ABC’s of Pediatric C-spine Management

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Objectives

Understand the anatomical and developmental issues surrounding C-spine clearance in the pediatric population

Review optimal C-spine immobilization for the pediatric patient

Discuss criteria necessary for clinical clearance of the C-spine in children

Discuss current practice and controversies over use of plain films, CT and MRI in the evaluation of pediatric C-spine injuries
Epidemiology

- Incidence cervical spine in children low at 1-2%

- National Pediatric Trauma Registry 1098 /10 yr. period: average 100 new case per yr.

- Mortality rate 4-47%; most studies quote 16-17%; dependent on level of injury, mechanism, age
Epidemiology

- Majority result of blunt trauma
  ◦ MVA: 48-61%
  ◦ Occupants > pedestrians / bike riders

- Males predominate: 1.5-1.9:1

- 83% bony cervical spine injuries/fractures

- Only 35% with spinal cord involvement
Anatomical / Biomechanical Differences

- Horizontal orientation of facet joints
- Relative laxity of cervical ligaments
- High fulcrum of motion (C2-C3) with underdeveloped neck musculature
- Craniocervical junction more vulnerable
  - occipital condyles smaller
  - articulation lateral masses C1 more planar
  - odontoid synchondrosis
Anatomical / Biomechanical Differences

-SCIWORA:
  ° acute spinal cord injury with sensory/motor deficits
    without radiographic evidence
  ° predominately in pediatric patients: 67%
  ° increase elasticity and motion of cervical spine
  ° infant spinal column withstand 2 inch stretch but cord shear > ¼ inch
Patterns of Pediatric Injury

- Age dependent: upper vs lower cervical

- Nitechi and Moir: subluxation injuries more common; 45% of all children < 8 years

- Eleraky et al: four general radiographic patterns from retrospective series 102 cases
  ◦ vertebral fractures- 33%
  ◦ fractures with subluxation – 27%
  ◦ subluxation without fracture- 22%
  ◦ SCIWORA – 18%
Imaging Characteristics
- Prevertebral soft tissue thickening: indicates adjacent cervical spine injury in adults; may be related to expiration or crying the child
Imaging Characteristics

- Increased atlantodental interval (ADI): < 3mm adults but acceptable up to 5mm child; reflects incomplete occification of the dens and laxity of the transverse ligament

- Overiding of the anterior arch of C1 on dens during extension: mistaken for atlantoaxial instability; normal 20% children < 8yrs
Imaging Characteristics

- C1 lateral mass displacement: >6.9 mm adults considered disruption of transverse ligament; 6mm often seen in children up to age 4yrs and in some up to 7yrs

- Pseudosubluxation: C20 on C3 22-24%; may persist up to mid teens

- Shallow Facets

- Wedge shaped vertebra
Imaging Characteristics

- Cattell and Filter: looked at frequency of these findings

  ◦ 160 randomly selected children; no history of trauma
  ◦ 24% incidence moderate to marked C2 on C3 subluxation age < 7 yrs
  ◦ 46% < 8 yrs had 3mm or more anterior/posterior motion C2 on C3 with flexion and extension
  ◦ 14% pseudosubluxation C3 on C4
  ◦ Overriding anterior arch of atlas on adontoid 20% < 8 yrs
  ◦ Synchondosis radiolucency all children up to 4 yrs/ half up to age 11 yrs
Interpretation of Plain Films

- Measurements:
  - Waxhenheim’s Clivus line: line drawn along posterior portion of clivus intersects with odontoid or runs tangential; failure suggestive of atlantoaxial instability
  - Power Ratio: distance tip of basion to posterior arch / distance opisthion to posterior aspect anterior arch atlas; >1 suggestive anterior atlantoaxial dislocation
Interpretation of Plain Films

- Measurements (cont)
  - Rules of 12/ Harris criteria: distance between basion and rostral tip of odontoid and the distance between basion and rostral position of posterior cortical margin axis; both < 12mm; not always valid < 13yrs
  - Atlantodens interval: distance posterior cortex anteror arch axis to anterior cortex of dens; >5mm indicated atlantoaxial instability
Interpretation of Plain Films

- Measurements (cont)
  ◦ Rules of thirds: dens and spinal cord each fill 1/3rd of spinal canal space with last third free
  ◦ Soft tissue distance: retropharyngeal space < 7mm; retrotracheal space < 14mm
Interpretation of Plain Films

