Important Pediatric Differences

• Not just “little adults”
• Anatomic / Radiographic differences/variants
• Flexible
• Large heads relative to body
• Physeal/synchondrosis/periosteal tube fractures - apparent dislocations
• Surgery rarely indicated
• Immobilization well tolerated
Epidemiology

- Incidence
  - 108 per million
- 3M:2F
- >15 yr highest risk
- Etiology:
  - MVC
  - Falls
  - Sports
  - Non-accidental Trauma

Epidemiology

- Injury Distribution

<table>
<thead>
<tr>
<th>Age Group</th>
<th>Cervical Spine (%)</th>
<th>Thoracic Spine (%)</th>
<th>Lumbar Spine (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-4 yrs</td>
<td>52%</td>
<td>27%</td>
<td>21%</td>
</tr>
<tr>
<td>5-9 yrs</td>
<td>42%</td>
<td>24%</td>
<td>34%</td>
</tr>
<tr>
<td>10-14 yrs</td>
<td>43%</td>
<td>29%</td>
<td>28%</td>
</tr>
<tr>
<td>15-20 yrs</td>
<td>41%</td>
<td>26%</td>
<td>33%</td>
</tr>
</tbody>
</table>

- Overall Neurologic Injury 15%

> 50% cervical origin

Epidemiology

- Patterns vary
  - Age (Adolescents predominate)
  - Race
    - Ie. African American – 24% firearm, caucasian – 1% firearm
  - Economic Status

- Young children <9yo
  - Ligamentous injury > Bony Injury
  - SCIWORA

Cervical Spine Injuries

- **Rare** - < 1% of children’s fractures
- **Neurologic Injury** – “rare” to 44%
  
  Mortality in ≤ 9 yrs

- **Age ≤ 7 yrs**
  - Majority **upper cervical**, esp. craniocervical junction
  - Larger Head:Torso ratio

- **Age > 7 yrs**
  - **Lower cervical** injuries predominate

Cervical Spine Injuries

- Upper cervical anatomy
  - Occiput-C1 articulation horizontally based
  - Child: large head/body ratio
  - Prone to occiput-C1 injury
Anatomy – C1

- **Birth**: 3 ossification centers
  - Body & 2x neurocentral arches

- **7 yrs**: Neurocentral synchondroses fuse

Anatomy – C2

- **Birth**: 4 ossification centers
  - Body, 2x neural arches, dens
- **3-6 yr** – Fusion of:
  - Neurocentral synchondroses
  - Dentocentral synchondrosis

*Significance*: NO synchondrosis or physis should be visible on open mouth odontoid XR after 6 years of age
Anatomy – C2

• Summit ossification center
  – Appears at 3 – 6 yrs
  – Fuses ~ 12yrs

Do not confuse with os odontoideum.

Creates confusion with studies

Anatomy – C2
Os Odontoideum

- Origin hypotheses:
  - Congenital
  - Traumatic (favored)
- Potential C1-C2 instability
- Usually asymptomatic
- Debate about participation in contact sports

Arvin et al. Os Odontoideum: Etiology & surg Management, Neurosurgery, 2009
Subaxial Cervical Anatomy
C3 – C7

- **3-6 yrs**: Neurocentral synchondroses fuse
- Vertebral bodies *wedge shaped* until **7yo** → bodies square out
- Superior and inferior cartilage endplates firmly attached to disc
Mechanism of Injury

• Young child C-spine susceptible to injury:
  – *Very mobile* – ligamentous laxity & shallow angle of facet joints
  – Relatively larger head
  – Delayed ossification of uncinate processes
  – Anterior vertebral body wedging
  – Underdeveloped para-spinal muscles

• Combination leads to upper cervical injuries

• Most Common Etiologies: MVC & Falls
C-Spine Fracture Pattern

• Junction b/w cartilage endplate and bony vertebral body
• Fractures *split the endplate* b/w columnar growth cartilage and calcified cartilage
• Does *not* typically occur by fracture through the endplate – disc junction

