IMAGING OF CERVICAL SPINE TRAUMA

Cervical Spine Trauma Demographics
- Most common spinal injury
- Responsible for 65% of all spinal injuries
- Mechanism: MVA/Fall/Sport Injury
- Spinal Cord Injury: 40% (10,000 annually)

Cervical Spine Trauma Patterns
- Areas most commonly involved
  - C1-2 (particularly in children)
  - C5-7
- Other fractures 20%
- Particular association of low cervical fracture with high thoracic and thoracolumbar injury

Cervical Spine Trauma Radiographic Evaluation
- Standard 3 view series
  - AP, lateral, open-mouth odontoid
- Oblique views (not used much today)
- Trauma oblique views (not used much today)
  - Developed by Gehweiler and Abel
  - X-ray tube angled 30° - 40° from horizontal
  - Add 15° cranial tube tilt
  - Better than Swimmer view for cervicothoracic junction
- Swimmer (Twining) view
- Upright lateral, flexion, extension (Flex/ex not recommended in the ER after trauma—not sensitive)

Cervical Spine Trauma Tomography
- Conventional tomography - not widely available
- CT - indispensable modality, widely available, rapid study
  - 1-5 mm sections, coronal/sagittal reconstructions
  - 3D helpful to depict spatial relationships
  - CT – indications:
    - High risk (velocity, other fractures, head trauma)
    - Mod risk but > 50 y.o.
    - Mod risk but intox/uncooperative
    - Neuro findings
    - Unable to obtain open-mouth or C7/T1
    - C-spine fx seen on radiographs
    - Equivocal findings on radiographs
    - Ankylosing spondylitis
- Many now advocate CT for all trauma cases in which the c-spine needs to be evaluated: expected to be national standard over the next few years

Cervical Spine Trauma MR Imaging/Myelography
- MRI indications
  - Post traumatic cervical myelopathy/radiculopathy
  - Clinical symptoms unexplained by other radiologic studies
  - Assess ligamentous injury
  - Possible disc herniation
- Myelography (CT) largely replaced by MRI
  - CSF obstruction
  - Nerve root avulsion, dural tear

Cervical Spine Trauma Stability
- Mechanical - ability to not deform under physiologic stress
- Neurologic - potential to produce new or increase previous deficit
- Radiographic signs: Instability
  - Widened interspinous spaces (>2 mm)
  - Widened apophyseal joints (>2 mm)
  - Anterior listhesis > 3.5 mm
  - Narrowed/widened disc space
  - Focal angulation of > 11°
  - Vertebral compression > 25%
  - Involvement of 2 or more columns

Radiographic Signs: Normal
- ABC’s - alignment, bone integrity, cartilage (joint/disc space), soft tissues
- Lateral view - anterior/posterior vertebral body arcs
  - Spinolaminar arc (except pseudosubluxation C2-3)
- AP view-spinous process and lateral mass arcs

Cervical Spine Normal Measurements
- Lateral atlantoaxial offset (“open mouth” view) - 2 mm
- Predental space - 3 mm adult; 5 mm child
- Anterior vertebral height vs. posterior - 2 mm (except C5)
- Pretracheal space at C6 - 22 mm adult, 14 mm child
- Listhesis with flexion/extension - 2 mm
- Facet width - 2 mm
- Retropharyngeal space at C2 - 7-8 mm
  - Exceptions: ET/NG tubes; inflammatory process/crying child
  - Interspinolaminar space - 2 mm between 3 continuous levels

Radiographic Signs of Trauma
- Alignment - disrupted cervical arcs
  - Focal kyphosis/scoliosis/loss of lordosis
- Spinous process rotation
- Vertebral listhesis
- Cartilage (joint/disc) space - facet widening
  - Interspinous widening (“fanning”)
  - Widened predental space
  - Widened/narrowed disc space
- Bone Integrity - fracture/cortical buckling
  - Disrupted posterior vertebral body line
  - Anterior wedging
  - Disrupted C2 ring (“fat” C2 sign)
- Soft Tissue - widened prevertebral space
  - Displaced prevertebral “fat” strip
  - Vacuum disc phenomenon
  - Deviated airway

