Pediatric Cervical Spine Trauma

When Is Cross-sectional Imaging Needed?

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RSNA 2013
Spine Fractures in Children

- Uncommon – 1-3% of pediatric trauma patients
- 60-80% spine fxs in children involve C-spine, especially those <8 yrs of age
- Combined injuries common
  - >60% with C spine injury have head injury, neurologic deficit
  - 0.2% with head injury have C spine injury
- Causes
  - MVC, auto-ped, falls, sports
  - Birth trauma (breech delivery)
  - Non-accidental trauma
Pediatric Spine Differences

• Fractures are rare
• Clinical assessment challenging
• Immobilization can be difficult
• Ossification incomplete
  – Normal variants common
• Mild normal laxity can be present
  – Injuries can occur without fracture
Objectives

• Plan safe and effective imaging protocols for C-spine injuries in infants and children
• Understand mechanisms and patterns of pediatric cervical spine injuries
• Recognize anatomical variations and subtle injuries that benefit from cross-sectional imaging.

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What percentage of patients in your practice are < 15 years of age?

1) 80 - 100%
2) 50 – 79%
3) 25 – 49%
4) 5 – 25%
5) < 5%
When Is C-spine Imaging Needed?

- NEXUS (National Emergency X-ray Utilization) study
  - Children evaluated as part of large, multi-age study (9% of all patients)
  - Criteria
    - Midline cervical tenderness
    - Altered mental alertness
    - Evidence of intoxication
    - Neurologic abnormality
    - Painful distracting injury
  - Only 30 injuries in 3065 patients <18 yrs (0.98%)
    - 4 younger than 9 yrs
  - Decision rule predicted 100%, but not directly applicable to children
Radiographic Evaluation

• Lateral view most valuable
  – Should include C7-T1 disc space
  – 65 – 87% accuracy
• AP view usually obtained, but of questionable value
• Odontoid view difficult to obtain in children <5 years
  – Not needed under age of 9
• Flexion/extension views
  – Not used in acute injuries
  – May be helpful for FU of ligamentous injury
Radiographs for C-spine Injury in Children

• Useful for those familiar with the differences of the immature spine
  – Incomplete development
  – Normal degree of laxity
  – Challenges of obtaining good quality images
  – Congenital anomalies
Which of the following C-spine radiograph findings can be normal in children?

1) Atlantodental distance of 6 mm
2) Anterior tilting of the dens
3) 4 mm anterior displacement of C2 on C3
4) Basion to dens distance of 15 mm
5) Anterior wedging of the C3 vertebral body
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Precervical Soft Tissue Thickness

Can be misleading on radiographs
Normal Neurocentral Synchondrosis (gone by age 8)
Dens Tilting

- Posterior often normal
- Beware of anterior or lateral tilt
Physiologic Hypermobility in Young Children

- Ligamentous laxity leads to misleading appearances on XR
  - Pseudosubluxation
  - Increased interspinous distance
  - Increased dens-to-C1 distance
Wide Interspinous Distance

- Can be as wide as 10-12 mm
Physiologic Subluxation

- 1-2 mm
- Normal spinolaminar line
- Caveat
  - Apophyseal joints intact
Pseudosubluxation occurs in 19% of normal children between 1 – 7 yrs age.
Normal V-shaped apophyseal joints (mild)
Anterior Atlantodental Distance

- May be as wide as 4-5 mm
Change in atlantodens interval of 2mm is normal, with maximum of 5 mm
Normal Mild Lateral Motion
C1 Anomalies

- Common
- Vary from absent posterior arch to hairline defects
Congenital Defects of C1

- Stable as long as dens is normal
Clues to Congenital Defects

- Tapering or rounding of margins
- Hypertrophy of anterior arch
Patterns of Injury

• Infantile (before head control)
  – Birth injuries (traction, torsion)
  – Shaking
  – Stretching may lead to vertebral artery injury

• Young juvenile (head control-8 yrs)
  – Usually above C4
  – Fulcrum at C2-3
  – Incomplete development of vertebra complicates assessment
Patterns of Injury

• Old juvenile
  (greater than 8 yrs age)
  – More like adults
  – Midcervical more common
  – Most ossification centers fused
    • Except for os terminale, ring apophyses, spinous and transverse processes
What initial cervical spine screening exam is used at your facility for children with GCS > 8?

1) None
2) C-spine radiographs
3) C-spine CT
4) C-spine CT if non-verbal
5) MRI
Spine CT in Children

• Use has increased
  – Higher in teenagers, at non-Level I Trauma centers
    Mannix, Acad Emerg Med. 2011 September; 18(9): 905–911

• Concerns about radiation dose in children
  – Dose to thyroid 90-200 X that of multiple x-rays
    Excess risk for thyroid CA 2X higher in 0-4 yr olds
    Jiminez, Pediatr Radiol 2008; 38:635-644
  – Adolescents with spine injury get more studies and have cumulative effective dose 3X that of children
    Lemburg, AJR 2010; 195:1411

• Osseous injuries usually visible on XRIs
  – 4/147 with CT showed abnormality, all seen on lateral Xray
Are Radiographs An Adequate Screening Exam?