- Measurements (cont)
  - Swishchuk’s Line (spinolaminar line / posterior cervical line):
    - Line drawn from the posterior arch of C1 to posterior arch of C3; posterior arch of C2 should be within 1-1.5mm of line; >2mm
Interpretation of Plain Films

- Measurements (cont)
  - Swishchuk’s Line (spinolaminar line / posterior cervical line):
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    - Posterior arch of C2 should be within 1-1.5mm of line; >2mm

![Image showing measurements and line drawings]
Management

- Proper immobilization: again variation on adult theme
  ◦ Need allowance for relatively large head compared to torso; forces neck into position of flexion
  ◦ Studies showing mean amount elevation of head 27mm 4yr ; 22mm > 4yrs
  ◦ Aim alignment external meatus with shoulder = neutral spine position
Management

- Clinical Clearance: Adult support?
  ◦ National Emergency X-Radiography Utilization Study (NEXUS)
    - prospective observational study 21 centers
    - decision instrument with 5 criteria to determine low risk injury
      ▫ midline cervical tenderness
      ▫ evidence of intoxication
      ▫ altered mental status
      ▫ focal neurologic deficits
      ▫ painful distracting injury
  
  - included all patients blunt trauma undergoing radiographic study
  - questionnaire completed prior to review of films
  - standard film series: AP, Lateral, Open mouth odontoid
Management

- Clinical Clearance: Adult support?
  - National Emergency X-Radiography Utilization Study (NEXUS)
    - 34069 pts; 814 with studies (2.4%) showed cervical injury
    - 8/818 false negative: 2 met predetermined criteria for clinically significant injury
    - all 810 correctly identified met all 5 low risk criteria

- overall missed 1/4000
- based # ED physicians- would be 1 every 125yrs
- decreased X-ray by 12.6%
Management

- Clinical Clearance: Adult support?
  ◦ Canadian C-spine Rule
    - prospective study aimed at deriving clinical decision rules for clinically clearing C-spines in those with low risk
    - based on 3 high risk and 5 low risk criteria plus ability of patient to rotate head 45 degrees in each direction
      ▫ high risk: age, dangerous mechanism of injury, paresthesia
      ▫ low risk: simple MVA, Sitting in ED, Ambulating, Delayed onset pain, absence C-spine tenderness
Management

- Clinical Clearance: Adult support?
  - Canadian C-spine Rule
    - 151/8924 pts with CSI
    - Sensitivity 100%
    - Specificity 42.5%
    - Estimated reduction X-rays 15.5%

**Table 5. Performance of the Canadian C-Spine Rule for Clinically Important Cervical Spine Injury**

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Sensitivity, % (95% CI): 100 (98-100)
Specificity, % (95% CI): 42.5 (40.44)
Radiograph ordering rate, %: 56.2

*CI indicates confidence interval.*
Management

- Clinical Clearance: What about pediatric data
  - Viccellio et al: sub study of NEXUS looking at pediatric population
    - 3065 pt < 18 yrs
    - Nexus criteria
    - 30 children (0.98%) with CSI; 3.7% of all injuries in NEXUS
    - 603/3065 considered low risk (19.7%); none with CSI
    - tenderness and distracting injuries most common
    - lead to 20% fewer x-rays preformed
Management

- Clinical Clearance: What about pediatric data
  ◦ Viccellio et al: issues with study based on numbers and age distribution; 817 2-8yrs; only 88 < 2yrs
    - low confidence interval for sensitivity -87.8% < 4yrs
    - negative predictive value 100% with CI 99.4%
    - would take 80,000 children in a study to reach CI for sensitivity of 0.5%
  ◦ American Association Of Neurological Surgeons felt data strong enough to recommend application of NEXUS criteria for children >9yrs
Management
- Clinical Clearance: What about pediatric data
  ◦ Lee et al: increased sensitivity by expanding criteria and use of imaging when NEXUS criteria present or child inconsolable
  ◦ imaging if met any one of these criteria
    - conscious: AP/Lateral and Odontoid---- CT or MRI
    - unconscious: AP/Lateral and CT
  ◦ still showed drop in time of clearance from 12.3 to 7.5hrs in conscious patient and 40hrs to 19.4 hrs unconscious pts
Management

