Spine and Spinal Cord Injury in Children

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Introduction

• Trauma remains the leading cause of death and disability in children

• While not as common as head injury, spine and spinal cord injuries are frequently missed in the pediatric evaluation.

• Conversely, the natural development of the cervical spine and variants are often mistaken for abnormalities.

• The neurosurgeon is frequently called upon as a consultant to distinguish true pathology and to “clear” the cervical spine.
The Spine is really TWO ORGANS!

- Spinal Column
  - Bone
  - Ligaments and tendons
  - Muscle
  - Disks
Spinal Cord
Neural tissue
CSF and Meninges
Factors: Age at Injury

- Cervical spine reaches adult proportions at 8-10 years of age.
- Sequelae of injuries similar to adults after 10-12 years of age.
- C-spine injury is less common in children but when it occurs it is more likely to happen in the upper cervical spine.
- False positive and false negative radiology readings occur, most commonly in the upper C-spine.
Factors: Age at Injury

- 1/20th as common as severe closed head injury in children
- Less than 5% of injury admissions are due to spine injury
- Cervical injuries most common
  - 70-80% of all spine injuries in children
  - 50% occiput through C2
  - High C-spine: 36% with deficit
  - Low C-spine: 73% with deficit
- Multiple level involvement is common
Factors: Age at Injury and Inherent Risk

- Ligamentous laxity.
- Underdeveloped musculature of neck.
- Shallow and horizontally angled facet joints.
- Physiologic anterior wedging of the vertebral bodies.
- Fulcrum of motion
  - Children C2-3
  - Adults C5-6
Factors: Age at Injury and Inherent Risk

• Incomplete ossification of the odontoid process.
• Relatively large head.
• Absence of uncovertebral joint in children < 10 years
• Small occipital condyles.
Factors: Mechanisms of Injury

• Mechanism of injury likely to have resulted in significant spine trauma (high risk):
  – Child struck by motor vehicle (auto vs. peds)
  – Driver/ passenger involved in MVC, including motorcycle and ATV collisions
  – Falls > 10 feet
  – Diving injuries
  – All vehicle crashes (sled, bicycle, skateboard) where the patient was thrown (not fell) from the vehicle
  – Other mechanisms raising a high index of suspicion
Other Confounding Factors

• Altered level of consciousness
• Distracting injuries
• Systemic instability
• Neurologic function
• Transport for further imaging
  – Stability of patient
  – Distance
  – Extent of other injuries
Pathophysiology of Spinal Cord Injury

• The spinal cord has...
  – Afferent tracts that receive sensory information from the periphery and conduct it to the brain
  – Efferent tracts that control motor responses and mediate many autonomic functions

• Classifications of Spinal Cord Injury
  – Complete—interruption of all afferent and efferent nerve tracts below the level of injury
  – Incomplete—some afferent or efferent tracts are spared
• Sudden transection of the cord leads to spinal shock or a state of transient reflex depression below the level of injury
• This spinal shock can last from a few days to months after injury
• High cervical cord lesions that interrupt the sympathetic outflow can result in bradycardia and hypotension
Initial Evaluation and Management

- All actual or suspected injury to the cervical spine are fully and correctly immobilized prior to or upon arrival to the ED.
• Cervical immobilization is maintained until clearance and in particular, patients with:
  – Altered mental status
  – Symptoms consistent with SCI, including:
    • History of transient paresthesias, dysesthesias, shooting pains or subjective extremity paralysis
    • Complaints of neck pain or discomfort or presence of muscle spasms, limited range of motion or tenderness over the spine
    • Presence of sensory-motor deficits
Low Risk- National Emergency X-Ray Utilization Study (NEXUS) Criteria

• Low risk group
  – No midline cervical tenderness
  – No intoxication
  – Normal mental alertness
  – Normal neurologic exam
  – No painful distracting injuries

• No cervical injuries in children who met above criteria!!

