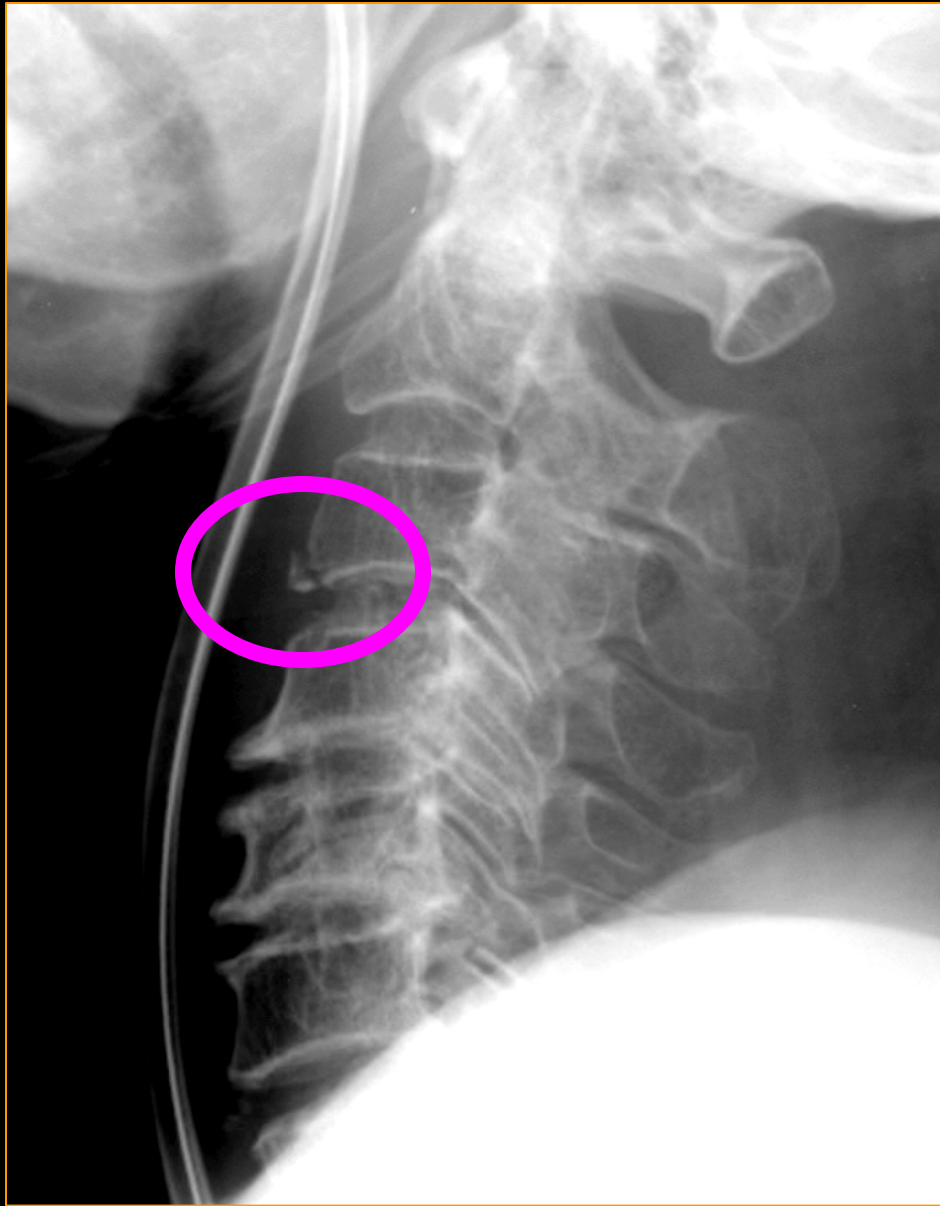
Accessory Ossicle

Atlas Posterior Arch Fracture



- Compression of arch between occiput and spinous process of C2
- FXs through both sides of the arch posterior to the lateral masses
- STABLE

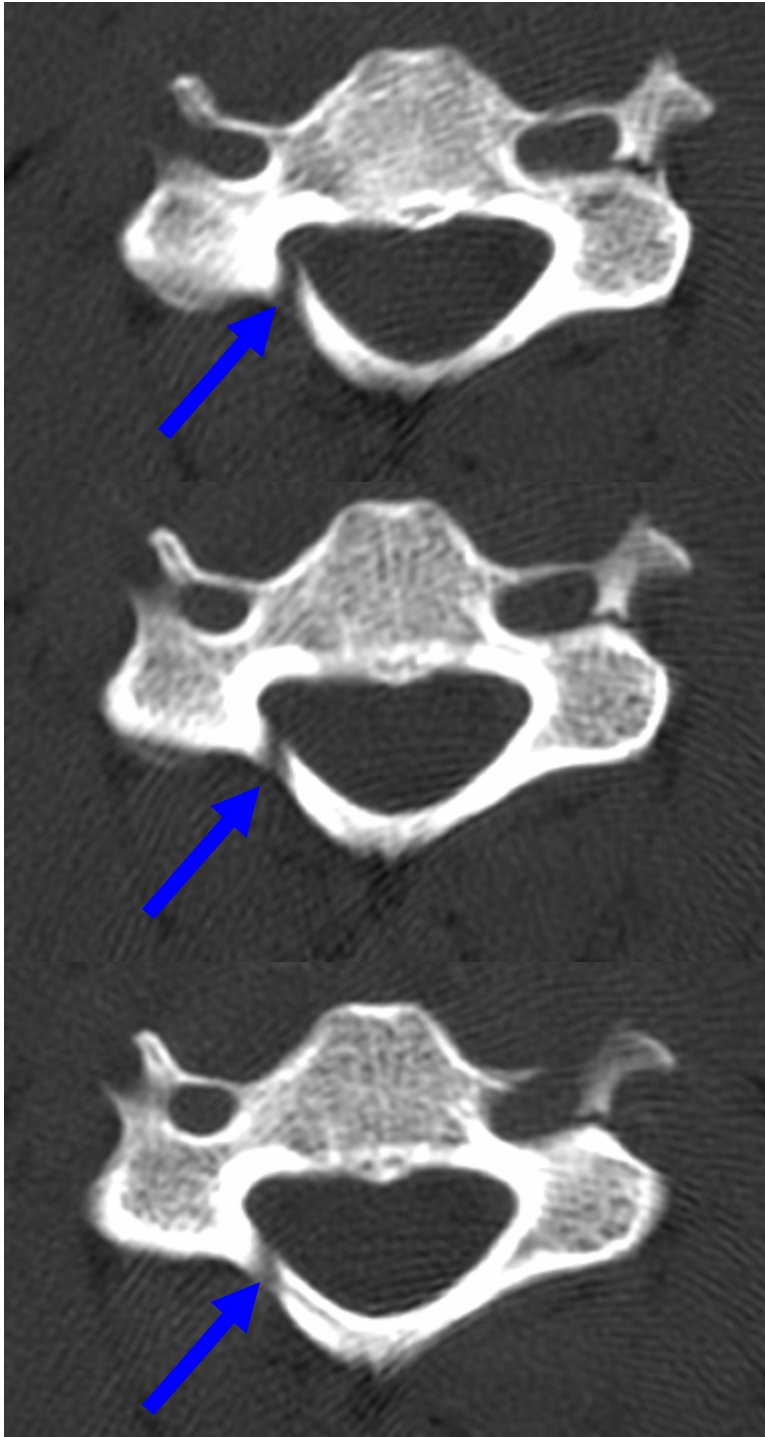
Extension Teardrop Fracture



- Triangular fragment from anterior inferior corner of vertebral body (axis)
- Vertical = or > transverse dimension
- Avulsion fracture mediated by ALL
- Prevertebral STS
- Elderly with osteopenia
- UNSTABLE- in extension, STABLE-in flexion

