Pediatric Cervical Spine Injuries

Objectives

• Anatomy and radiographic findings
• Types of injuries and treatment options
• Evaluating and clearing the pediatric C-spine
PEDIATRIC CERVICAL SPINE
ANATOMICAL DIFFERENCES

What’s different anatomically?

- Big head = more rostral fulcrum of movement = higher level of injury
- Shallow, horizontally-oriented facets = easier translation
- Weak paraspinal muscles = greater flexibility
- More elastic ligaments, underdeveloped spinous processes.
Ossification Centers

- **C1/Subaxial**
  - 3 ossification centers
    - Anterior arch
    - Right/left neural arches
  - **Fusion**
    - Neural synchondrosis fuse by 3yo
    - Acroneural synchondroses by 7yo
    - (subaxial) Arches to body between 3-6 yo

- **C2**
  - 6 ossification centers
    - Os terminale
    - Right/left neurocentral dens
    - Right/left neural arches
    - Centrum
    - *Ring apophysis
  - **Fusion**
    - Vertical neurocentral synchondrosis by birth
    - Posterior arch by 3yo
    - Neural arches to body between 3-6yo
    - Apicodental and os around 10.5yo
    - Subdental by 11-12yo

Acceptable Variations

**ADI: 5 mm**

**Pseudo-Jefferson fracture**

- Lateral atlantodental interval can be asymmetric up to 2mm in normal children
- Up to 6mm of displacement of lateral masses relative to dens
Pseudosubluxation

- C2-3 most common level
  - Anterior longitudinal line is offset by less than 3mm with an intact spinolaminar line
- Exacerbated by imaging on flat surface
- Children < 8 yo
  - > 3mm displacement 40% at C2-3
  - > 3mm displacement 14% at C3-4
- Can occur up to 14 yo
- Spinolaminar line (drawn through posterior arches of C1-3) should touch, pass through, or lie within 1 mm anterior to the anterior cortex of posterior arch of C-2

Synchondroses

**Subdental synchondrosis**

**Neural synchondroses**
Anterior Wedging

- Wedging of up to 3mm of the vertebral body
- Can be profound at C3
Mechanisms of Injury

- Children < 2
  - Falls
  - NAT
- 2-7 years of age
  - MVC
  - Falls
  - Pedestrian struck by MV
- 8-15
  - Sports injuries
  - MVC

Injury Patterns in Kids

- 72% of spinal injuries in children < 8 yrs occur in c-spine
- More occiput-C2 injuries, less subaxial injuries
  - Leonard et al, 2013: 540 children
    - < 2 yo: 74% axial (AOD)
    - 2-7yo: 78% axial (AARS, AOD)
    - 8-15 yo: 53% subaxial (vertebral body fractures)
- More purely ligamentous injuries, less fractures
  - 50% of cervical spinal cord injuries purely ligamentous
- Decreased incidence of blunt vascular injury
- Multilevel injury uncommon
- After age 12, injury pattern similar to adults
Atlanto-occipital Dislocation

- Extensive ligamentous injury
- Can be missed in the setting of head injury
- Cardiopulmonary instability, quadriplegia or quadriparesis, lower cranial nerve palsies, vascular injury
- Types
  - I: anterior displacement of occiput to atlas
  - II: longitudinal distraction
  - III: posterior displacement
- Treatment
  - External immobilization
  - Surgery

AOD

**Powers ratio**

**BAI/BDI, Rule of 12’s**

Ratio > 1 suggests instability

BAI and BDI should be < 12 mm
AARS/F

- Head rotated to one side, and head cocked to the other
- Unable to turn head past midline
- Painful to manipulate or move
- Neurologically normally intact
- Types
  - I: Unilateral pivoting of atlas around the dens with competent transverse ligament
  - II: Unilateral anterior subluxation of atlas, pivot being the contralateral C1-2 facet
  - III: Anterior subluxation of both C1 facets with incompetent transverse ligament
- Treatment: pain medication, muscle relaxation, traction, manipulation and immobilization
  - Fusion if not reducible or continues to recur

Non-accidental trauma

- Higher incidence of associated cervical spine injury in NAT vs accidental trauma
- Routine screening in NAT patients as part of skeletal survey
- Role for MRI
- Mechanisms of injury varied, seldom confirmed
- Ligamentous injury
- Treatment
  - External immobilization
  - Fusion if persistent instability
Odontoid Epiphysiolysis

- Incompletely fused neurocentral synchondrosis of C2 susceptible to injury
- Odontoid process angled anteriorly
- Treated with external orthosis first, if fail then surgical fusion