• Even with one positive criteria, only 1% had cervical spine injury

Viccello et al. Pediatrics, 2001
High Risk Criteria for C-Spine Injury

• High velocity blunt trauma
• Multiple fractures
• Significant head or facial injury
• Evidence of direct cervical injury (cervical pain, spasm, obvious deformity, tracheal injury)
• Altered mental status (loss of consciousness, alcohol and/or drug abuse)
• Drowning or diving accident
• Fall of >10 ft
• Thoracic or lumbar fracture
• Neurologic complaints- paresthesias or burning in extremities
Specific Issues for Clearance

- Clearance Issues:
  - Age
    - Pediatric vs. Adult
    - Young vs. Older Child
  - Mechanism of injury
  - Level of consciousness
  - Feasibility of further imaging
    - Transport
    - Extent of other injuries

- Criteria for clearance
  - Radiologic and Clinical
  - Literature basis

- Further Issues:
  - Maintaining C- Spine precautions
  - Clearance by Non-neurosurgical personnel
Criteria for Clearance (Basic)

- **Clearance requires both radiographic and clinical criteria!!**

- All patients who have **not** been both radiographically **and** clinically cleared remain in cervical spine precautions including a hard cervical collar.

- For patients with radiographic clearance on plain x-rays but not clinical clearance (i.e. have persistent tenderness on palpation or with active range of motion), consider performing further imaging (i.e. flexion/extension views, CT or MR).
Radiographic Clearance

- C- Spine series with Flexion/ Extension
- CT w/ 3D reconstructions
- MRI
Radiographic Clearance

• Radiographic clearance requires:
  – Standard 3 views (lateral, AP, and odontoid)/ 2 views in young children.
  – If lower cervical spine visualization is inadequate on the lateral x-ray, may try swimmer’s view.
  – If still inadequate, CT through the level(s) that were not well visualized.
  – Documentation in the medical record
Further Radiographic Clearance

• Despite radiographic clearance, tenderness or decreased AROM, consider further imaging.

• Options include: CT or dynamic views w/ F/E

• If CT normal, option for active (F/E) dynamic X-rays to ensure stability.
• If inadequate F/E views (limited range of motion), repeat F/E films considered at 2 weeks.

• Imaging of entire spine with:
  – Radiographic cervical spinal injury
  – Neurologic deficits on exam.

• Further radiologic clearance is necessary in patients who cannot be clinically evaluated (i.e. intubation, severe head injury, etc.)
Other Radiographic Options

• For “clearance” of the cervical spine (removal of the hard collar) in the intubated/obtunded patient, additional tests to evaluate potential injury may include:
  – Further c-spine films
  – MRI including STIR images
  – Helical CT of focal area of concern vs. complete spine
  – SSEP’s with flexion/extension films under fluoroscopy
Clinical clearance requires:

- Prior radiographic clearance
- No history of transient or residual neurological deficits
- An awake patient with no distracting injury and symptoms not masked by pain medications.
- Clinical examination resulting in no tenderness with palpation of the cervical spine and full active range of motion
- Documentation in the medical record
Issues of Clearance

• Obtunded and/or young child
• Maintenance of cervical spine precautions/cervical collar
  – Impedance of ICU management vs. risk to patient?
  – Inadequate immobilization, (i.e. poor fit)
  – Skin care?
  – Family concern?
• Need for Neurosurgical/Spine Service Clearance
  – Volume of patients?
  – Clearance by non neurosurgical/spine personnel?
Review of Radiographic Options
Plain X-Rays

- Three view (AP, lateral, odontoid?)
- Plain films fail to identify injury in 45-69% of adult patients (2001-06)
- Misdiagnosis of plain radiography in children (19%)
  - 14% developmental normal
  - 9% pathologic;
  - \( \leq 8 \text{ y} = 24\% \)
  - \( > 8 \text{ y} = 15\% \) (Avellino et al. 2005)
- Algorithm for clearance- no missed injuries (Anderson et al. 2006)
Radiography - Criteria for Stability

• Dynamic views (Flexion/ Extension)?
• Static Lateral C Spine X-ray

Recommendations/ Guidelines:
– Adults- (< 11° angulation or < 3.5 mm subluxation)
– Children (< 8 y)- (< 7° angulation or < 4.5 mm subluxation at C2-3, C3-4)
– < 15° anterior wedging
– Two vs. three column injury
CT/ Helical CT

