

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

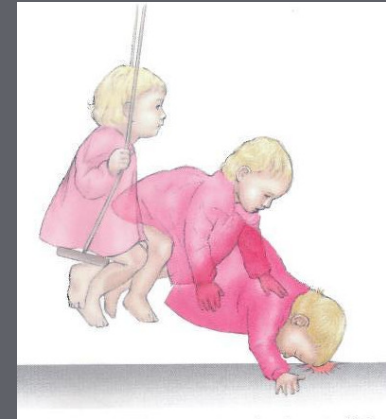
- Incidence cervical spine in children low at 1-2%
- National Pediatric Trauma Registry 1098 /10 yr. period: average 100 new case per yr.
- Mortality rate 4-47%; most studies quote 16-17%; dependent on level of injury, mechanism, age

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:

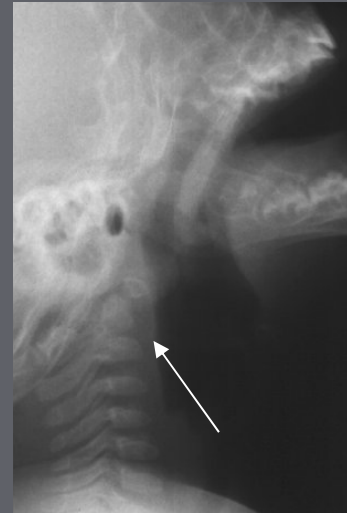
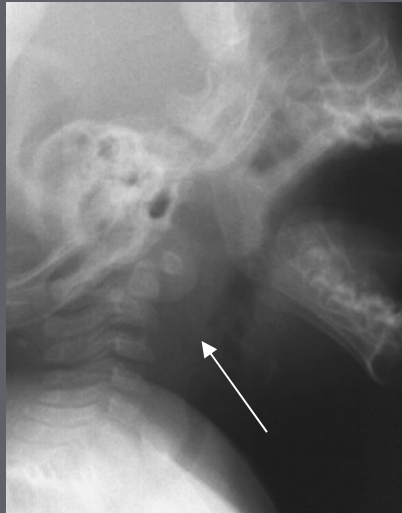
- acute spinal cord injury with sensory/motor deficits without radiographic evidence
- predominately in pediatric patients: 67%
- increase elasticity and motion of cervical spine
- infant spinal column withstand 2inch stretch but cord shear > 1/4 inch

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
 - o vertebral fractures- 33%
 - o fractures with subluxation – 27%
 - o subluxation without fracture- 22%
 - o SCIWORA – 18%

Imaging Characteristics

- Prevertebral soft tissue thickening: indicates adjacent cervical spine injury in adults; may be related to expiration or crying the child



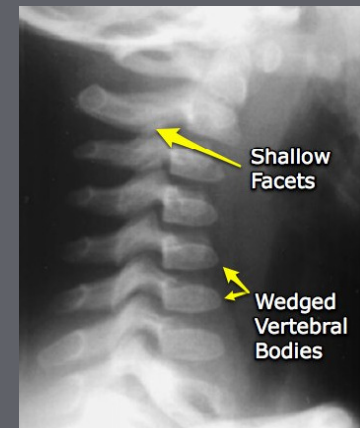
Imaging Characteristics

- Increased atlantodental interval (ADI): $< 3\text{mm}$ adults but acceptable up to 5mm child; reflects incomplete occipitation of the dens and laxity of the transverse ligament
- Overriding of the anterior arch of C1 on dens during extension: mistaken for atlantoaxial instability; normal 20% children $< 8\text{yrs}$



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

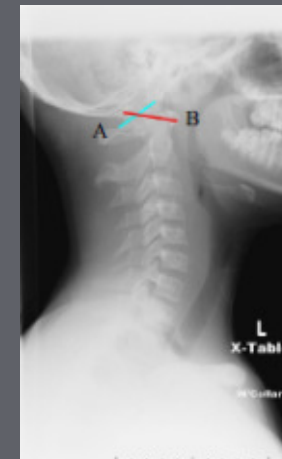
- Cattell and Filter: looked at frequency of these findings

- 160 randomly selected children; no history of trauma
- 24% incidence moderate to marked C2 on C3 subluxation age < 7 yrs
- 46% < 8yrs 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
- Synchondrosis radiolucency all children up to 4 yrs/ half up to age 11yrs

