Fractures of the Spine in Children

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February 2016

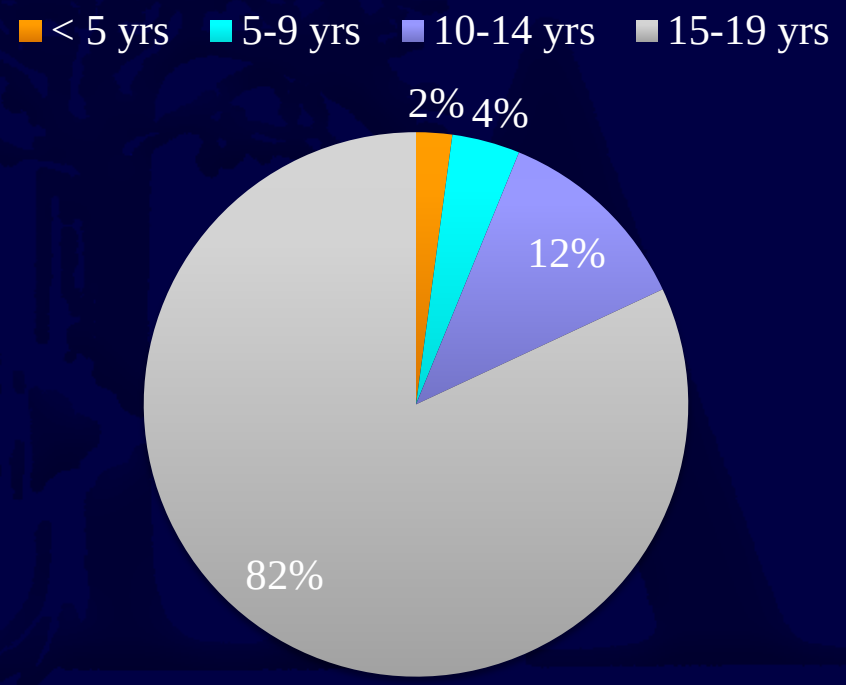
Original: *Steven Frick, MD; March 2004*
Past Revised: *Steven Frick, MD; August 2006*
Timothy Moore, MD; November 2011

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

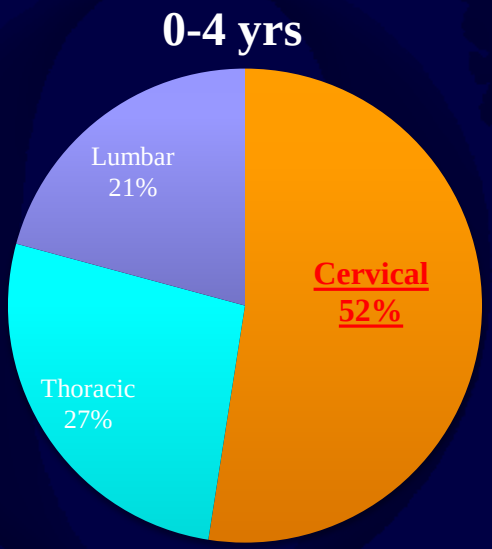


Mendoza et al. *Pediatric Spine Trauma in the United States*. Iowa Orthopaedic Journal, 2015.
Akbarnia (Ed) (2011). The Growing Spine. 1st Ed. Springer, 2011.

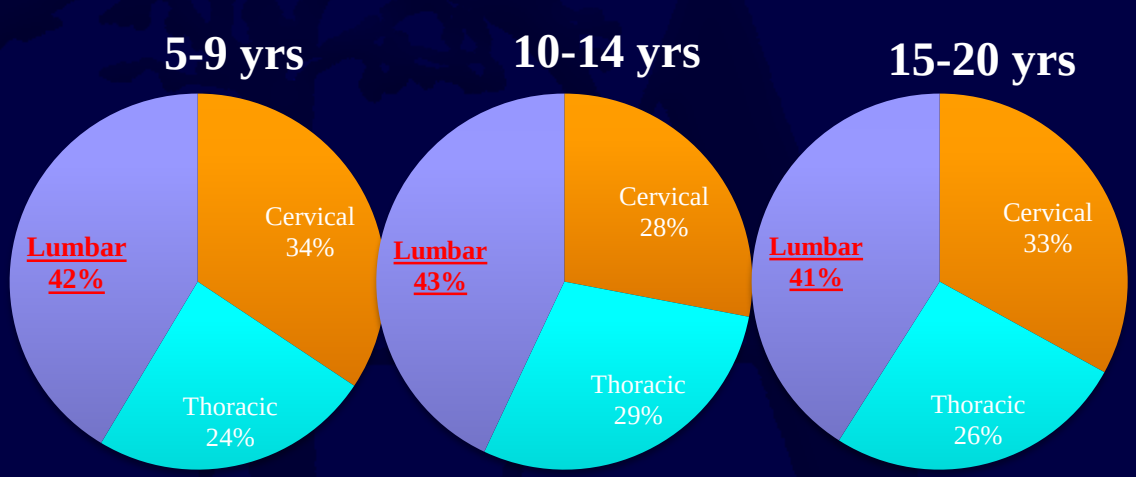
Epidemiology

- **Injury Distribution**

0-4 yr *Cervical* Spine



5-20 yr *Lumbar* Spine



- ***Overall Neurologic Injury 15%***

> 50% cervical origin

Mendoza et al. *Pediatric Spine Trauma in the United States*. Iowa Orthopaedic Journal, 2015.

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

Knox et al. Spine Trauma in Very Young Children. *JPedsOrthop*, 2014.
Piatt et al. Pediatric Spinal Injry in the US: Epidemiology and Disparities. *JNeurosurgPediatr* 2015.