• Axial, Sagittal, Coronal, 3-D Reformats
• Superior resolution to plain radiography
• Better to evaluate spinal cord injury
• Spinal canal evaluation:
  – Bone, disc, foreign bodies, blood can be identified
  – Faster, requires less patient manipulation/cooperation
• Cost-effective to perform in high-risk patients
• Multiple-trauma patients with altered mental status or those who are uncooperative
Further Criteria for CT

• When getting a head CT for trauma:
  – May include craniocervical junction
  – Consider inclusion of all of C-spine
  – High incidence of upper cervical fractures associated with head trauma

• Non-visualization C7-T1 on lateral or swimmers

• Directed examination through a specific area of known or suspected injury.

• When plain films are inconclusive of clinically suspected injury
CT/ Helical CT Literature

Adults

• No c spine injuries missed with CT and plain radiography combined
• No c spine injuries missed with CT alone

Pediatric

• CT has limited value *alone* since majority ligamentous injuries?
• Useful adjunct
• Need for awareness of normal variants and potential for misdiagnoses
• Concern of radiation risk
Common Misdiagnoses on Radiography and CT in Children

- Synchondroses
- Pseudosubluxation
- Loss of lordosis
- Pronounced vascular channels as fractures
- Increased ADI
- Pseudospread of the Atlas “Pseudo Jefferson Fracture”
- Anterior wedging
- Prominence of prevertebral soft tissue
- Overriding of Atlas on the dens (20%)
- Incomplete fusion of ossification centers
Synchondroses of Atlas and Dens in 2 yo
Radiation Exposure - Pediatric

• Radiation exposure is a concern in both adults and children, however, unique considerations in children.
  – Children are considerably more sensitive to radiation
  – Children also have a longer life expectancy, resulting in a larger window of opportunity for expressing radiation damage.

• The same exposure parameters used for a child and an adult will result in larger doses to the child.
## Exposure for a Typical Head CT Scan

<table>
<thead>
<tr>
<th>EXAM TYPE</th>
<th>RELEVANT ORGAN</th>
<th>APPROXIMATE EQUIVALENT DOSE TO RELEVANT ORGAN</th>
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<tbody>
<tr>
<td>Pediatric Head CT Scan</td>
<td>Brain</td>
<td>6000 mrem</td>
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<td>Unadjusted Settings (200 mAs, neonate)</td>
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**Natural annual exposure- 300 mrem**

**Maximal annual occupational exposure- 5000 mrem, (1/700 LD)**
Reducing Risk of Radiation

• No need for adult doses to children
• Currently, adjustments are not frequently made in the exposure parameters for children receiving a CT
• “Image Lightly!”
• CT settings can be reduced significantly while maintaining diagnostic image quality.
• Can limit field based on initial radiographic studies to area of “concern”
Magnetic Resonance Imaging in Cervical Trauma

• No radiation
• Improved image quality
• Modality of choice whenever there is neurologic dysfunction
• Often requires sedation
• Takes time
Magnetic Resonance Imaging in Cervical Trauma

• Does show:
  – Ligamentous injury (10%) but may not be “clinically significant”
  – Intraspinal pathology (i.e. spinal cord contusions, hematomas, herniated disc, etc.)

• May not:
  – Identify further bony injury than CT
  – Contribute further instability information for pediatric patients
  – Be useful in SCIWORA
MRI and Clearance

- Shown to be useful for:
  - Obtunded &/ or “unreliable” patient with normal radiography and need for cervical clearance
  - When radiography and CT are equivocal
  - Delayed neurologic symptoms to reveal further contributing pathology
  - Spinal cord injury
Spinal Cord Injury without Radiologic Abnormality (SCIWORA)

- Syndrome of traumatic myelopathy w/o vertebral column disruption based on radiography and early CT.
- ~5-70% (mean 36%) of pediatric spine injury though true incidence 15-25%.
- Majority in young children.
- Thought to be more common in children due to hypermobility, transient subluxation and/or localized hypoperfusion of the spinal cord.
- Immediate vs. Delayed presentation
- Pathologic findings more common with MRI