Laminar Fracture

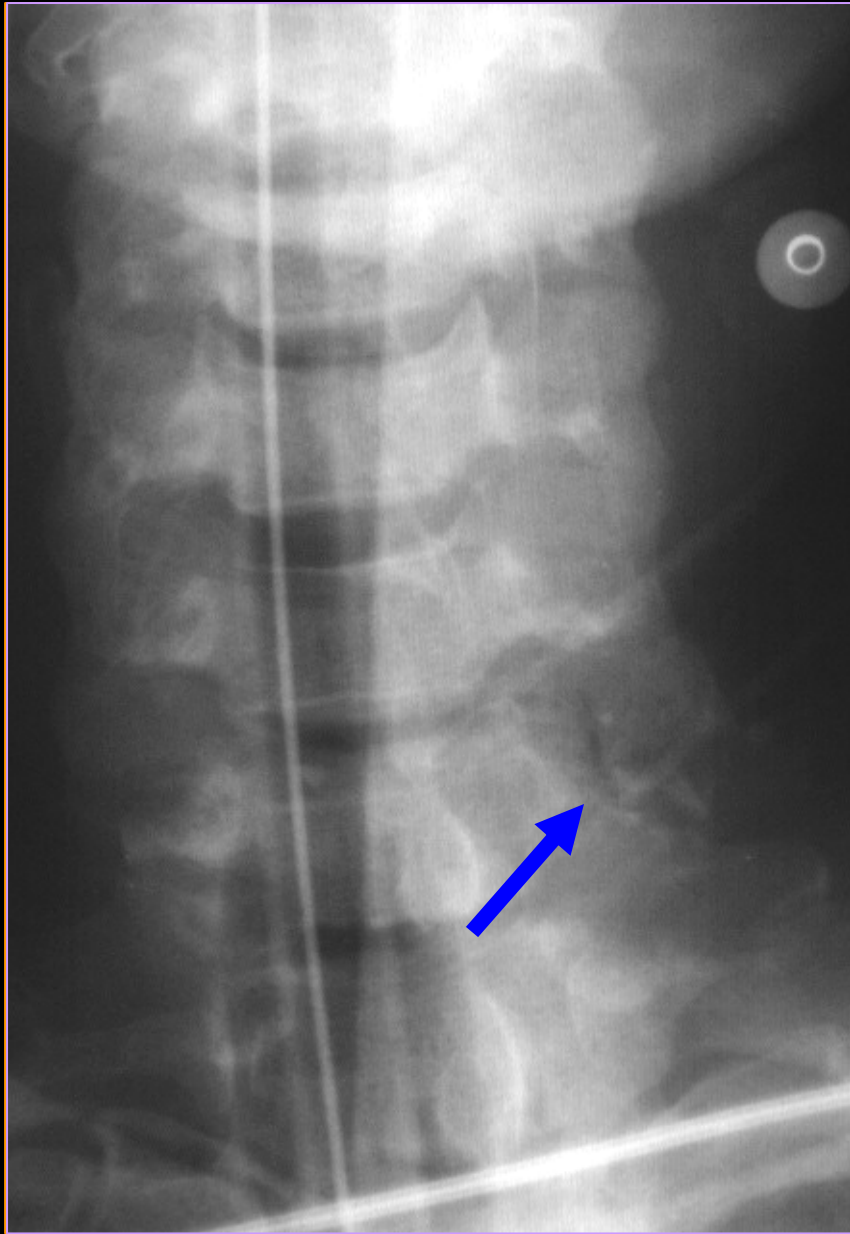
- Posterior arch FX of a lower cervical vertebrae as it is compressed between superior and inferior vertebral lamina
- FX through lamina
 - fragments → displaced into canal
- Lateral view & CT best imaging modalities
- STABLE



Hyperextension/Rotation

- Upward force on the forehead or upper face with head rotated
- Force which is not central is applied to forehead or upper face
- Injury Patterns
 1. Pillar Fracture
 2. Pedicolaminar Fracture-Separation

Pillar Fracture



- Vertical FX of the articular pillar(mass) from impaction by superior articular mass
- "double outlet" sign - lateral view
- FX line through lateral mass - AP view
- Best seen on obliques, CT and pillar views
- STABLE

Pedicolaminar Fracture - Separation

- Fracture through ipsilateral pedicle and lamina → free floating lateral mass
- Articular pillar fragment frequently rotated → horizontalized facet
- Anterior displacement of vert body (similar to hyperflexion injuries)
- If FX extends into foramen transversarium, then possible vertebral artery injury
- Best seen on oblique images
- UNSTABLE - if associated with contralateral interfacetal dislocation

Pedicolaminar Fracture - Separation

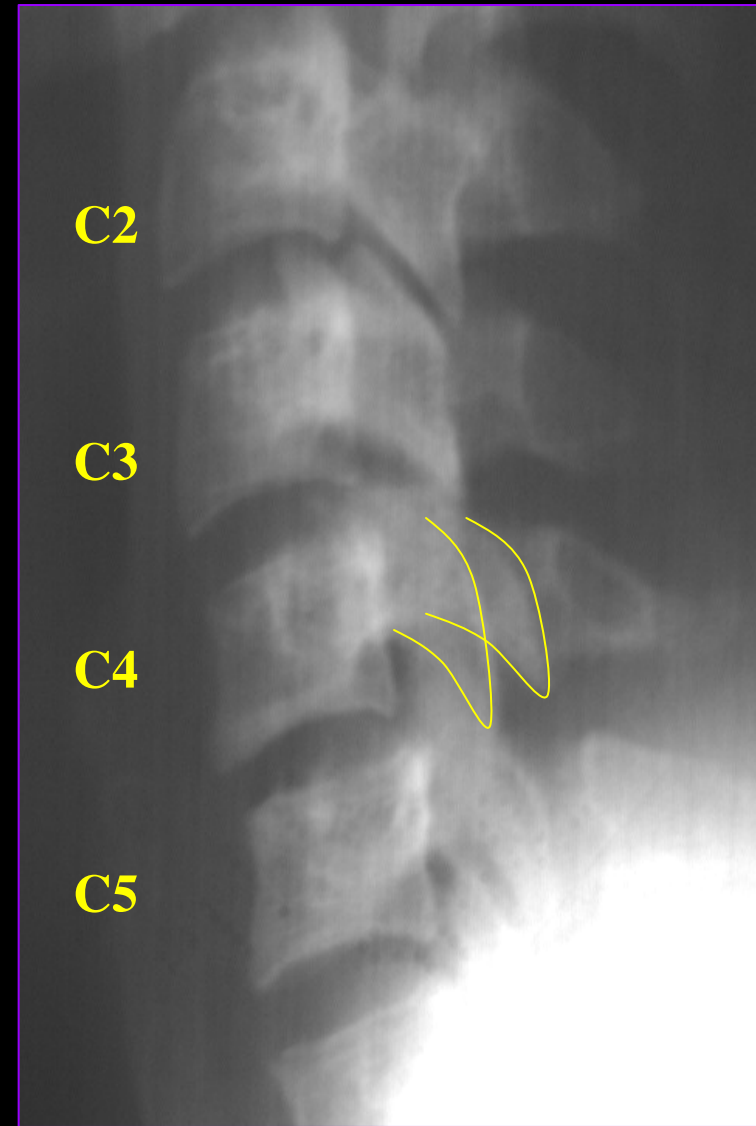
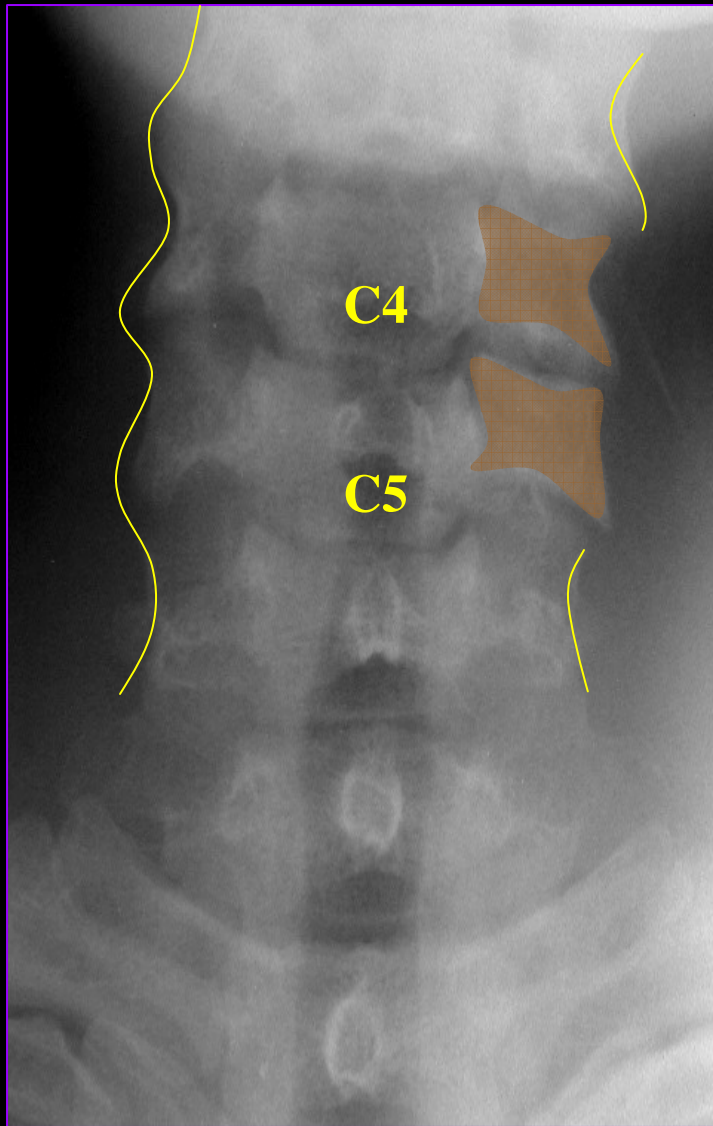
Type I - articular mass FX fragment