Transport & the Pediatric C Spine

- **Large head!**
  - Standard backboard → increased flexion of C spine

- Remedy:
  - Pediatric backboard w/ cut-out for head (A)
  - Elevate trunk relative to head (w blankets) (B)

C Spine Evaluation in Children

- Mechanism extremely important
- High incidence associated systemic injury
  - 50% other injuries, 20% neuro injury
- Physical exam – tenderness (age, distracting injuries), neurological exam
  - Unexplained hypotension = SCI
- Xrays not commonly used
- CT scan to define bony detail
- Low threshold to obtain MRI w/ stir

ED C Spine Evaluation

PR – Powers Ratio. ADI – Atlanto-dens interval. & Others (see reference)

Swichuk’s Line

Spinolaminar line drawn from C1 to C3
Distinguishes normal variant from Hangman’s fracture
C Spine XR Evaluation in Children

- Be aware of normal ossification centers and physes

- C2/3 pseudosubluxation common in children < 8yrs (Check spinolaminar line of Swischuk)

- Evaluation of anterior soft tissues unreliable in crying child

- In uninjured normal patients <8yrs, 20% can demonstrate ADI 3-5mm (Adult ADI normal ≤ 3mm)

Normal Radiographic Findings

- Ossiculum terminale
- C1 override C2 (20%)
- Multiple secondary ossification centers
- Normal synchondrosis
- Odontoid angulation (4%)
- Basilar subdental synchondrosis (>7ys)
- Pseudosubluxation (<9yrs)
- $ADI < 5\text{mm}$ (why? ↑ ligamentous laxity & cartilage components in kids)
- RSTS
- Normal anterior body wedging <7yrs
- Horizontal facets as pillar fxs
- Single-level kyphosis (16%)
C2-3 Pseudosubluxation

• Anatomic variant - C2 pseudosubluxing on C3 (occasionally C3 on 4)
  – Swichuk intact

• Differentiate from true injury (which is uncommon):
  – Presence of prevertebral soft tissue swelling
  – **Break** in the spinolaminar line of Swischuk

Traumatic Spinal Cord Injury

- Rare in children
- Better prognosis for recovery than adults
- Treat aggressively with immobilization +/- decompression
- Late sequelae = paralytic scoliosis (affects almost all quadriplegic children if injured when < 10 yrs old)

SCIWORA
Spinal Cord Injury W/o Radiographic Abnormality

- Distraction Mechanism - Spinal column more flexible than Spinal Cord
- Cord traction injury w/ normal XRs
- Usually upper C spine and <8yrs
- MRI – diagnose cord injury & eval posterior soft tissues
- SCIWORA & dislocations ↓ w/ age
  - 16.99% toddlers (w C spine injuries)
  - 5.04% young adults (w C spine injuries)

High Suspicion - GCS 3 w/ normal CT head →
may be upper cervical spinal cord injury!

SCIWORA

- $\text{Stretch}_{\text{skeleton}} > \text{Stretch}_{\text{cord}}$

- Stretch Capacity
  - Spinal Column 2” > Spinal Cord $\frac{1}{4}”$

- Cord restricted by horizontal cervical roots, foramen magnum

Leventhal, JPedsOrthop 1960
C-Spine Clearance & Evaluation

- 3 view plain film series still used
- Low threshold for further imaging
- CT scan upper C-spine (O-C2)
- Consider MRI if intubated or obtunded

C-Spine Clearance & Evaluation
Not “Cleared” by Plain Radiographs

• CT scan
  – **Advantages** – Fast, No sedation or anesthesia
  – **Disadvantages** – radiation, Limited evaluation soft tissues & cartilage

• Assess alignment & bony injury

Not “Cleared”

- MRI scan – currently favored
- Rapid sequence/image acquisition algorithms – gradient echo
- Evaluate non osseous tissues and spinal cord
- MRI scan should be considered in critically injured child for whom adequate plain films cannot be obtained to rule out spinal injury

If not “Cleared” within 12 Hours

- Switch to pediatric Aspen or Miami J collar
- Consider CT or MRI

Child in C-spine collar

Meets NEXUS criteria:
1. Absence of midline cervical tenderness
2. No evidence of intoxication
3. Normal level of alertness
4. Normal neurological exam
5. Absence of a painful, distracting injury