Cervical Spine Injuries

- **Rare -** < 1% of children's fractures
- **Neurologic Injury** – "rare" to 44%
- ⑩ ↑ Mortality in ≤ 9yrs

- Age ≤ 7 yrs
  - Majority upper cervical, esp. craniocervical junction
  - Larger Head:Torso ratio
- Age > 7 yrs
  - Lower cervical injuries predominate

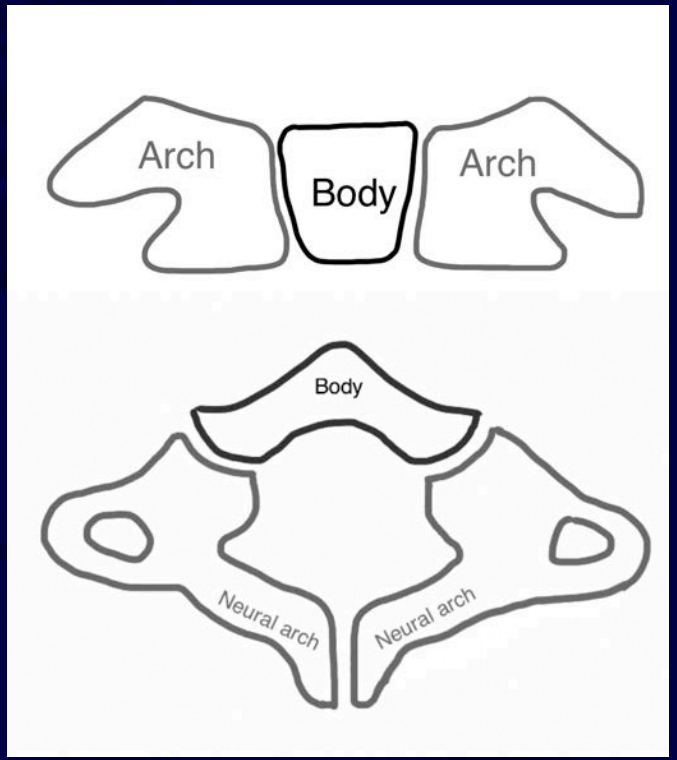
Jones. Pediatric cervical spine trauma. *J Am Acad Orthop Surg*. 2011;19:600
Shin. Pediatric C Spine and SCI: A National Database Study. Spine. 2015;Epub Ahead of print.

Cervical Spine Injuries

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

Anatomy – C1

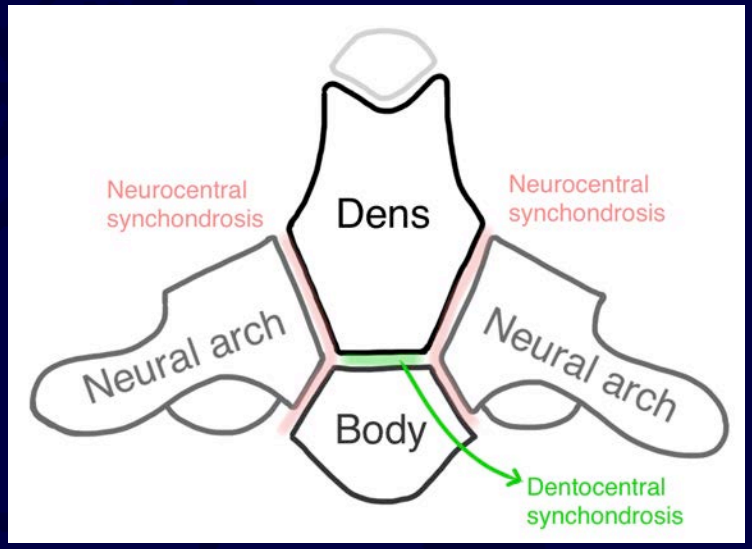
- **Birth**: 3 ossification centers
  - Body & 2x neurocentral arches
- **7 yrs**: Neurocentral synchondroses fuse



Copley. Cervical spine disorders in infants and children. *J Am Acad Orthop Surg.* 1998;6:204.

Anatomy – C2

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

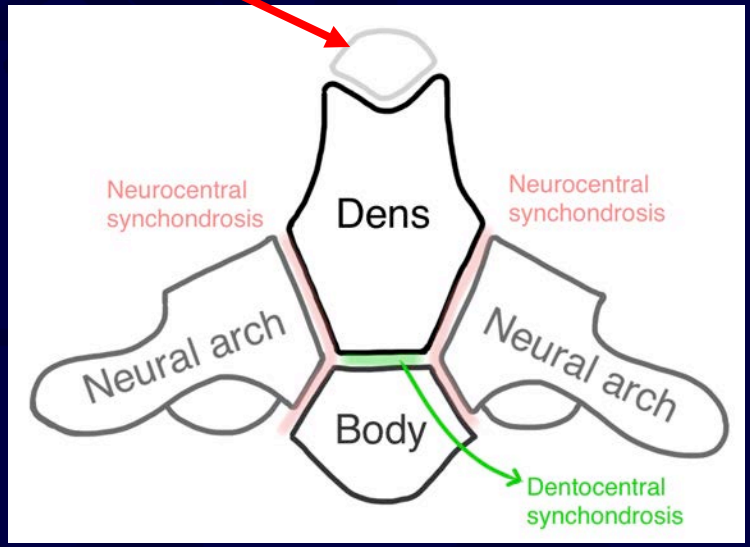


Significance: NO synchondrosis or physis should be visible on open mouth odontoid XR after 6 years of age

Copley. Cervical spine disorders in infants and children. *J Am Acad Orthop Surg*. 1998;6:204.
Obrien et al. The Dens: normal development, dev variants and anomalies and traumatic injuries. *JClinImagingSci*. 2015;5:38

Anatomy – C2

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



Do not confuse with os odontoideum.

Creates confusion with studies

Copley. Cervical spine disorders in infants and children. *J Am Acad Orthop Surg*. 1998;6:204.
Obrien et al. The Dens: normal development, dev variants and anomalies and traumatic injuries. *JClinImagingSci*. 2015;5:38

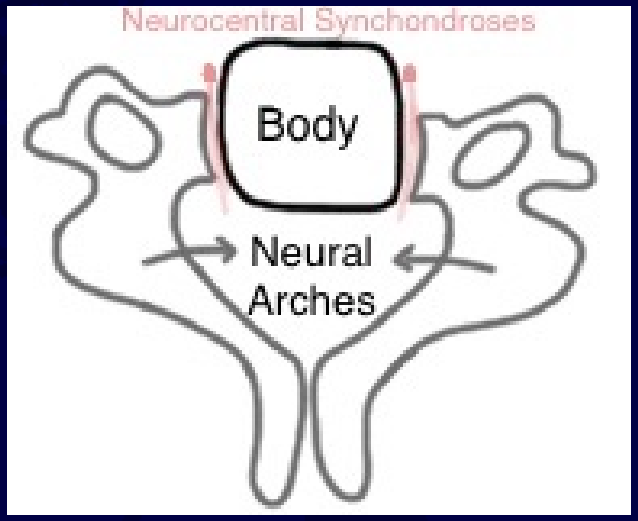
Anatomy – C2
Os Odontoideum

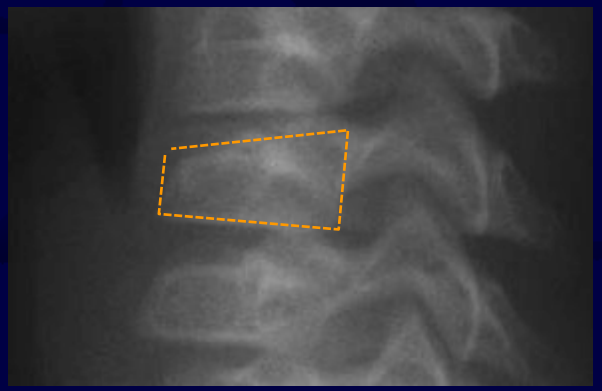
- **Origin hypotheses**:
  - Congenital
  - Traumatic (favored)
- Potential C1-C2 instability
- Usually asymptomatic
- Debate about participation in contact sports