Type II - FX + ant subluxation

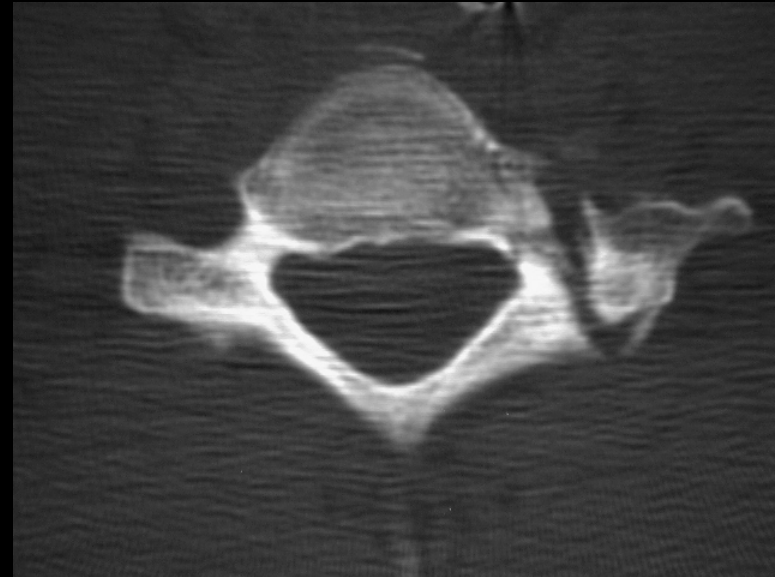
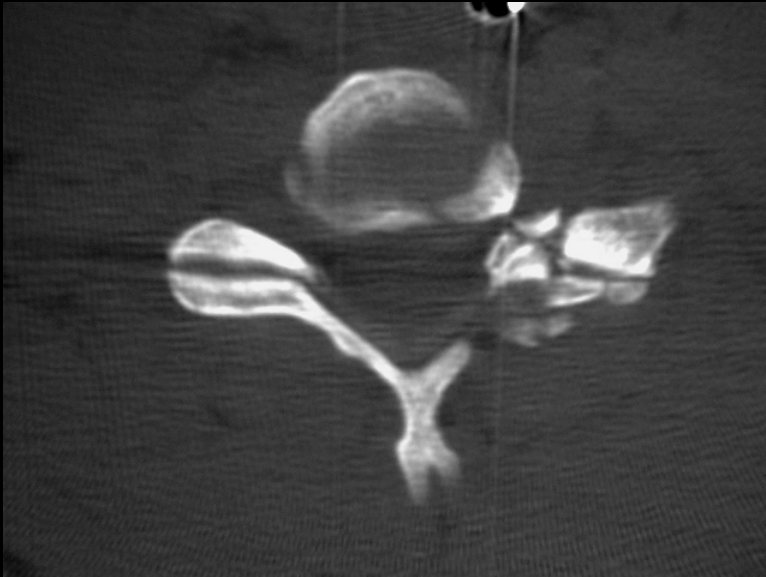
Type III - type II + disc narrowing

Type IV - bilateral involvement with
interfacetal dislocation
contralaterally

Pediculolaminar Separation



Pediculolaminar Separation



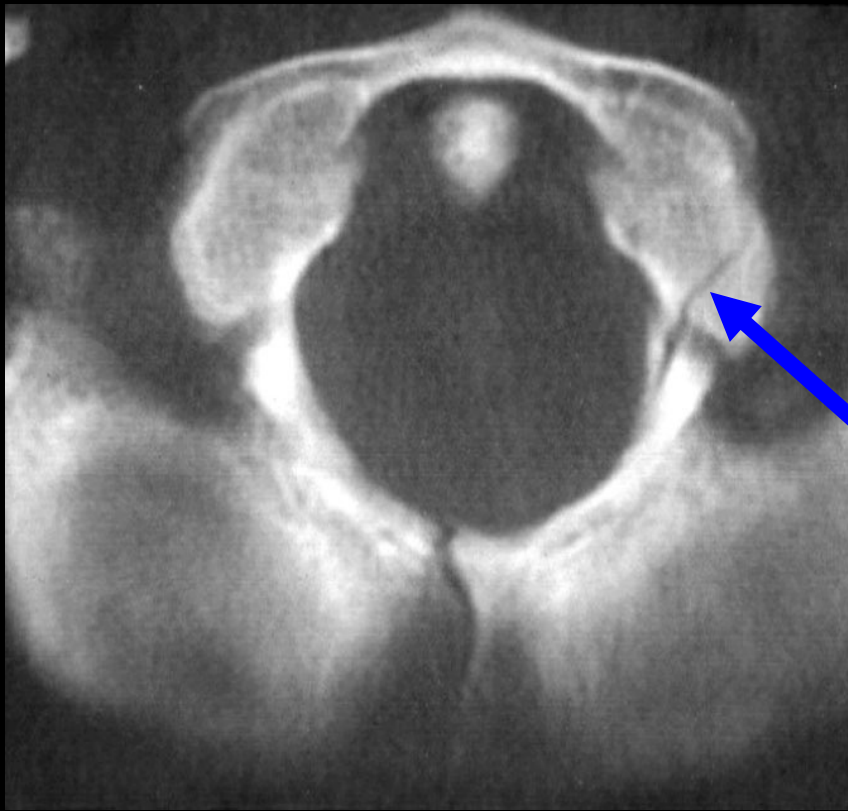
- Fracture of the pedicle and lamina
- Articular mass becomes free-floating fragment

