Imaging of Spinal Trauma and Spinal Cord Injury: Cervical Spine

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OUTLINE

- Conceptual Framework
- Normal Anatomy
- Families of Injuries
- Pitfalls
- Normal Variants
- Emphasis on DX
Cervical Spine
Trauma Imaging

WHO?
HOW?
WHY?
• 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)
• THE FIVE LINES
  - Anterior prevertebral soft tissues
  - Anterior vertebral body line
  - Posterior vertebral body line
  - Spinolaminar line
  - Spinous process line
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
• 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
• 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 Interfacetial 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

>50%
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
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 subluxed/dislocated
- “fanning” with severe flexion of c-spine
  - Kyphotic deformity at and above level fracture
- Prevertebral STS
Flexion Teardrop Fracture
1. Unilateral Interfacet 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 Unilateral Unilateral Unilateral Interfacetal Interfacetal Interfacetal Interfacetal Dislocation

- “fanning”
- “laminar space” abrupt increase
- VB anterior sublux <1/2 AP dimension but >3mm
- 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 to superior facets of 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 >4mm, possible rupture transverse ligament
- Posterior arch FX
Jefferson Fracture
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, $\Delta$ 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
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
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. Pedicoloaminar 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
Pedicololaminar 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

C2 C3 C4 C5
C5 C4
disrupted lateral column "double outline" sign
Pediculolaminar Separation

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

- Tilt in the coronal plane
- Associated with vertebral artery injury
- Best seen on AP view and CT

FXs:
- uncinate 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 of articulating surfaces between axis and atlas
- Asymmetry of joint spaces between axis and atlas
- Asymmetry of lateral atlantodental intervals
- Pre-vertebral STS (traumatic)
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  base of dens, transverse (59%)
(HIGH)

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

Type III  body of axis, facets (33%)
(LOW)
Prominent Mach Line
Type II

• Type II tendency to nonunion (64%)
Type II
The Axis Ring
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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