Trauma evaluation and Cervical spine radiographs:
AP/lateral/odontoid for age > 5 yr
AP/lateral only for age ≤ 5 yr

C-SPINE CLEAR

Communicative child ≥ 3 years

YES

Meets NEXUS criteria:
1. Absence of midline cervical tenderness
2. No evidence of intoxication
3. Normal level of alertness
4. Normal neurological exam
5. Absence of a painful, distracting injury

NO

Normal neurological exam

YES

NO

Abnormal neurological exam

Spine Service Consult

Spine Service Consult

Spine Service Consult

ABNORMAL

ABNORMAL

Flexion/Extension C-spine x-rays

ABNORMAL

C-SPINE CLEAR

NO

Normal neurological exam

YES

NO

Leave in collar; refer to neurosurgery clinic in 1-2 weeks

If You See a Spine Fracture in a Child

• Look hard for another one

“The most commonly missed spinal fracture is the second one”. -J. Dormans

• High incidence of noncontiguous spine fractures in children
Thoracic Spine Fractures

• Less common spinal fracture in children than in more mobile regions
• Rib cage offers some support / protection
• Motor vehicle crashes, falls from heights
• Child abuse in very young
• Compression fractures in severely osteopenic conditions (OI, chemotherapy)
• Multiple contiguous – hyperflexion neck/chest injury (motorcross)
• 11M, motorcross, flew over handlebars
Thoracic Spine Fracture Dislocations

- High energy mechanisms
- Often spinal cord injury, can be transected
- Prognosis for recovery most dependent on initial exam – complete deficits unlikely to have recovery
- Infarction of cord (artery of Adamkiewicz) may play some role – especially in delayed paraplegia

Thoracolumbar Junction Injuries
T11-L2

- Classically lap-belt flexion-distraction injuries
- Chance fractures and variants
- High association with intraabdominal injury (50-90%)
- Neurologic injury infrequent but can occur

Chance Fractures and Variants

- Flexion over fulcrum
- Posterior elements fail in tension, anterior elements in compression
  - Can occur through bone, soft tissue or combination
- Treatment
  - Pure bony injuries can be treated with immobilization in extension
  - Partial or whole ligamentous injuries may be best treated with surgical stabilization

Seatbelt/Flexion-Distraction Injury Classification

A B

C D

Bony Flexion Distraction Injury
Ligamentous Flex/Dist Injury 1

- 5yF, MVC, bowel perforations

**Tx:**
L 2-3 open short-segment fixation/fusion
Ligamentous Flex/Dist Injury 2

12yM, MVC, initial *missed injury*

Upright lateral + Flexion/Extension XR

Tx: L3-4 *Percutaneous fusionless fixation* w/ removal @ 6mo

30 months post op
Combined (Bony+Ligamentous) Flexion Distraction Injury

16yM, MVC, bowel injury

Tx: Closed reduction, perc fixation

Postop

3 yrs postop
Healed
Broken
screws (disc motion)
- removed
Lap Belt Sign

- High association with intraabdominal injury and lumbar spine fracture

- Lumbar spine films mandatory

Lumbar Spine Fractures
L3-L5

- Infrequent until late adolescence
  - Can be associated with lap belt injuries
- Usually compression fractures that are stable injuries
- Burst fractures
  - May progress to kyphosis
- Lumbar apophyseal injuries
  - Posterior displacement can cause stenosis, may need surgical excision

Lumbar Apophyseal Injuries
Slipped Apophysis

• Compression-shear injuries
• Same age group as SCFE
• Typically adolescent males, inferior endplates of L4 or L5
• Traumatic displacement of vertebral ring apophysis and disc into spinal canal
• If causes significant compression of cauda equina, treatment is surgical excision

Burst Fractures

- Usually in older adolescents
- Treatment similar to adults
- May not need surgery in neurologically intact patient
- Injuries at thoracolumbar junction higher risk for progressive kyphosis

Bibliography

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