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

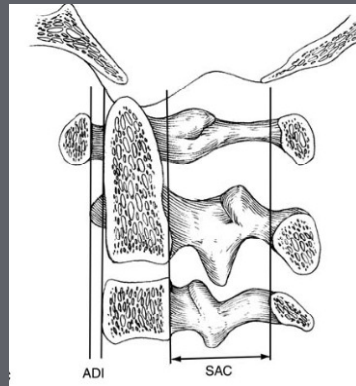
- Measurements (cont)

- 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 $< 12\text{mm}$; not always valid $< 13\text{yrs}$
- Atlantodens interval: distance posterior cortex anterior arch axis to anterior cortex of dens; $>5\text{mm}$ 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



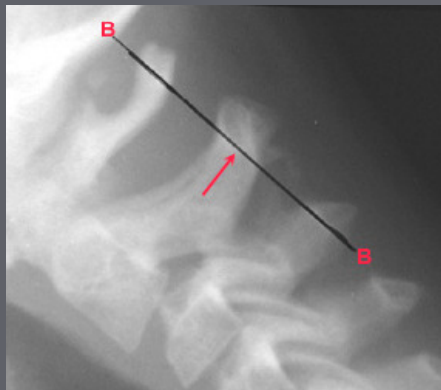
Swelling retropharyngeal space

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

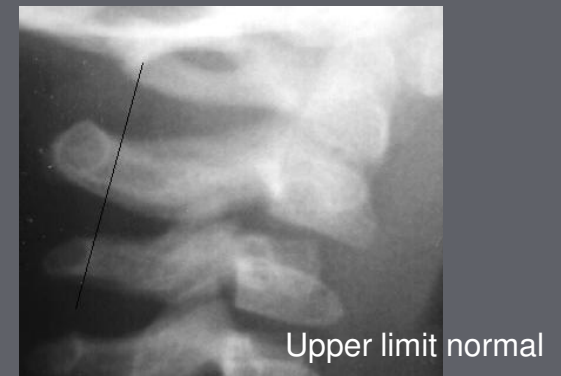
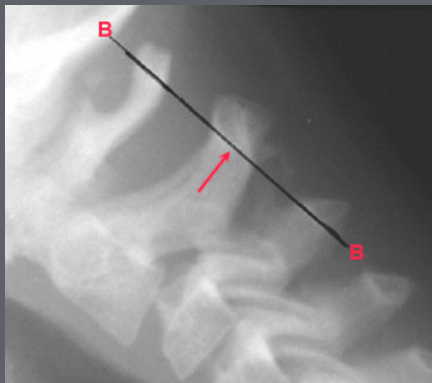


Interpretation of Plain Films

- Measurements (cont)

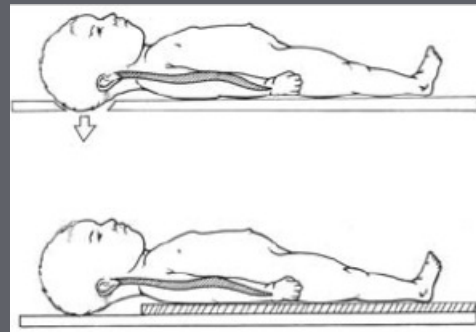
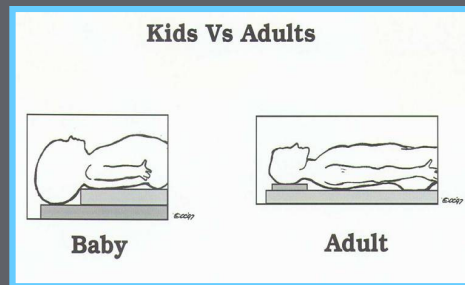
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Management

- 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?
 - o 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

TABLE 3. PERFORMANCE OF THE CLINICAL CRITERIA IN RULING OUT CERVICAL-SPINE INJURIES IN PATIENTS WITH BLUNT TRAUMA.

CHARACTERISTIC	VALUE (95% CI)*
All patients	
Sensitivity	99.0 (98.0–99.6)
Negative predictive value	99.8 (99.6–100)
Specificity	12.9 (12.8–13.0)
Positive predictive value	2.7 (2.6–2.8)
Patients with clinically significant injuries	
Sensitivity	99.6 (98.6–100)
Negative predictive value	99.9 (99.8–100)
Specificity	12.9 (12.8–13.0)
Positive predictive value	1.9 (1.8–2.0)

*CI denotes confidence interval.