Pang & Wilberger 1982; Pang 2004
SCIWORA

- SCIWORA accounts for about 15-25%
  - Cervical spine and TLJ most common
  - Spinal column allows distraction to 2 inches in newborn, spinal cord distracts only few mm
  - 75% are complete at time of presentation
SCI Pathogenesis

- Hypotension
- Hypoxia
- Inflammation
- Glutamate
- Toxic eicosanoids
- Cord compression
- Free radicals
- Calcium changes
Spinal Cord Injury Treatment

IMPORTANT

- MAP (Adults) 85-90 mmHg
  - Continue 7 days
  - Keep SBP >90
- MAP (Children) ? “Slightly hypertensive!”
- Hct >28
- O₂ Sat >95%
- CVP normal to high
- Treat compression if present
Spinal Cord Injury Treatment
NASCIS I,II,III

• Steroids?

• “Bracken Protocol”
  – Methylprednisolone
    • 30 mg/ kg, then 5.4mg/ kg/ hr
    • 24 hrs if < 3 hrs from injury
    • 48 hrs if 3- 8 hrs from injury

• Present Level I recommendation in adults is NO STEROIDS!
Spinal Cord Injury
Promising? Future? Treatments

- **Medical**
  - Gangliosides
  - Opiate antagonists
  - Excitatory Amino Acid Receptor Antagonists
  - Ca++ Channel Blockers
  - Antioxidants and Free Radical Scavengers

- **Surgical**
  - Tissue implantation
  - Stem Cells
  - Regenerative strategies
  - Regeneration conduits
Spinal Column Injury Treatment
Initial Evaluation and Management

- Patients with suspected injury immobilized immediately
  - Hard collar
    - Cobb angles -27 deg to +27 deg
    - 60% shown to be greater than 5 deg
  - Soft collar
  - SOMI or CTLSO
  - Halo or tongs
Treatment

- Wide variety of options
- Depends on patient specifics
Nursing Care

• Therapies for spinal cord injuries have been shown to be most effective if instituted within 4 hours of the traumatic event.

• The spinal cord injured victim requires immediate attention in three areas:
  – immobilization of the head and neck
  – restoration and maintenance of respiratory function
  – restoration and maintenance of cardiovascular function
• **Head and Neck**
  - maintained in a neutral position
  - patient should be placed on a hard, flat surface with sandbags on either side of the head

• **Respiratory interventions**
  - jaw-thrust to open airway
  - Oxygen to maintain sats > 95%
  - assist ventilations
  - intubate
  - arterial blood gases
  - pulmonary toilet
• Cardiovascular interventions
  – IV access
  – fluid replacement
  – inotropie support

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Involve Physical Medicine and Rehabilitation EARLY in the care of the child
Obvious Injury

- Atlanto-occipital dislocation (AOD) is 2.5 times more likely in children vs. adults.
- Ligamentous attachments in children are more easily ruptured.
- Devastating neurological injury.
- Children more likely to suffer AOD with no neurologic impairment.
Case 2 - Clinical Exam

- 10 yo male restrained passenger in MVC
- GCS 10
- Quadriparetic on exam
- No other distracting injuries
Case 3 - Clinical Exam

- 15 yo male, unrestrained passenger, head on MVC
- Tracheal laceration
- Altered mental status
- Quadriparetic on exam though multiple other distracting injuries
Plain X-Rays
MRI

- C1-2 Normal
- Cord edema at C5-6
- Correlated with exam (significant weakness in hands, triceps, stronger more proximal at deltoid, biceps)
Summary

• The pediatric cervical spine has unique anatomy and unique responses to injury.
• Clearance does not differ between adult and children, need both radiologic and clinical
• Children have normal developmental anatomy that often leads to misdiagnosis.
• The young and/or obtunded, intubated child presents challenges for clearance.
• No one protocol has been shown superior to others though a multidisciplinary approved protocol decreases missed injuries and limits unnecessary and costly evaluation.