Fielding. Os odontoideum. *J Bone Joint Surg Am* 1980;62:376.
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





Copley. Cervical spine disorders in infants and children. *J Am Acad Orthop Surg.* 1998;6:204.

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

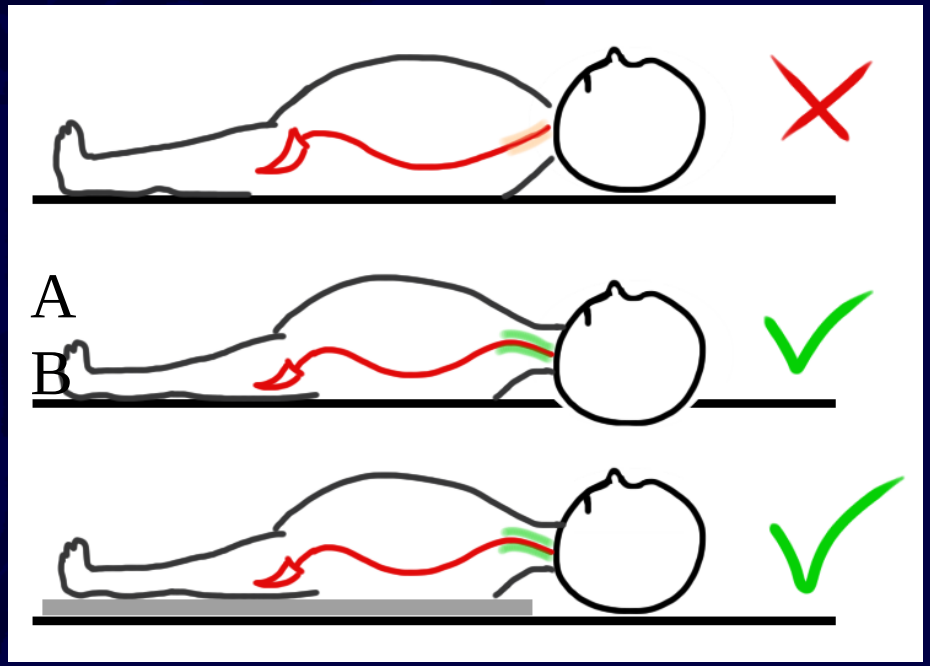
C-Spine Fracture Pattern

- 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

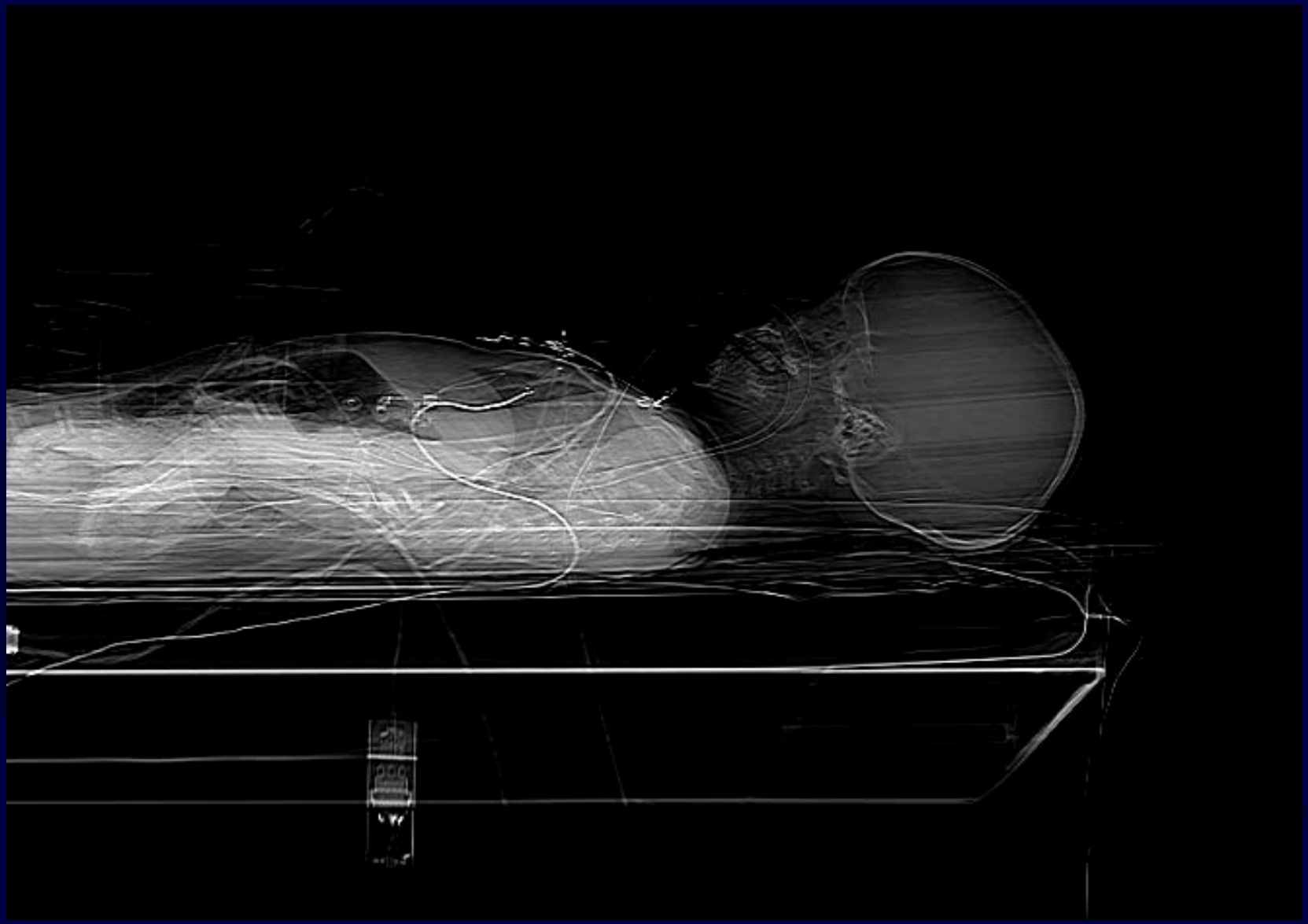
Jones. Pediatric cervical spine trauma. J Am Acad Orthop Surg. 2011;19:600.