**Cervical Spine Trauma Classification By Mechanism**

- Hyperflexion
  - Modified by rotation/lateral flexion
- Hyperextension
  - Modified by rotation
- Axial loading - burst
- Complex, poorly understood mechanisms

**Cervical Spine Trauma Hyperflexion Injuries**

- Account for 50 - 80% of injuries
- Flexion forces maximal at C4-C7 anterior; distraction posterior
- Sprain; compression fracture
- Facet fracture/subluxation/dislocation

**Cervical Spine Trauma Hyperflexion Injuries**

- Flexion teardrop fracture
- Clay (coal) shoveler fracture
- Lateral flexion fractures
  - Unilateral occipital condyle/lateral mass C1
  - Uncinate or transverse process

**Cervical Spine Trauma Hyperflexion Sprain**

- Disrupted one-level posterior ligaments by distraction
- Acute focal pain/limited ROM
- Delayed instability 30-50% - lack symptoms (delayed flexion/extension views)
- Radiographic findings
  - Focal kyphosis, mild anterolisthesis
  - Widened facet, interspinous/ interlaminar spaces
  - Widened space between posterior vertebral body and facet below
- Widened posterior, narrowed anterior disc space
- Compression fracture often associated
- All findings accentuated with flexion; MRI to confirm ligament injury

**Cervical Spine Trauma Wedge (“Compression”) Fracture**
- Compression is poor name—implies axial load
- Associated hyperflexion sprain common
- Usually stable unless > 25% compression
- Radiographs
  - Loss of height superior endplate
  - Focal cortical angulation
  - Band of increased density from impaction

**Cervical Spine Trauma Facet Injury: Unilateral**
- Hyperflexion and rotation
- Common injury - 13% of cervical injuries
- Radicular symptoms common
- Most frequent C4-C6
- Often mechanically stable, PLL partially intact
- Unstable with prominent articular mass/laminar fractures
- Radiologic Characteristics
  - Anterolisthesis < 50% vertebral width
  - Dislocated facet anterior (oblique view in foramen)
  - Abnormal spinolaminar space/facet rotation (“bow-tie” sign)
  - Spinous process rotation toward side of dislocation
- CT - “naked” facet (may be subtle and partial)
  - Contralateral facet subluxation common
  - Articular mass fracture (73%) isolating pillar (17%), posterior vertebral body fracture (25%)
- MRI/MRA - disc herniation and vertebral artery injury not uncommon

**Cervical Spine Trauma Facet Injury: Bilateral**
- Hyperflexion, maybe some rotation
- At least as common as unilateral injury
- Disrupted PLL, disc, and often ALL
- Unstable injury
- High incidence of cord damage (72% quadriplegia)
- Bilateral facet dislocation may be partial or complete
- Radiologic characteristics
  - Anterolisthesis > 50% vertebral body diameter
  - Dislocated inferior facets anterior to superior facets
  - Dislocated facets in foramen - oblique views
  - Findings of hyperflexion - fanning, focal kyphosis, disc narrowing
  - Spinous processes not rotated
- CT - “naked” facets, small fracture fragments often not seen on radiographs

**Cervical Spine Trauma Flexion Teardrop Fracture**
- Most severe/devastating flexion injury
- Usually lower cervical spine C5-6 (70% of cases)
- Diving accident shallow pool common cause
- Immediate, complete and permanent quadriplegia (90% of cases)
- Acute anterior cord syndrome - loss pain, temperature, and touch retention position, motion, vibration (posterior column senses)
- Radiologic characteristics
  - Involved vertebrae and levels above severe flexion
  - Vertebral body fracture with triangular fragment from anteroinferior corner
  - Central vertebral body not severely involved but posteriorly displaced
  - Bilateral facet subluxation/dislocation
Cervical Spine Fracture Clay Shoveler’s Fracture
- Avulsion C7, C6, T1 spinous process
- Result of abrupt flexion against opposing interspinous ligament
- Stable injury
- Oblique fracture spinous process
- May see “double” spinous process sign (AP radiograph)
- Spinous process fractures can also result from extension/direct trauma