- Clinical Clearance: What about pediatric data
  ◦ Pediatric Emergency Care Applied Research Network (PECARN)
  - case controlled study 17 centers: 3 control groups as well
  - multiple logistic regression analysis: identified predictors of CSI
  - 540 children with trauma/ total 1774 controls
  - Eight factors identified
    ▫ altered mental status
    ▫ focal neurologic findings
    ▫ neck pain
    ▫ torticollis
    ▫ substantial torso injury
    ▫ conditions predisposing to cervical injury ie Down Syndrome
    ▫ diving
    ▫ high risk MVA
Management

- Clinical Clearance: What about pediatric data
  - Pediatric Emergency Care Applied Research Network (PECARN)
    - One or more factors was 98% (95% CI 96-99%) sensitive; 26% (CI 23-29%) specific
  
    - Comparison to NEXUS: contained 3/5 variables; contained 2 mechanisms of injury that important to pediatrics; also predisposing conditions
  
    - Compared to Canadian Study: 7 of 8 factors consistent; again difference with inclusion associated injuries
  
    - Conclusion: would have detected 98% CSI; reduced exposure to spinal immobilization and ionizing radiation for non CSI children by more than 20%
Management

- Clinical Clearance: What about pediatric data < 3 yrs age
  - Anderson et al: AP /Lateral and exam; cleared 80%
  - PEDSPINE: American Association for Surgery Trauma:
    - 4 independent predictors: GCS <14, GCS eyes =1, MVA, Age
    - weighted system: those with score 0-1 negative CSI
Management
- Imaging issues:
  ◦ What studies to obtain?
  ◦ Controversy regarding radiation:
    - Brenner: malignancy with CT; lifetime risk in 1yr old 0.18% from abd CT and 0.07% head; those <15yrs– 500 will die from cancer
    - pediatric thyroid more radiosensitive
Management

- Imaging issues: What view for X-rays
  ◦ Agreement with AP/Lateral
  ◦ Open mouth Odontoid
    - Swisschuk et al: pediatric radiologist survey; missed fx rate 0.007 per radiologist per year without this view
    - Buhs: open mouth did not improve diagnosis
  ◦ Flexion /Extension: intended to demonstrate stability
    - Khanna: no cases where aided in diagnosis
    - Ralston: neg if static films normal

  ◦ AANS and Congress of Neurological Surgeons recommend only
    AP and Lateral studies < 9yrs
Management
- Imaging issues: What about CT
  ◦ Obtained adults: 99% sensitive, 100% specific
  ◦ Sensitivity in children as low as 87%
  ◦ Again concern radiation: lead to 18 newly diagnosed cases of thyroid cancer /yr; higher risk those < 5yrs
  ◦ Need for sedation
  ◦ Studies:
    - Hernandez/ Rana: no findings not noted on plain films
Management

- Imaging issues: MRI?
  ◦ Data still out
  ◦ Studies:
    - Frank et al: detected previously unrecognized injury 31%; abnormalities of posterior ligamentous complex and soft tissue
    - use with SCIWORA
    - use obtunded patient: decrease time to spinal clearance
Recommendations: Canadian Subcommittee

- Possible to clinically clear Pediatric C-spine:
  ◦ Combination of NEXUS low risk criteria and CCR criteria; pain-free ROM and mechanism of injury considered; caution <2 yrs

- What are risks of radiation exposure:
  ◦ Increased lifetime risk of malignancy with CT: use low dose radiation when using and only perform when necessary

- Plain Films vs CT:
  ◦ Plain film should be initial assessment tool: CT reserved for those cases diagnostic uncertainty or suspected injury
**Recommendations:** Canadian Subcommittee

- **Use of flexion/extension films:**
  - Little diagnostic value in pediatric patient with normal plain films; may benefit if persistent spine tenderness

- **Is Odontoid view beneficial:**
  - Difficult to obtain and adds little diagnostic value

- **What is best utilization of MRI:**
  - View of soft tissues of C-spine; superior mode direct evaluation of spinal cord
Conclusions:

- Understand anatomical and biomechanical differences in pediatric patients necessary for successful management/clearing of Cervical spine

- Have an established protocol
  ◦ NEXUS > 9yrs; PECARN inclusive and more comprehensive for younger group

- If need of images start with plain films: CT for further concerns

- MRI use for those obtunded patients and concern soft tissue injury
Questions
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