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)



Herzenberg et al. Emergency Transport and positioning of young children who have an injury of the cervical spine, *JBJS*. 1989;71:!5-22

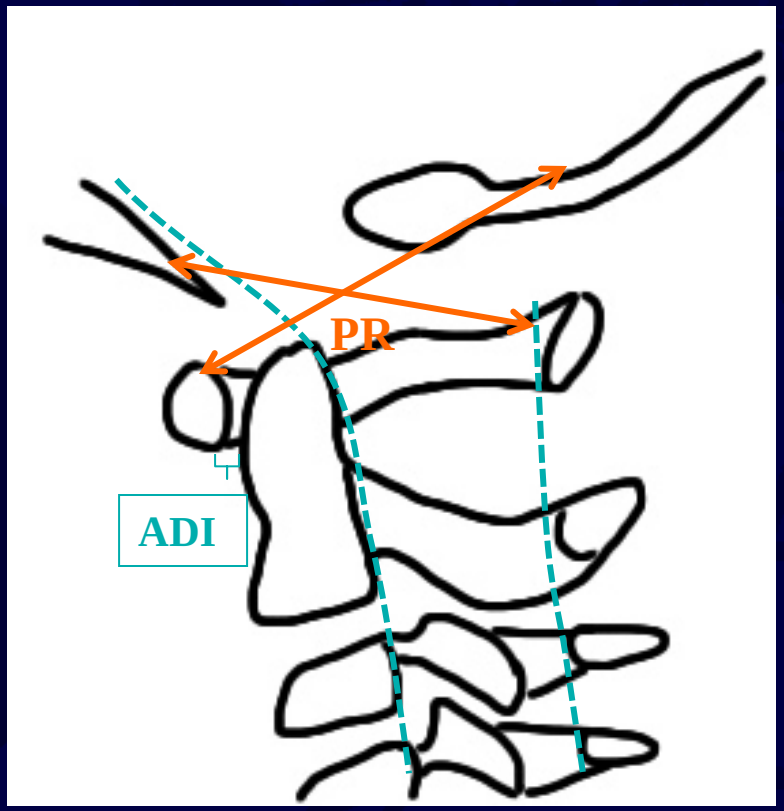


C Spine Evaluation in Children

- 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

Anderson. Cervical spine clearance after trauma in children. J Neurosurg. 2006;105(5 Suppl):361–364.

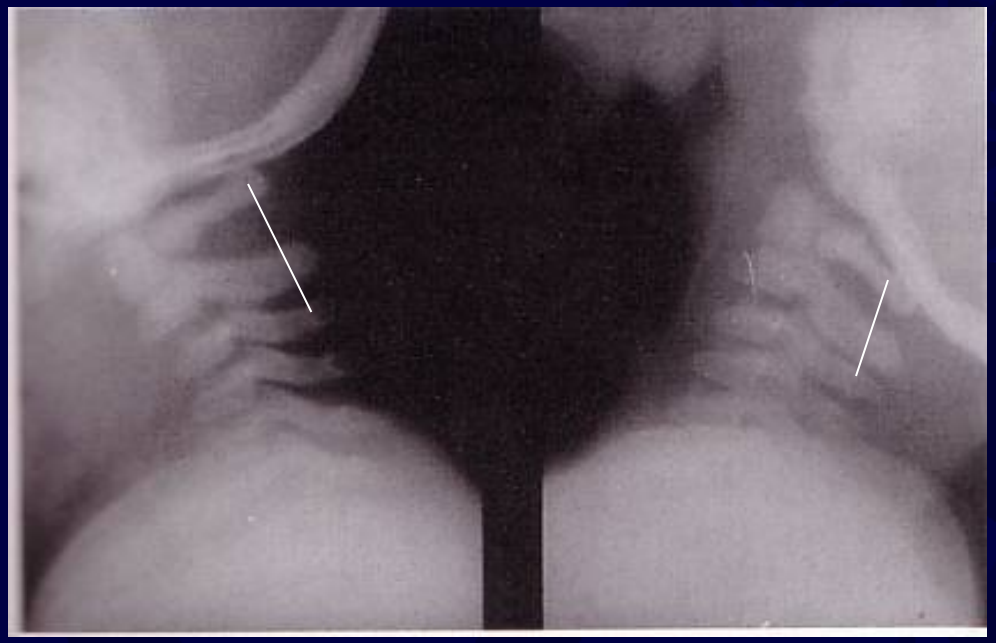
ED C Spine Evaluation



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

Anderson. Cervical spine clearance after trauma in children. J Neurosurg. 2006;105(5 Suppl):361–364.

Swichuk's Line

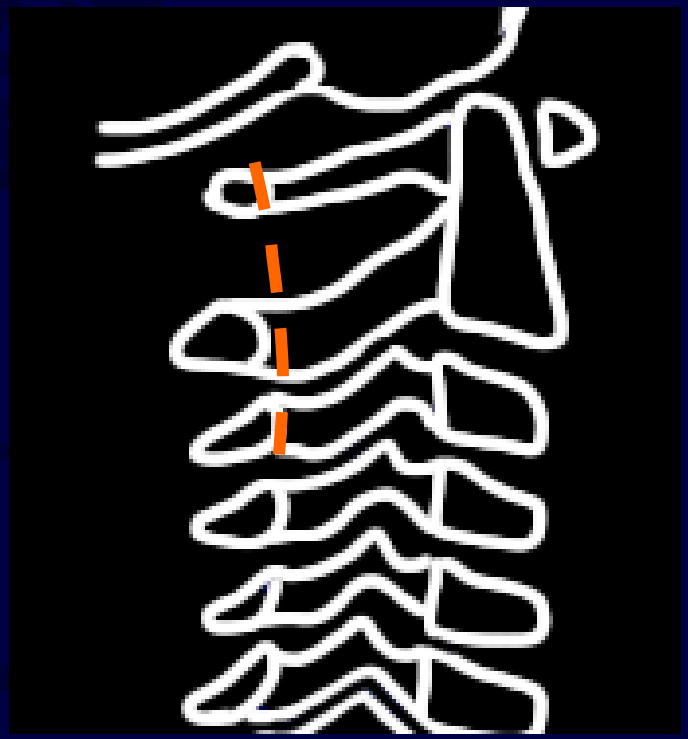


Spinolaminar line drawn from C1 to C3
Distinguishes normal variant from Hangman's fracture

Anderson. Cervical spine clearance after trauma in children. J Neurosurg. 2006;105(5 Suppl):361–364.