Lateral Flexion Injury

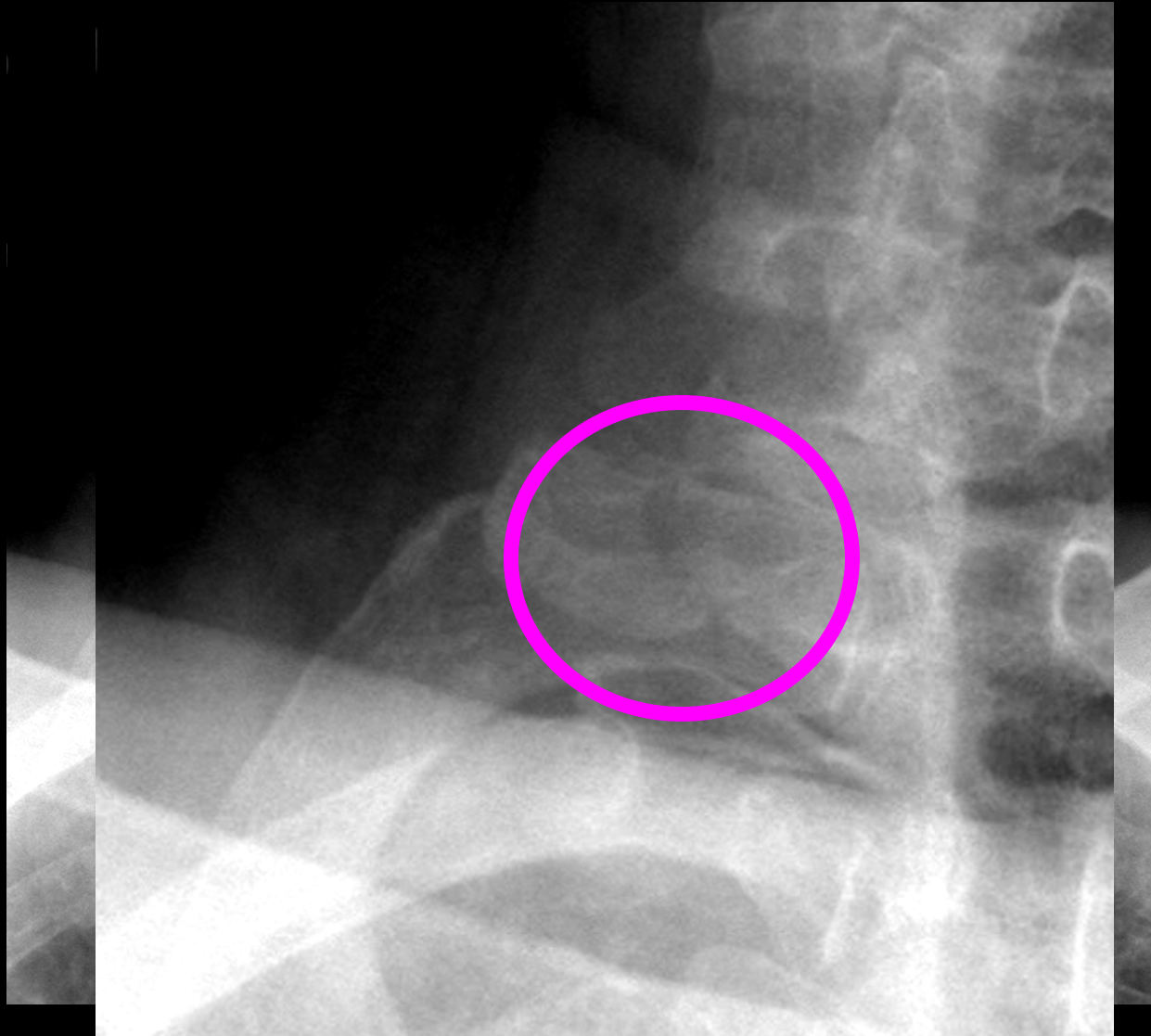
FXs:

- Tilt in the coronal plane
 - Associated with vertebral artery injury
 - Best seen on AP view and CT
- unciniate process
 - occipital condyles
 - transverse process
 - odontoid
 - lateral wedge compression
 - eccentric atlas burst fracture

Lateral Flexion Injury: Occipital Condyle FX



Lateral Flexion Injury: Transverse Process FX



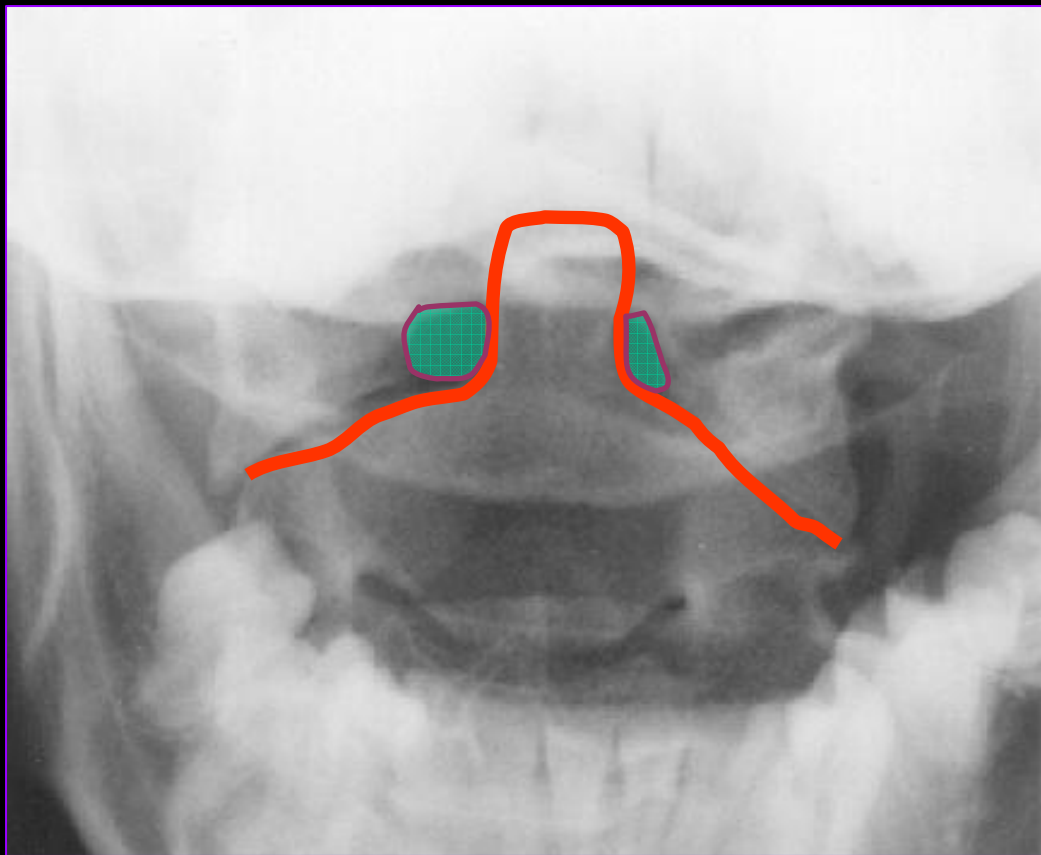
Other Fractures/Injuries

- Rotary fixation of C1/C2 - torticollis
- Odontoid fractures
- Transverse atlantal ligament rupture
- Occipitoatlantal dissociation

Rotary Atlantoaxial Dissociation (Rotary Fixation of C1/C2)

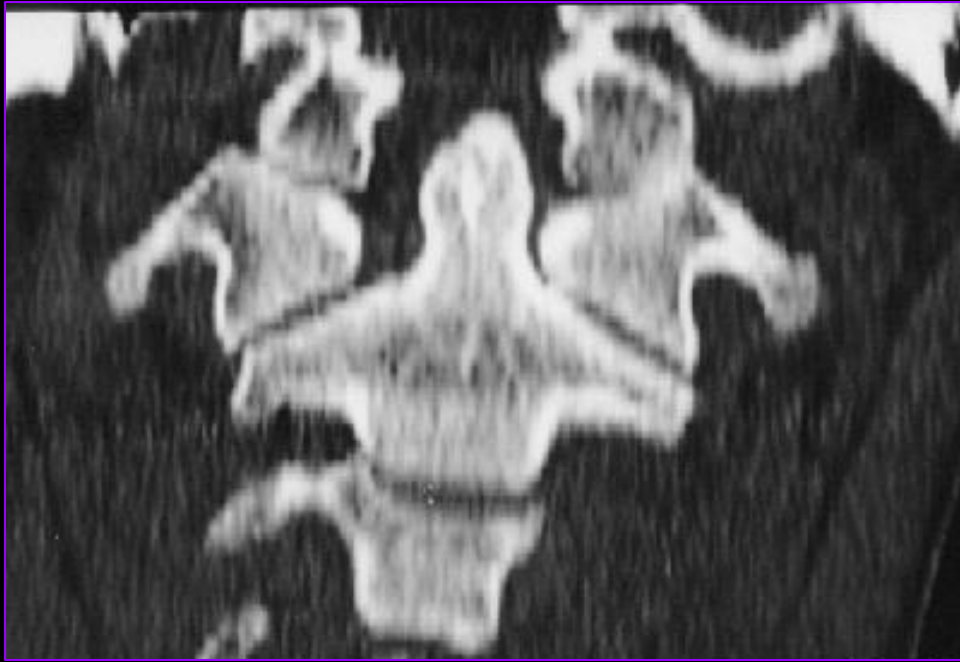
- Usually secondary to mild trauma
 - sleeping in an unusual position
 - torticollis
- Rotation and lateral tilt at the atlantoaxial joint
- Fixation occurs when symptoms not resolved in a few days