Cervical Spine Fracture Lateral Flexion Injury
- Results from MVA side impact
- Not common - 6% cervical fractures - stable
- Compression fractures of occipital condyle, uncinate/transverse process, vertebral body
- Avulsion fractures/brachial plexus injuries distraction side

Cervical Spine Trauma Hyperextension Injuries
- Compression posteriorly, distraction anterior
- Usually caused by force to face/forehead
- Less common than hyperflexion injuries (19-38%)
- Atlas and laminar fractures
- Hyperextension dislocation; fracture/dislocation
- Extension teardrop fracture
- Hangman fracture
- Pillar fracture

Hyperextension Dislocation
- Common in older patients with spondylosis
- Rupture of ALL, disc and stripping of PLL (unstable)
- Patients usually severe neurologic symptoms - acute central cord syndrome

Hyperextension Dislocation
- Spinal cord impinged by subluxation and intact posterior elements
- Often recoils back to relatively normal position
- Radiographic characteristics
  - Relatively normal cervical alignment in quadriplegic patient
  - Soft tissue swelling (100%) - only finding 33%
  - Avulsed fragment anteroinferior - vertebrae (65%)
    - Longer horizontally (unlike extension teardrop fracture)
    - In young patients ring apophysis, no neuro deficit
  - Widened disc anteriorly and vacuum (15%)
Hyperextension Fracture/Dislocation Pedicolaminar Fracture-Separation

- Combined hyperextension, compression and rotation
- Fractures of pillar, lamina, pedicles and spinous process opposite side of translation
- Vertebral body often mildly (3-6 mm) anteriorly displaced
- Spinous process not rotated
- Disc narrowing and vertebral rotation above injury
- Opposite facet may be widened/dislocated
- Commonly involve foramen transversarium - vertebral artery (MRA)
- Important to distinguish from flexion injury

Hyperextension Teardrop Fracture

- Often occur in older osteoporotic patients
- Avulsion by ALL of triangular fragment
- Anteroinferior vertebral body (usually C2)
- Fragment vertical height same or larger than length
  - Unlike avulsion with hyperextension dislocation
- Soft tissue swelling more prominent in younger patients
- Unstable in extension

Atlas Fractures

- Avulsion of anterior arch C1
  - Rare stable injury
  - Results from anterior atlantoaxial ligament
  - Horizontal cleft in anterior arch (difficult on CT)
- Posterior C1 Arch Fracture
  - Bilateral posterior fractures (no anterior component)
  - No anterior soft tissue swelling; stable
  - Distinguish from normal congenital clefts

Laminar Fractures

Lamina crushed on extension from above/below
Often in older patients with spondylosis
Usually C5 to C7
Difficult to detect on radiographs
CT/conventional tomography optimal
Mechanically stable (intact anterior column/facets)
Neurologically unstable due to cord impinged by fragments

Traumatic Spondylolysis: “Hangman” Fracture

- Common - 5% of all cervical spine injuries
- Hyperextension is probably transient modified by flexion compression/ distraction
- Unstable injuries
- Neurologic symptoms unusual unless distraction
  - Large canal relative to cord at C2
  - “Auto-decompression” from bilateral posterior fractures
- Radiologic characteristics
  - Oblique C2 fracture - lateral view
  - Mild anterolisthesis, posteriorly displaced spinolaminar line
  - Associated injuries - anterior corner fractures C2/C3
    - C1/high thoracic fractures (10%)
    - Vertebral artery injuries