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*)



-Eubanks. Clearing the pediatric cervical spine following injury. J Am Acad Orthop Surg 2006;14:552.
-Shaw. Pseudosubluxation of C2 on C3 in polytraumatized children: Prevalence and significance. Clin Radiol 1999;54: 377.

Normal Radiographic Findings

- *Ossiculum terminale*
- *C1 override C2 (20%)*
- *Multiple 2ndary ossification centers*
- *Normal synchondrosis*
- *Odontoid angulation (4%)*
- *Basilar subdental synchondrosis (>7ys)*
- *Pseudosubluxation (<9yrs)*
- *ADI < 5mm (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 *pseudo*subluxing 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

Shaw. Pseudosubluxation of C2 on C3 in polytraumatized children: Prevalence and significance. Clin Radiol 1999;54: 377.

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)

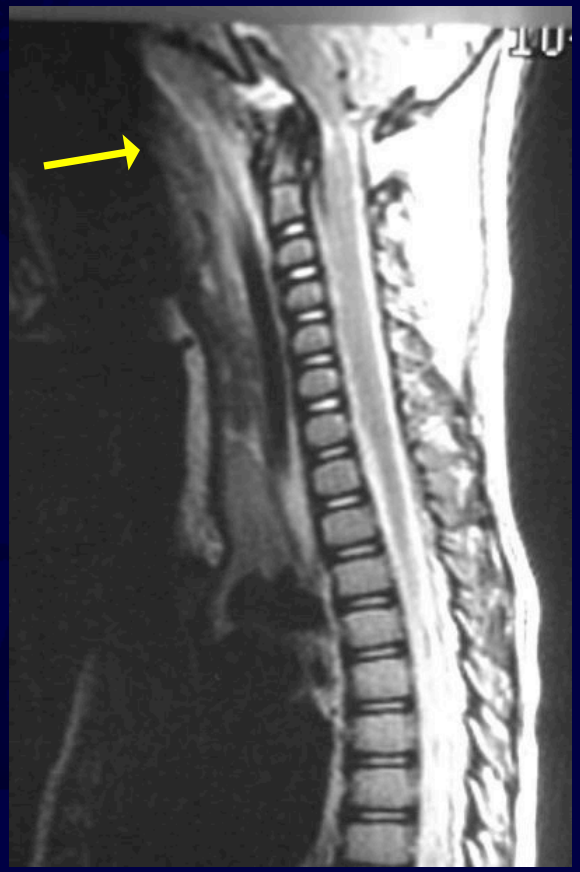
Parent. Spinal cord injury in the pediatric population: a systematic review of the literature. J. Neurotrauma. 2011;28:1515.

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!



Occiput –C1 SCIWORA

Parent. Spinal cord injury in the pediatric population: a systematic review of the literature. J. Neurotrauma. 2011;28:1515.
Shin. Pediatric C Spine and SCI: A National Database Study. Spine. 2015;Epub Ahead of print.

SCIWORA

- *Stretch* $_{skeleton}$ > *Stretch* $_{cord}$
- Stretch Capacity
  - Spinal Column 2” > Spinal Cord ¼”
- 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

Sharma. Assessment for additional spinal trauma in patients with cervical spine injury. Am Surg. 2007;73:70.

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

Sharma. Assessment for additional spinal trauma in patients with cervical spine injury. Am Surg. 2007;73:70.

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

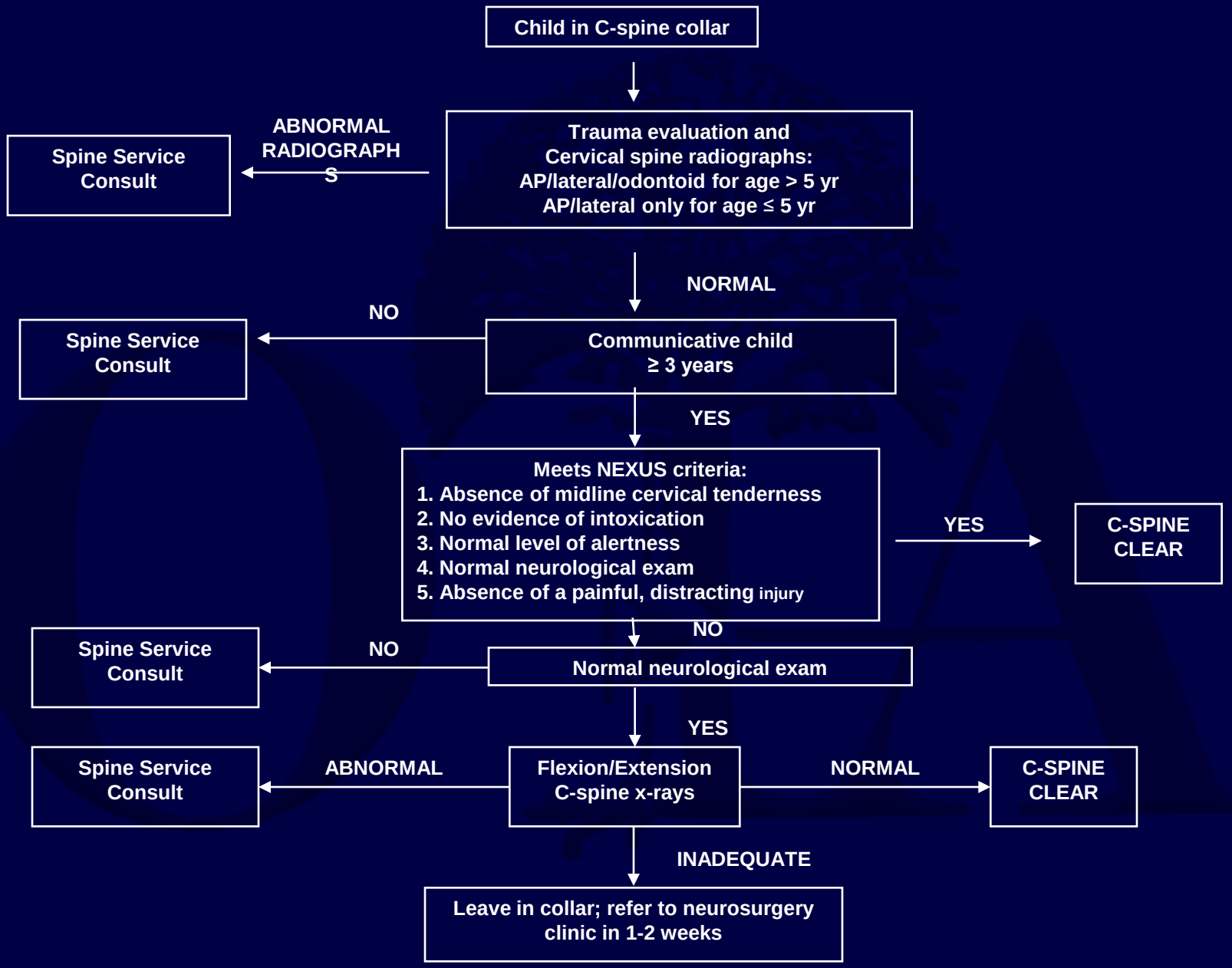
Sharma. Assessment for additional spinal trauma in patients with cervical spine injury. Am Surg. 2007;73:70.