Rotary Atlantoaxial Dissociation



- Incongruity articulating surfaces axis and atlas
- Asymmetry of joint spaces axis and atlas
- Asymmetry lateral atlantodental intervals
- Pre-vertebral STS (traumatic)

Rotary Atlantoaxial Dissociation



CT findings:

Disruption of one
or both facet
joints, including
locking

Odontoid (Dens) Fractures:

- 11-13% c-spine injuries (up to 27% in some series)
 - 75% of cases are children
- Classification
 - Anderson & D'Alonzo (I, II and III)
- Associations
 - atlantoaxial dislocations
 - Jefferson FX
- Radiography → may be subtle
- Prevertebral STS nasopharynx

Anderson & D'Alonzo Classification



Type I
(?)

upper dens, oblique (8%)



Type II
(HIGH)

base of dens, transverse (59%)

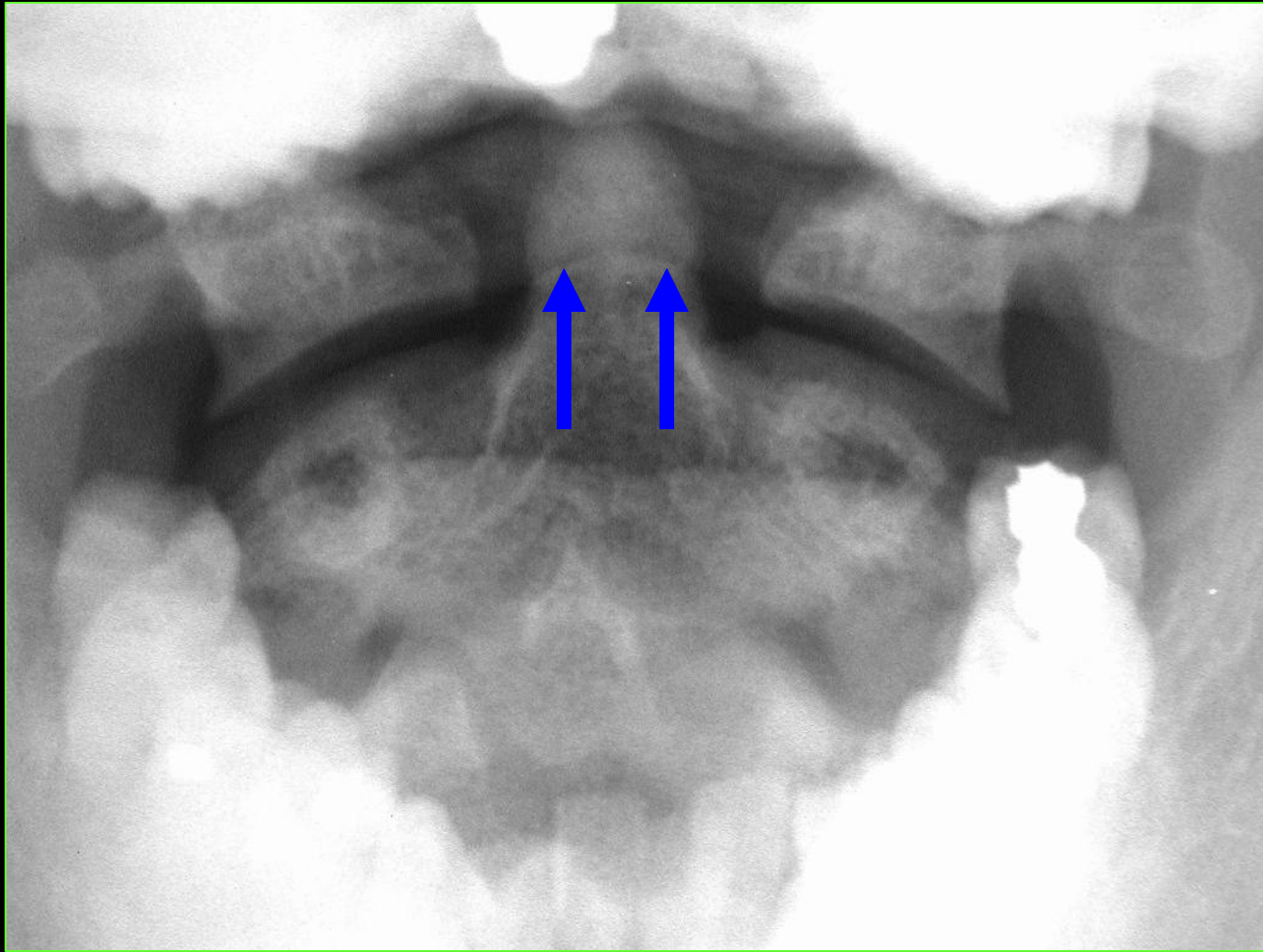
can be considered UNSTABLE as dens and atlas may move as a unit