- Nigrovic, PECARN C-spine study group. Pediatr Emerg Care 2012; 28(5):426-432
- Multicenter study of 206 children <16 yrs age
  - 168/186 injuries identified on radiographs
  - Sensitivity 90%
  - Missed 15 fractures and 3 isolated ligamentous injuries
- Factors showing higher risk:
  - Abnormal mental status
  - Endotracheal intubation
  - Focal neurologic deficits
When Is CT Worthwhile?

• Consequences of a missed cervical injury can be devastating
  - Error rates (included CT) – false + and -
    • 8 yrs or less – 24% (4/17)
    • 9 yrs or greater – 15% (3/20)
    • Occiput – C2 most common sites
    • Failure to recognize normal anatomy, normal variants

• Ages < 10 years – Should be restricted to problem solving when radiographs are inconclusive
  - Natl. Institute of Health and Clinical Excellence (U.K.) –
    • GCS 8 or less
    • Strong clinical suspicion with normal XR
C1 Synchondroses

Anterior arch:
Ossifies by 1 year
Fuses by age 7

C2 Synchondroses

Injuries can occur at synchondroses, so be wary of asymmetrical widening
Unilateral Absence of C1

C1-2 anomalies are common, difficult to assess on radiographs.

1/3 develop torticollis and symptoms after birth.
Jefferson Fracture

- Uncommon in children
- Falls on head, diving accidents
- Often not visible on radiographs
MRI for Pediatric C-spine Injury

- Highly sensitive for soft tissue injury
  - Sensitivity 100%, NPV 75%, PPV 100%
  - Relevance of subtle findings not established
- Decreases time to clearance and cost
- Cost effective in certain patients
  - Obtunded or non-verbal with severe mechanism of injury
  - Equivocal radiographs
  - Neurologic findings with normal XRs
  - Inability to clear spine within 72 hours
    Frank, Spine 2002; 27(11): 1176-1179
- Important in patients with unstable injuries
C-spine MRI Protocols

- Axial
  - T2 gradient echo
  - T1
- Sagittal
  - T1
  - STIR or T2 fat sat
- Coronal
  - STIR
Dens Anomalies

Prone to instability in some patients

Swischuk, Imaging of the Cervical Spine in Children
Os Odontoideum

- Os is often fused to anterior arch of C1 or to basion
- Posterior atlantodental interval more important than AADI
Controlled flexion/extension under fluoroscopy
Clinical Implications of Os Odontoideum

- Pain
- Myelopathy – varies from transient to paralysis
- Asymptomatic
  - Cases of sudden injury after minor trauma
- MRI evaluates cord atrophy
Odontoid Fractures

- Most common pediatric cervical fracture
- Most occur through basilar synchondrosis
  - Fuses at 5-7 yrs, but remains partially visible until 11
- Heal with halo immobilization (6-8 weeks)
Type II Dens Fractures

Displacement can be subtle on radiographs
Fracture at Neurocentral Synchondrosis
Fracture at C2 Synchondrosis

- Anterior tilt
- Anterior offset
Fracture-Subluxation at C2 may resemble physiologic laxity
Atlanto-occipital dissociation:

1) Is more common in adults than children.
2) Is fatal in 90% of patients.
3) Can manifest as asymmetry of the AO joint.
4) Cannot be diagnosed reliably with radiographs or CT.
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Atlantoccipital Dislocation

- More common in children than adults
  - Small condyles
  - More horizontal orientation
- High velocity trauma
- Survival improving, but neurological deficits are common
**Basion – dens distance**
Should be 12 mm or less

**Powers ratio**
Should be less than 1
Atlantoccipital Dissociation

- CT allows more accurate measurement of dens-basion distance
- Soft tissue injuries visible when severe
Retroclival Hematoma

- Rare injury
- Elevated tectorial membrane
- Associated with CC ligamentous injuries
- May be treated conservatively if patient asymptomatic
Condyle – C1 Interval

- Highest sensitivity and specificity for AOD
- 4-5 mm or greater – abnormal
- Asymmetry, offset
6 yr old in MVC
Isolated Ligamentous Injuries

- Rare
- Avulsed fragments difficult to see

Transverse Ligament Injury with Avulsion
C1-2 Ligamentous Injuries
Cervical Instability –– Trisomy 21

- Due to ligamentous laxity
- Can occur at multiple levels
- C1-2 instability – 14-17%
- C1 hypoplasia (posterior) - 26%
- <10% have signs of cervical myelopathy
- CT or MRI not usually needed
SCIWORA Injury

- Incidence 6 -20%
- Normal ligamentous laxity allows excess motion without bone injury
- Most common at C5-8
- Spinal column can withstand 2 in. of distraction (infants) – cord and vessels only .25 in.
Pediatric Cervical Injuries without Fracture

- Children under 8 yrs age
  - More severe injuries
  - Upper spine more common
- 52% - delayed paraplegia (up to 4 days)
- Susceptible to reinjury - occult instability?
Cervical Epidural Hematoma

• May result from shearing forces without spine fracture
Spine Injuries in Children

- CT best for questionable fractures on radiographs, neurologic symptoms
- Mild laxity is normal
  - MRI may help identify subtle instability or injuries
- Anomalies
  - CT for better anatomical definition
  - MRI for effects on spinal cord
- More cross-sectional imaging may be warranted in infants with NAT