If not “Cleared” within 12 Hours

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

McCall. Cervical spine trauma in children: a review. Neurosurg Focus. 2006;20(2):E5.

Clearance Protocol



Anderson. Cervical spine clearance after trauma in children. J Neurosurg. 2006;105(5 Suppl):361.

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

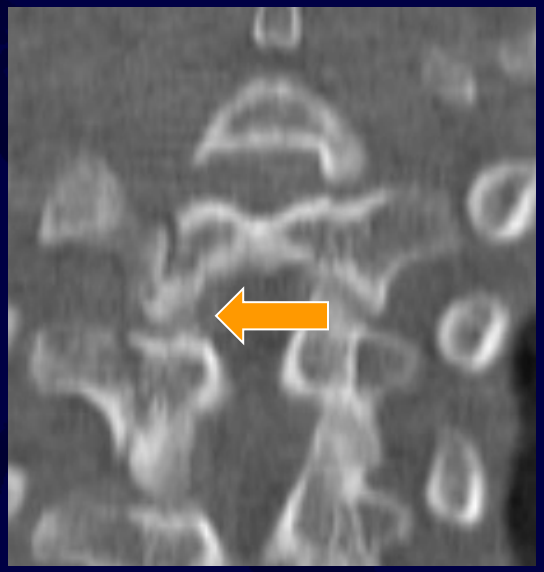
Firth. Pediatric Non-Contiguous Spinal Injuries: The 15 year Experience at One Pediatric Trauma Centre. Spine. 2011 Nov. 14 (Ahead of Print)

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)

Slotkin. Thoracolumbar spinal trauma in children. Neurosurg. Clin. N. Am. 2007;18:621.

- 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

Slotkin. Thoracolumbar spinal trauma in children. Neurosurg. Clin. N. Am. 2007;18:621.

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

Arkader. Pediatric chance fractures: a multicenter perspective. J Pediatr Orthop. 2011;31:741.

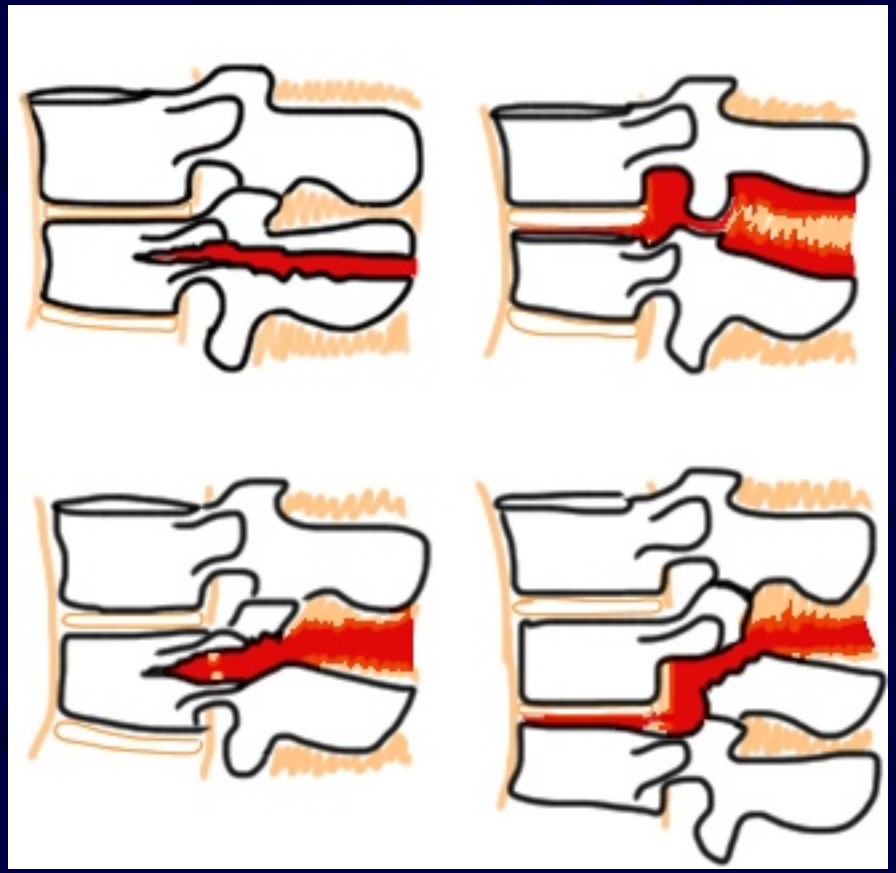
Chance Fractures and Variants

- 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

Arkader. Pediatric chance fractures: a multicenter perspective. J Pediatr Orthop. 2011;31:741.