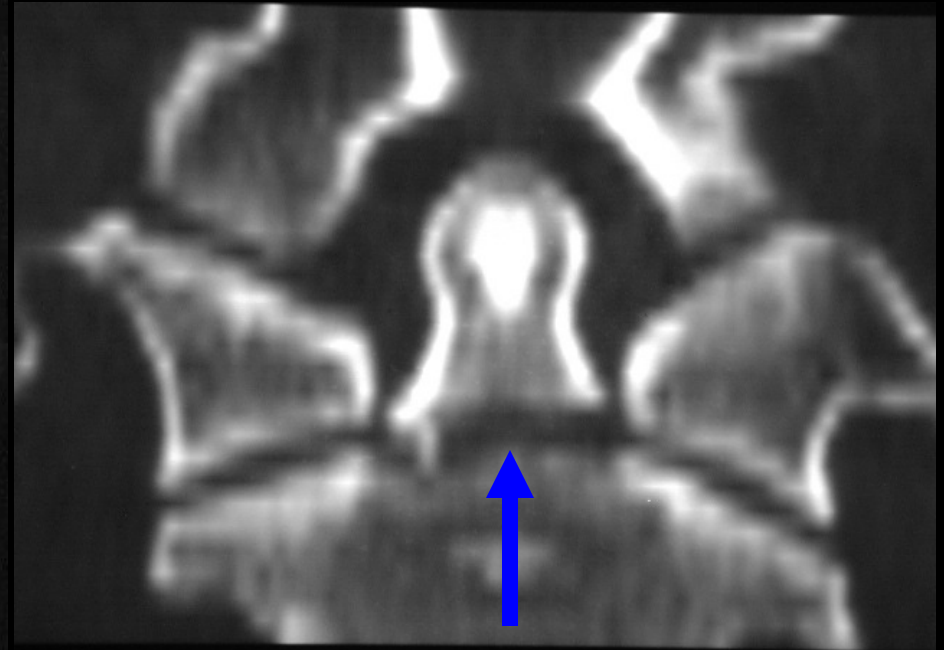
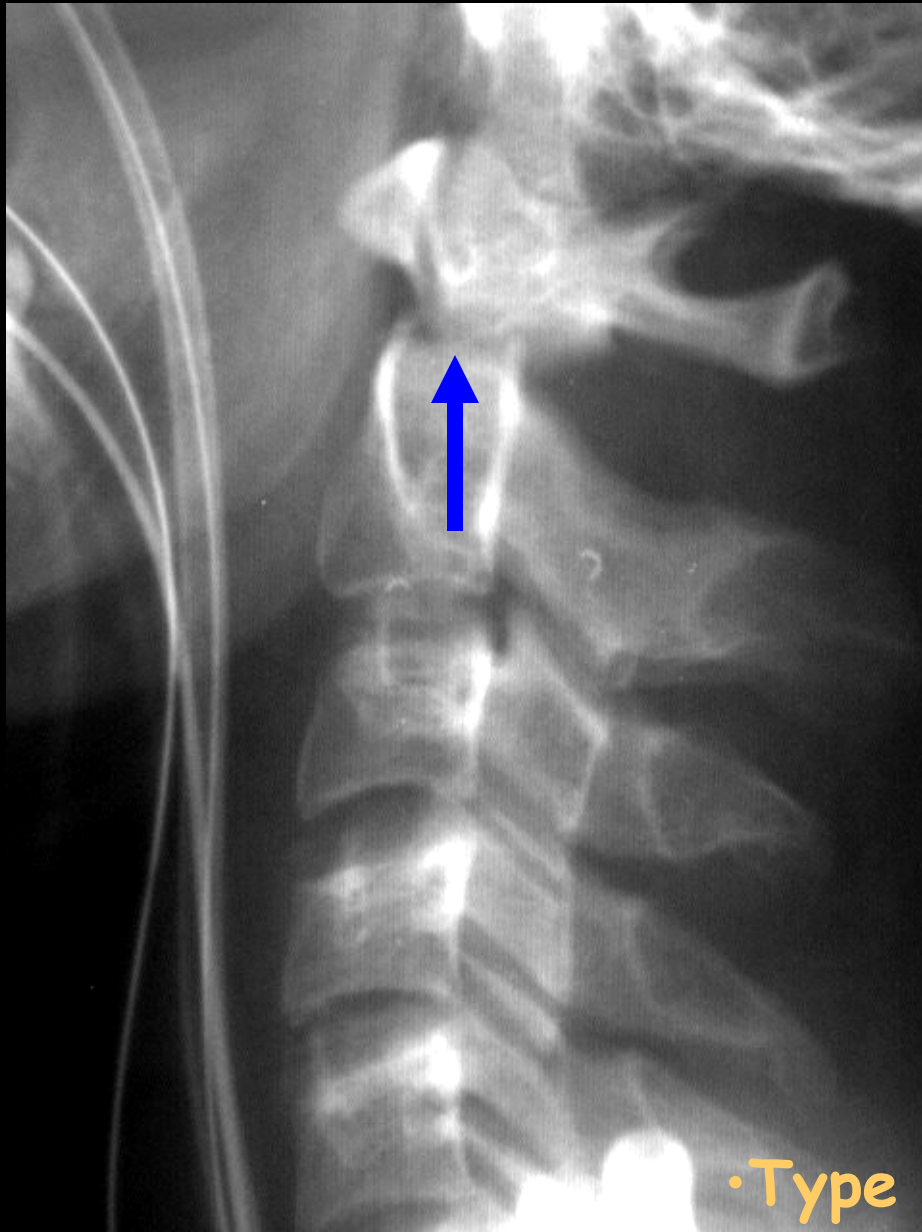
Type III
(LOW)

body of axis, facets (33%)