**Pillar Fracture**
- Not common; 3-11% of cervical injuries (C6-7)
- Hyperextension and rotation
- Articular mass compressed on side of rotation
- Stable, radiculopathy common without cord damage
- Radiologic characteristics
  - Subtle on radiographs
  - Disrupted lateral cortical margin (AP view)
  - Visualize facets on AP radiograph
  - Loss of posterior articular mass overlap
    - Lateral radiograph (“double outline” sign)
  - CT optimal - degree of fragmentation - other fractures, pedicle, transverse process, lamina

**Axial Compression Injury Burst Fracture**
- Not common, 4% of cervical injuries
- Only occurs where cervical spine in neutral position
- C1 - Jefferson fracture
- Lower cervical burst fracture C3-7

**Jefferson Fracture**
- Axial compression drives occipital condyles toward atlas
- Bilateral fractures anterior/posterior - lateral displacement
- Unstable; neurologic symptoms unusual
  - Large neural canal
  - Outward displacement of fragments
- Radiologic characteristics
  - Open mouth view best - laterally displaced lateral masses
  - Lateral radiograph may only show soft tissue swelling
  - CT optimal for bilateral fractures
  - Lateral mass displacement > 6.9 mm or predental space > 6 mm ruptured transverse atlantal ligament
  - Small nondisplaced fragment medial to articular mass - intact ligament
Cervical Burst Fracture
- Caused by vertical force driving nucleus pulposis through endplate with body exploding from within
- Mechanically stable unless posterior ligament injury
- Neurologically unstable - deficit may progress
  - Fragments change position
  - Symptoms transient paresthesias to quadriplegia
- Radiologic characteristics
  - Soft tissue swelling with straightening (but no kyphosis)
  - Retropulsed fragments disrupted posterior vertebral bodyline
  - Degree of vertebral body comminution variable
  - Vertical fracture - midline/eccentric
  - Disrupted joints of Lushka

Indeterminate Mechanism Cervical Injuries
- Odontoid fractures
- Occipitoatlantal dissociation
- Torticollis
- Rotary atlantoaxial subluxation/ dislocation

Odontoid Fracture
- Most common of C2 fractures (41%)
- 11-13% of all cervical spine injuries
- Mechanism - flexion and/or extension
- Other fractures (13%) - face, mandible, posterior arch C1, extension teardrop, hangman, atlantoaxial dissociation
- Radiologic characteristics
  - Prevertebral soft tissue swelling (may be only finding)
  - Type I - rare avulsion at tip from alar ligaments
  - It is more common to see normal variants that simulate this (ossiculum terminale)
  - Type II - at base (60%) - may miss on axial CT
  - High nonunion rate (72%), higher if displacement > 5 mm
  - Open mouth view (simulated by mach effect); atlantoaxial instability
  - Angulation of dens and cortex lateral radiograph
  - Os odontoideum distinguished by sclerotic margins
  - Type III - C2 body - disruption of Harris ring
  - “Fat” C2 sign, invariably heal

Cervical Spine Trauma Role of MR Imaging
- Thecal sac/spinal cord impingement
- Disc herniation/extrusion: 20-40% patients
  - Highest (100%) in patients with anterior cord syndrome
• Epidural hematoma (1-2%); spinal cord edema/hematoma
• Ligamentous disruption; cervical spondylosis
• Vertebral artery, injury - MRA
• Subsequent complications - syrinx, myelomalacia

**MR Imaging Spinal Cord Injury**

- Intramedullary swelling
  - T1W - Increased cord caliber
  - T2W - Increased signal
- Intramedullary edema
  - T2W - Increased signal
- Intramedullary hemorrhage
  - Variable MR appearance (often heterogeneous)
  - Bad prognostic sign

**MR Imaging Intramedullary Hemorrhage**

- Intracellular oxyhemoglobin
  - Intermediate signal all pulse sequences (hyperacute < 24 hrs)
- Deoxyhemoglobin
  - Low signal all pulse sequences (acute 1-3 days)
  - Can be up to 8 days with hypoxia
- Methemoglobin
  - Seen after 3 days
  - High signal T1W; low signal T2W

**Selected References**