Seatbelt/Flexion-Distraction Injury Classification

A



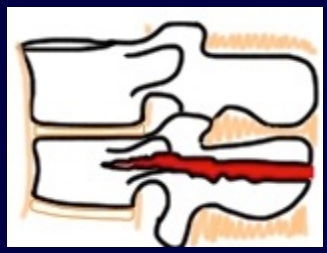
B

C

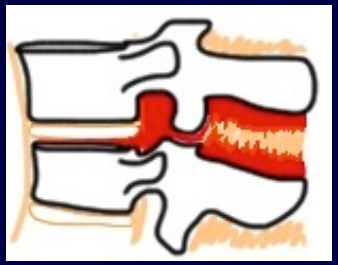
D

Rumball. Seat-belt injuries of the spine in young children. J Bone Joint Surg Br. 1992;74:571.

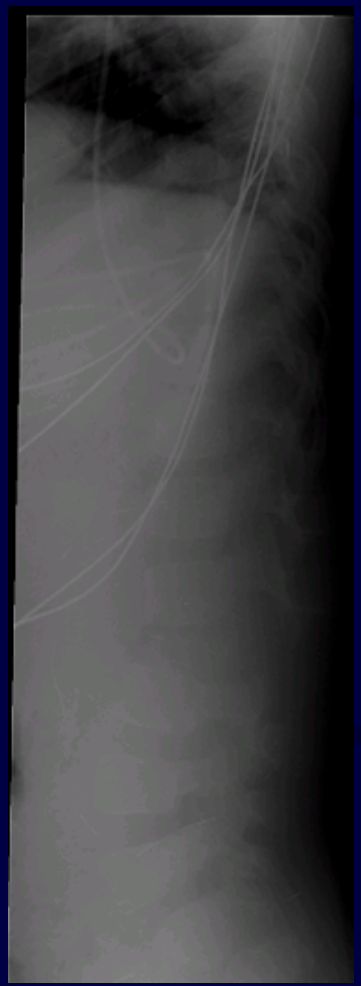
Bony Flexion Distraction Injury



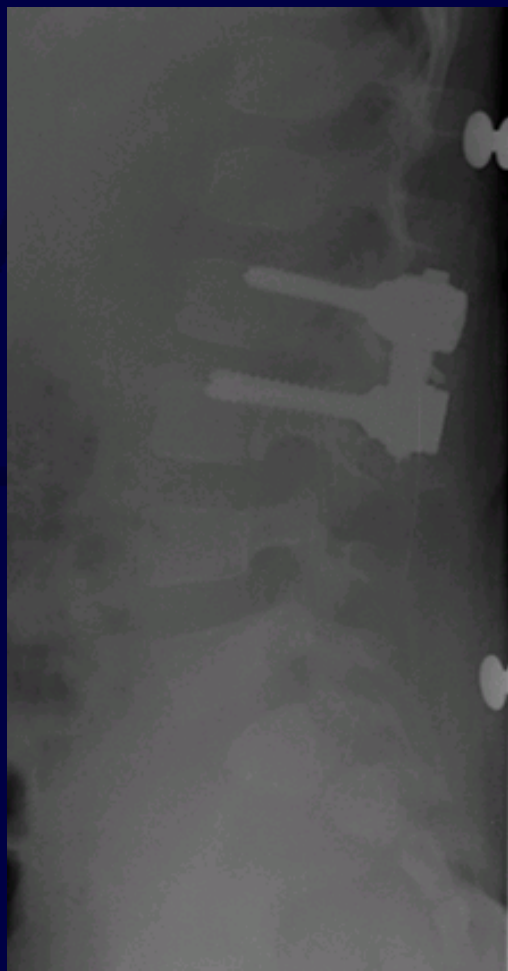
Ligamentous Flex/Dist Injury 1



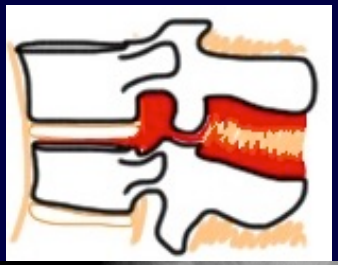
- 5yF, MVC, bowel perforations

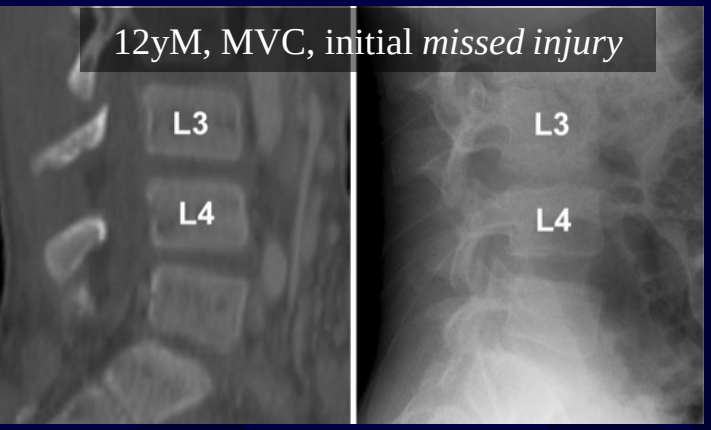


Tx:
L 2-3 open short-segment fixation/fusion

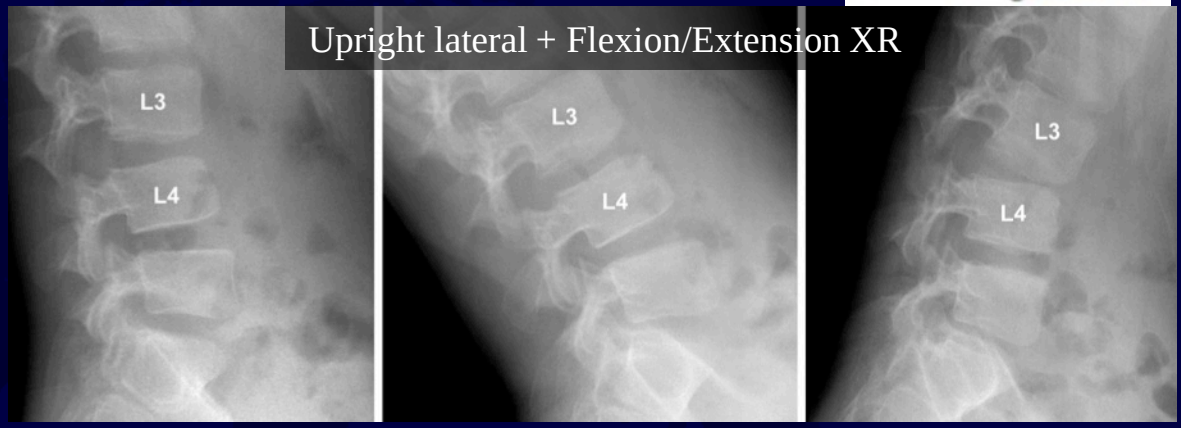


Ligamentous Flex/Dist Injury 2

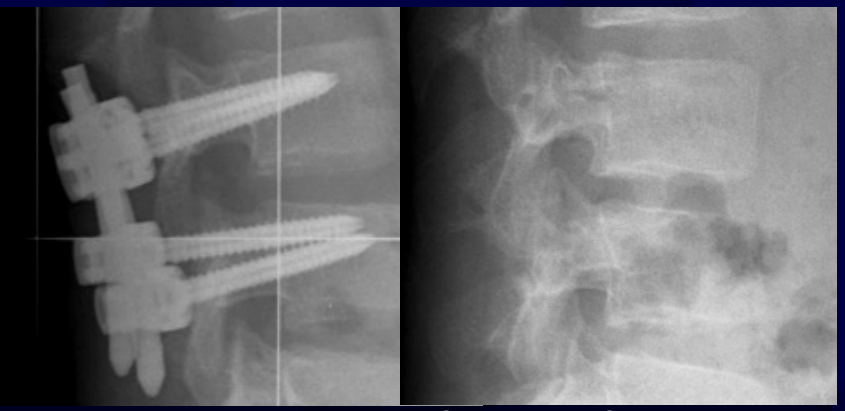




12yM, MVC, initial *missed injury*



Upright lateral + Flexion/Extension XR



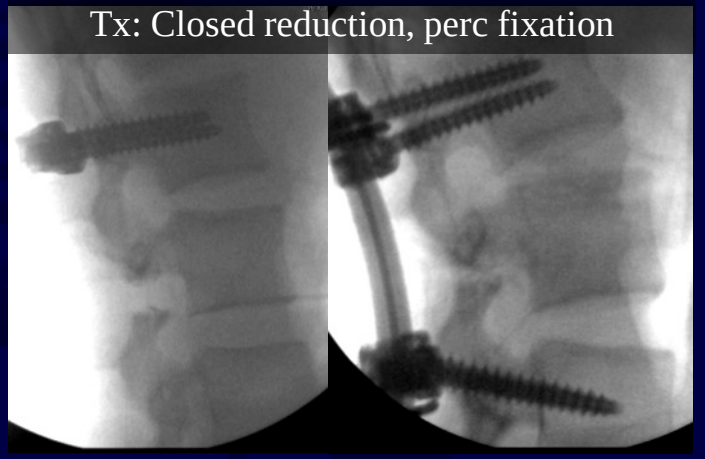
Tx: L3-4 ***Percutaneous fusionless fixation*** w/ removal @ 6mo

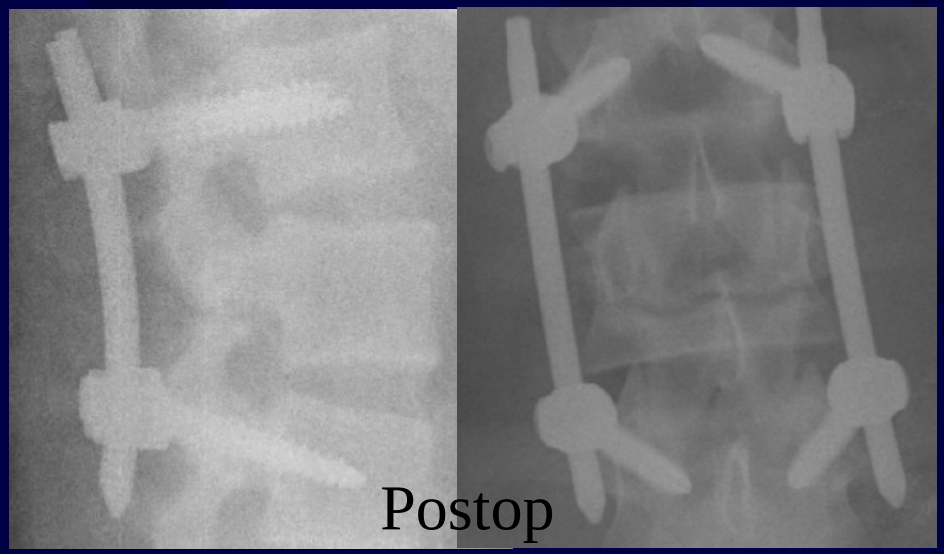
30 months post op

Combined (Bony+Ligamentous) Flexion Distraction Injury

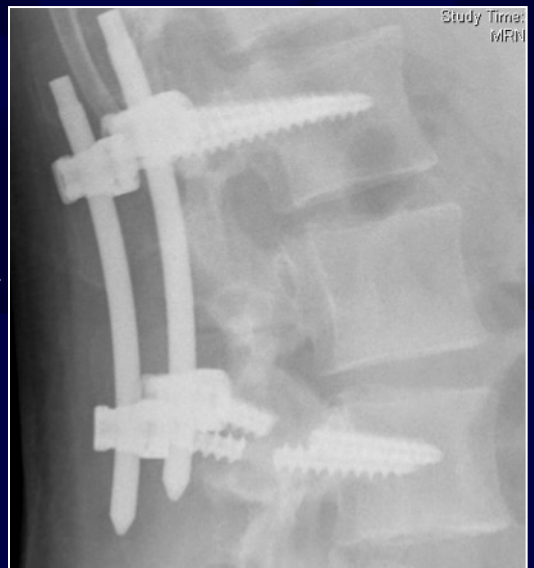
16yM, MVC, bowel injury

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*

Arkader. Pediatric chance fractures: a multicenter perspective. J Pediatr Orthop. 2011;31:741.

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

Slotkin. Thoracolumbar spinal trauma in children. Neurosurg. Clin. N. Am. 2007;18:621.

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

Chang. Clinical significance of ring apophysis fracture in adolescent lumbar disc herniation. Spine. 2008;33:1750.

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

Slotkin. Thoracolumbar spinal trauma in children. Neurosurg. Clin. N. Am. 2007;18:621.

Bibliography

- **Special Thanks - Additional Cases and imaging from**:
  - Dr. John C France (West Virginia University, Ruby Memorial)
  - Dr. Aki S Puryear (St Louis University, Cardinal Glennon Children's Hospital)

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- Arvin et al. Os Odontoideum: Etiology & surg Management, *Neurosurgery*, 2009
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