- 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 45degrees 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

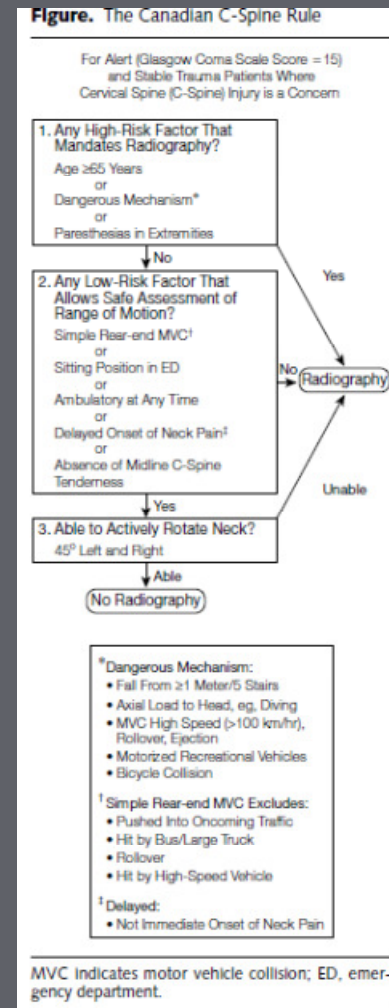
Management

- Clinical Clearance: Adult support?
 - o 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*

Decision Rule	Clinically Important Injury	
	Yes	No
Yes	151	5041
No	0	3732
Sensitivity, % (95% CI)	100 (98-100)	
Specificity, % (95% CI)	42.5 (40-44)	
Radiograph ordering rate, %	58.2	

*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
 - o Lee et al: increased sensitivity by expanding criteria and use of imaging when NEXUS criteria present or child inconsolable
 - o imaging if met any one of these criteria
 - conscious: AP/Lateral and Odontoid---- CT or MRI
 - unconscious: AP/Lateral and CT
 - o still showed drop in time of clearance from 12.3 to 7.5hrs in conscious patient and 40hrs to 19.4 hrs unconscious pts

Table 1

Risk Factors for Cervical Spine Injury

Reasons for Immobilization and Radiographic Evaluation

1. Unconscious patient
2. Mechanism of injury suggestive of possible CSI: high-speed motor vehicle crash, fall greater than body height, bicycle or driving accident, forced hyperextension injury, acceleration-deceleration injury involving the head
3. Neck pain
4. Focal neck tenderness or inability to assess neck pain secondary to a distracting injury
5. Abnormal neurologic examination findings (motor, sensory, reflex examination)
6. History of transient neurologic symptoms suggestive of SCIWORA (eg, weakness, paresthasias, or lightening/burning sensation down the spine/extremity or related to neck movement)
7. Physical signs of neck trauma (eg, ecchymosis, abrasion, deformity, swelling, tenderness)
8. Unreliable examination secondary to substance abuse
9. Significant trauma to head or face
10. Inconsolable child

CSI = cervical spine injury, SCIWORA = spinal cord injury without radiographic abnormality

Adapted with permission from Lee SL, Sena M, Greenholz SK, Fledderman M: A multidisciplinary approach to the development of a cervical spine clearance protocol: Process, rationale, and initial results. *J Pediatr Surg* 2003;38:358-362.

Management

- Clinical Clearance: What about pediatric data
 - o 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:

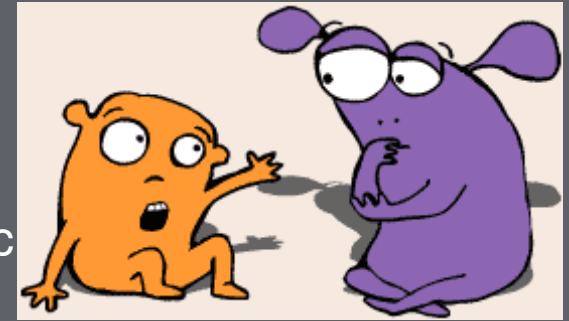
- What studies to obtain ?
- Controversy regarding radiation:
 - Brenner: malignancy with CT; lifetime risk in 1yr old 0.18% from abd CT and 0.07% head; those <15yrs– 500 will die from cancer
 - pediatric thyroid more radiosensitive

Management

- Imaging issues: What view for X-rays
 - Agreement with AP/Lateral
 - Open mouth Odontoid
 - Swischuk 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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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



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