Prominent Mach Line

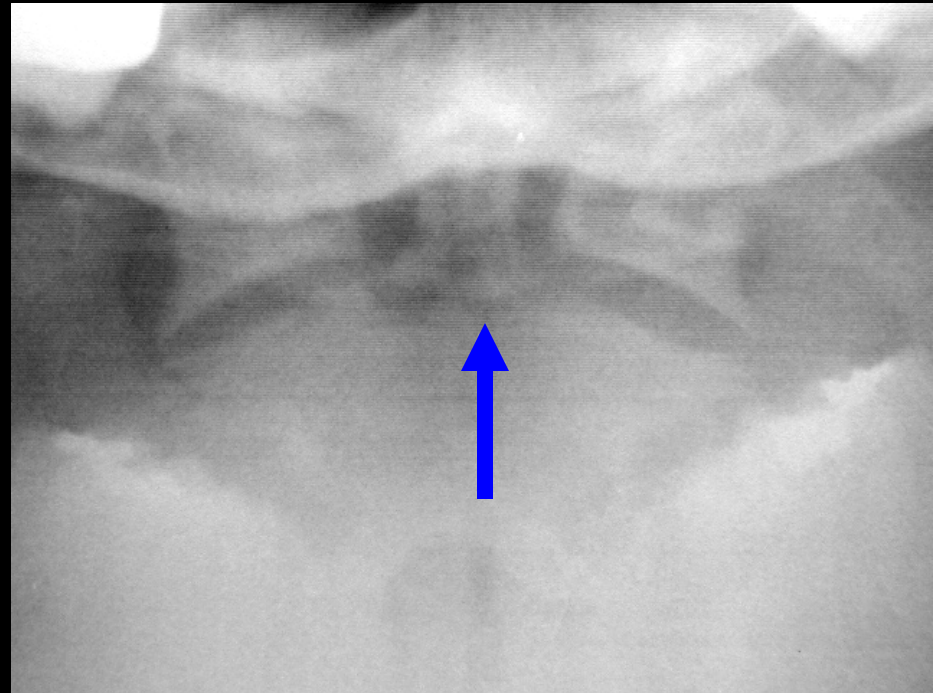


Type II

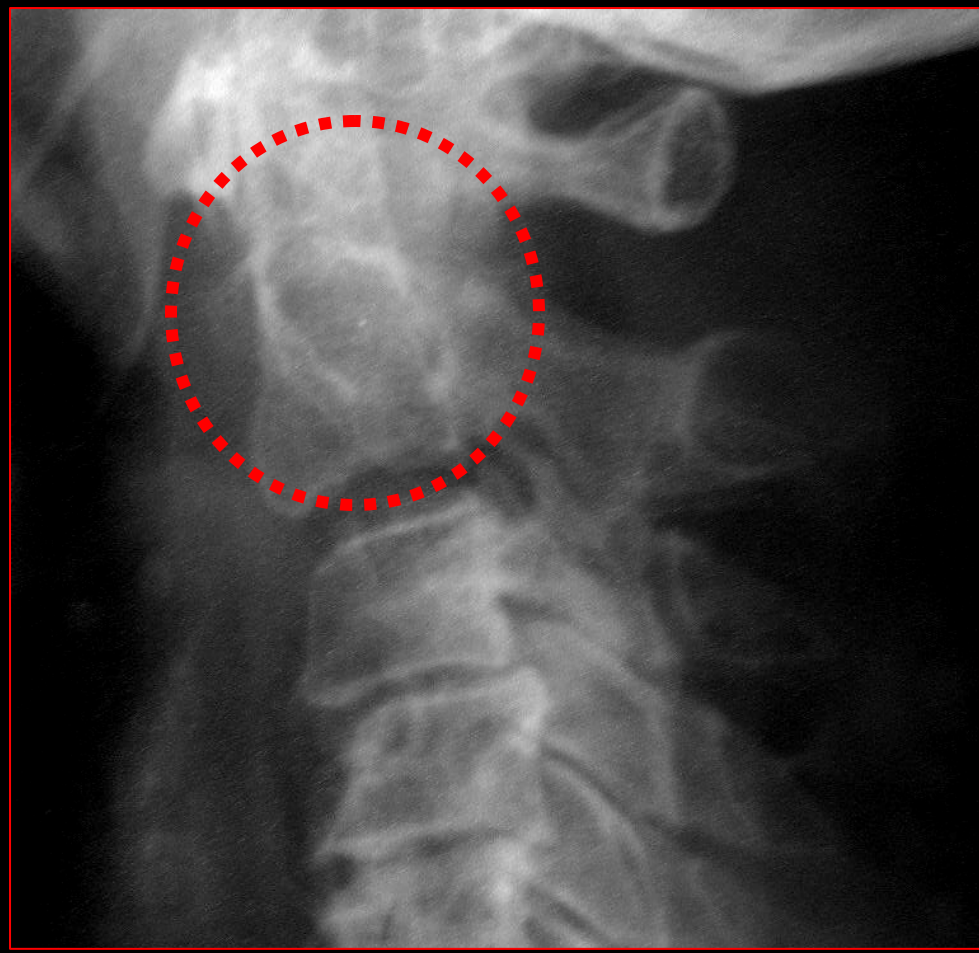


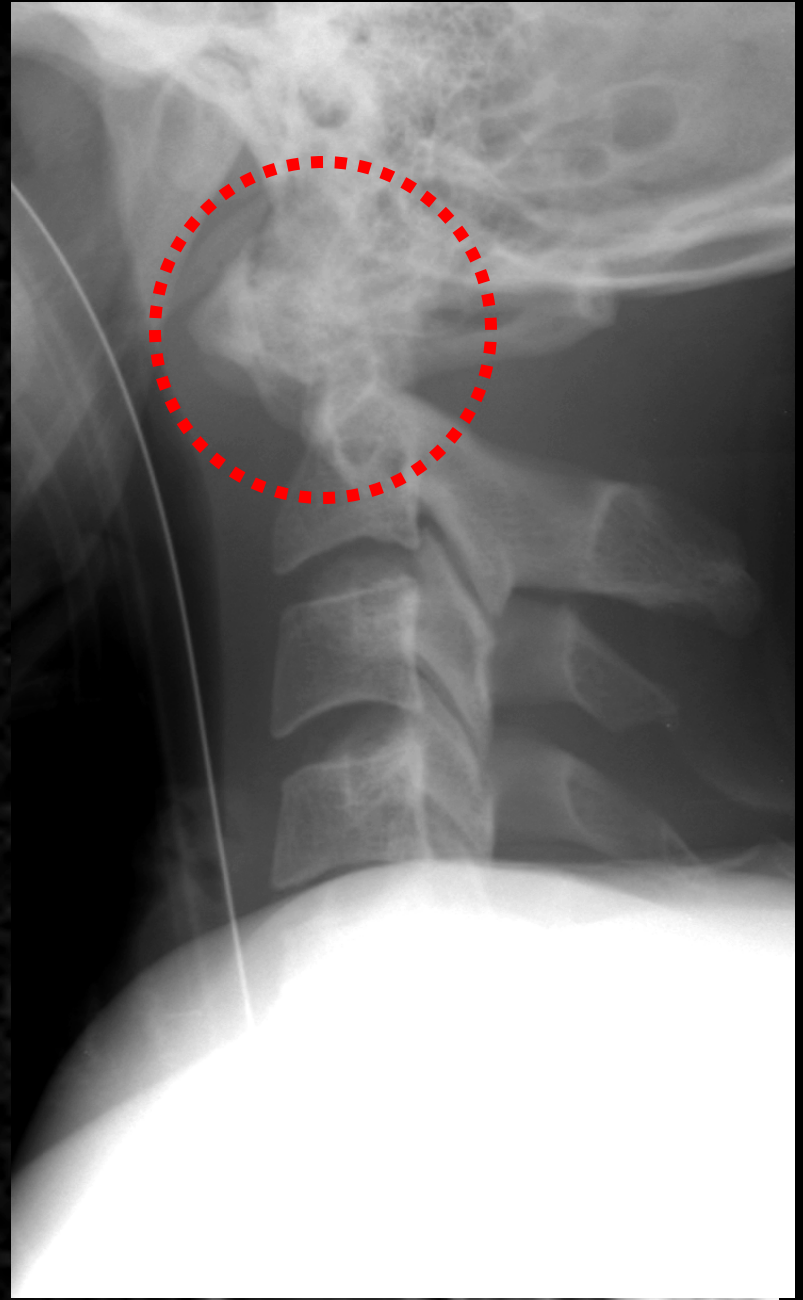
• Type II tendency to nonunion (64%)