Os Odontoideum

- Separation of the odontoid from the body of the axis
- Can present at any age
- 2 potential etiologies:
  - Congenital
  - Post-traumatic – now the prevailing theory
    • Indistinguishable radiographically from chronic non-union of the odontoid after known fracture
    • Often distant or unrecognized prior trauma
- Many speculate that os odontoideum is from unrecognized/untreated traumatic odontoid epiphysiolysis
- Treatment
  - Stable: monitor or decompress if necessary
  - Unstable: fusion, decompress is necessary
Neonatal Birth Trauma

- 1:60,000 births
- Associated with rotational cephalic manipulation with forceps
- Cervical >> cervicothoracic > thoracolumbar
- Diagnosed by
  - Clinical findings of acute spinal cord injury for 1+ day
  - Imaging or electrophysiologic studies
- Extremely high mortality rate

SCIWORA
Spinal cord injury without radiographic abnormality

- Closed spine trauma of the spine with significant neurologic deficits in the absence of radiographic findings (XR, CT)
  - Reflection of propensity for significant soft tissue trauma without fracture or dislocation in children
  - Includes subset of patients with normal MRIs and transient neurological deficits
- Literature dates back to 1944
- Mechanisms of injury:
  - Longitudinal distraction
  - Hyperextension
  - Hyperflexion
  - Ischemic spinal cord injury
- Treatment?
Management of Pediatric Cervical Spine and Spinal Cord Injuries
Rozelle CJ, Aarabi B, Dhall SS, Gelb DE, Hurlbert RJ, Ryken TC, Theodore N, Walters BC, and MN Hadley

- Level I
  - CT to determine condyle-C1 interval for peds pts with potential AOD is recommended

- Level II
  - Imaging not recommended for children > 3 yrs, suffered trauma, and
    - Are alert
    - No neuro deficits
    - No midline c spine tenderness
    - No painful distracting injury
    - Do not have unexplained hypotension
    - Are not intoxicated
    - Imaging not recommended in children < 3 yrs, suffered trauma, and
      - GCS > 13
      - All of the above and
      - Were not in an MVA, fall > 10ft, NAT

- Level III
  - CT recommended to exclude occult fractures or evaluate regions not adequately seen on plain XR
  - Flex/ex XR or fluoroscopy recommended to exclude gross ligamentous instability when there is suspicion
  - MRI recommended to exclude SC or nerve root compression, ligamentous injury or provide info for neurologic prognosis
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- **Level III**
  - Thoracic elevation or an occipital recess is recommended for children < 8 yo to prevent flexion of the head and neck when restrained supine on an otherwise flat backboard for better neutral alignment and immobilization of the cervical spine.
  - Closed reduction and halo immobilization are recommended for injuries of the C2 synchondrosis in children < 7 yo.
  - Reduction with manipulation or halter traction is recommended for patients with acute AARF (<4 weeks duration) that does not reduce spontaneously. Reduction with halter or long/halo traction is recommended for patients with chronic AARF (>4 weeks duration).

- **Level III**
  - Internal fixation and fusion are recommended in patients with recurrent and/or irreducible AARF.
  - Consideration of primary operative therapy is recommended for isolated ligamentous injuries of the cervical spine and unstable or irreducible fractures or dislocations with associated deformity.
  - Operative therapy is recommended for cervical spine injuries that fail non-operative management.

Cervical spine clearance after trauma in children
Anderson RCE, Scaife ER, Fenton SJ, Kan P, Hansen KW, and DL Brockmeyer

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Utility of a cervical spine clearance protocol after trauma in children between 0 and 3 years of age

Anderson RCE, Kan P, Vanaman M, Rubsam J, Hansen KW, Scaife ER, and DL Brockmeyer

Management Quirks

Physical Exam
- Due to large head, may not be neutral on a backboard
- Children < 8 yo elevate thorax
TAKE HOME POINTS

CHILDREN ARE NOT LITTLE VERSIONS OF ADULTS

• Big heads, poor muscle tone, flat condyles, ligamentous laxity
  – Watch positioning on the backboard
  – Anatomy predisposes to certain types of injuries
• Be aware of imaging characteristics that are considered normal in children
  – Pseudosubluxation at C2-3
  – Synchondrosis that may look like fracture
  – Widening of the ADI
  – Vertebral body wedging
• Unexplained hypotension or absent vital signs in trauma patients likely severe high cervical cord injury
• External immobilization is oftentimes tried before surgical intervention
THANK YOU

References

• Lustrin ES et al. (2003) “Pediatric cervical spine: normal anatomy, variants, and trauma.” Radiographics 23:539-560