Type II

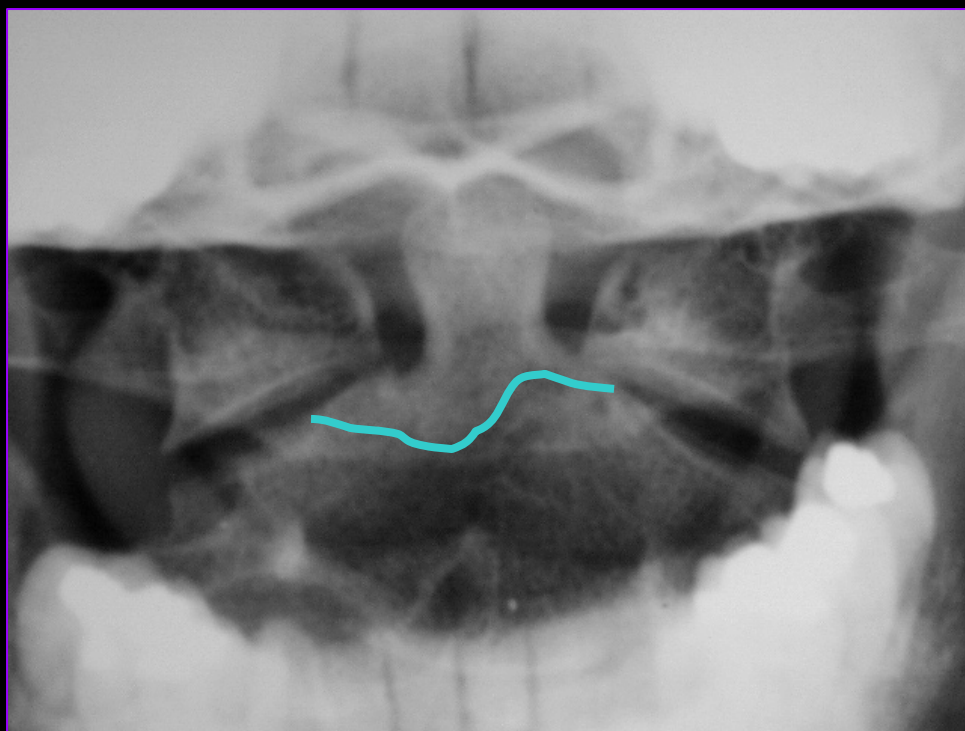


The Axis Ring

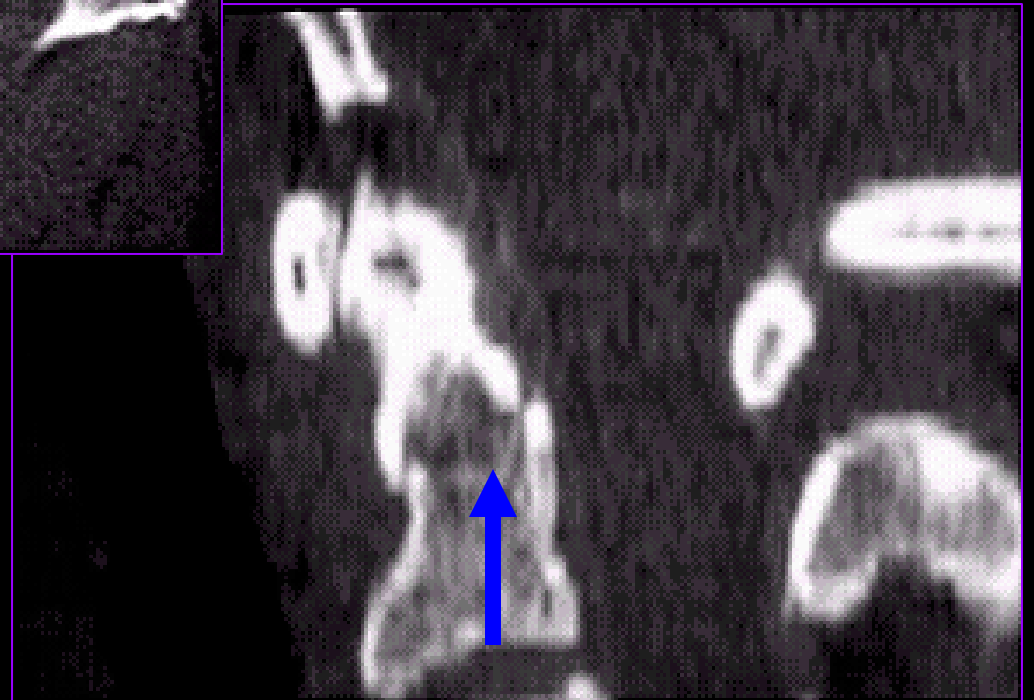
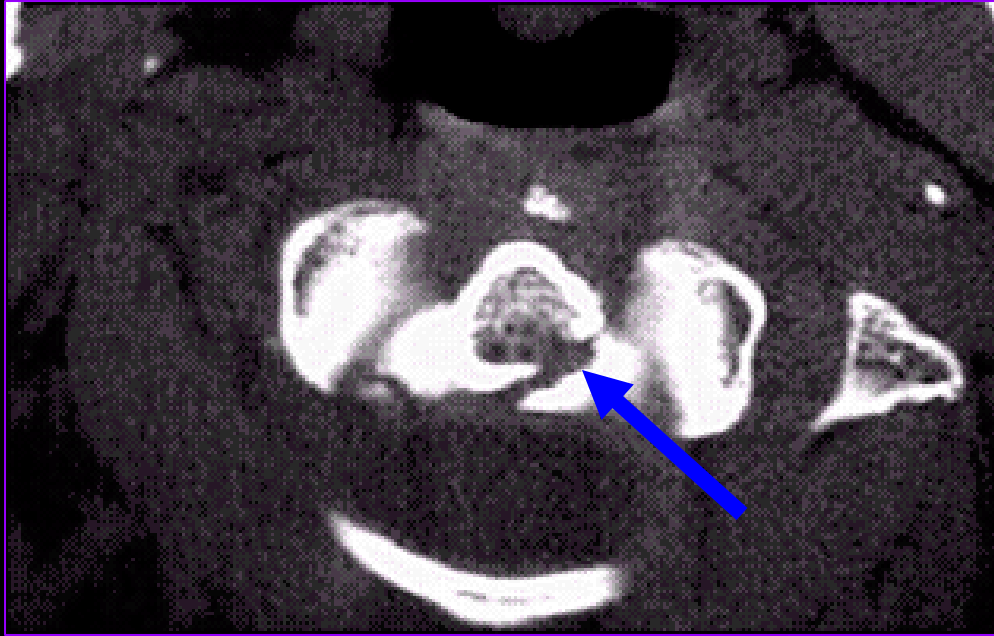




Type III



Type III



Transverse Atlantal Ligament Rupture

- Increased atlantodental space
- Anterior translation of atlas and skull
- Associated with Jefferson fracture

Occipitoatlantal Dissociation



- Disruption of craniovertebral articulation - ligament injury
- Complete → usually fatal from medullary transection; incomplete → subluxation
- Unstable; significant neurologic / vascular compromise
- rotational and shearing forces on alar and tectorial ligaments
- Difficult DX: suspect if STS w/o fracture

C-spine Fractures

- 20% of c-spine injuries have a second injury at another level
- Injuries, when multiple, occur within same group of mechanism
- Lower cervical spine is most commonly injured

Radiographic Instability

- Panjabi & White Criteria
 - > 3mm translation of vertebra AP
 - > 11 degrees in the sagittal plane
- Delayed instability - associated with incomplete healing of posterior ligament complex
 - Hyperflexion Sprain (Anterior Subluxation)
 - Simple Wedge Compression

Stability of C-spine Fractures

- UNSTABLE

- BID
- Flexion teardrop
- UID + fracture
- Jefferson
- Hangman's
- HD
- Extension teardrop (in extension)
- Odontoid

- STABLE

- Anterior sublux
- Simple Wedge
- Clay Shoveler's
- Laminar
- Pillar
- UID
- Simple Burst
- Atlas arch fractures

Summary

- Normal anatomy
- Common variants
- Imaging modalities
- Mechanism of injury
- Stable vs Unstable
- Checklist Approach
- Prediction Rule for Imaging

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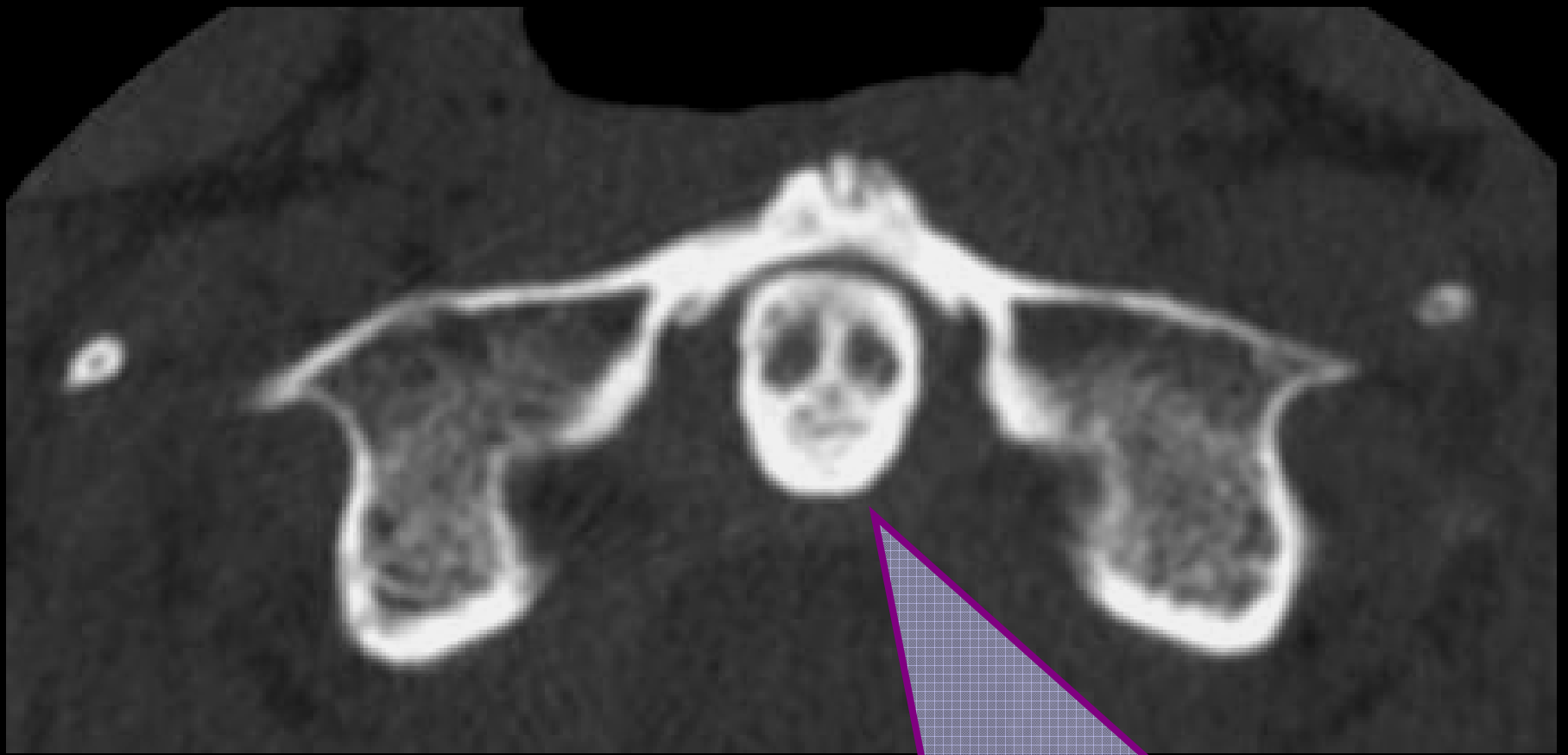
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Thank

You