Spinal Injuries: Optimizing the Clinical and Radiological Workup

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Spinal Cord Injury

- Incidence: 40 cases per million per year
  - 11,000 cases per year in US
- Prevalence: 247,000 persons in US
- 78% males
- Average age 28.6 years
- 50.4% motor vehicle crashes
Spinal Cord Injury

- Cost
  - $2,000,000 lifetime
  - $6,000,000,000 per year in US

- Life expectancy
  - Half of age expectation

National Spinal Cord Injury Statistical Center
Imaging

• Extremely low yield
  – 0.9% to 2.8% of imaging studies are positive
  – Most common imaging exam on trauma patients (HMC)
  – High cost
Issue 1: Clinical Clearance of Cervical Spine Injuries-NEXUS versus Canadian C-Spine Rules
Clinical Clearance of Cervical Spine Injuries: NEXUS v. Canadian C-Spine Rules

• Clinical prediction rule with 100% sensitivity for fracture
  – Do NOT need to image

• Develop predictors
  – Statistical modeling (retrospective)

• Validate on separate population
  – Prospective
NEXUS

• 21 emergency departments
• 34069 patients
  – Imaging requested
  – 818 (2.4%) with fracture
• Use existing criteria
• Evaluate sensitivity and specificity of criteria
• Prospective
NEXUS

- Absence of posterior midline tenderness
- Absence of focal neurological deficit
- Normal level of alertness
- No evidence of intoxication
- Absence of painful distracting injury
NEXUS

- Sensitivity of 99.6%
- Specificity of 12.6%
- Kappa 0.73 (excellent)
- Highly reliable to identify fracture
- Limited impact on utilization
Canadian C-Spine Rule

• Prospective development
  – 8924 subjects
  – 10 hospitals
  – Evaluate 20 potential predictors

• Set of three criteria
  – 100% sensitivity
  – 42.5% specificity
Canadian C-Spine Rule

• Prospective validation
  – 8283 patients
  – 10 hospitals
• Clinical prediction rule
  – 99.4% sensitivity
  – 45.1% specificity
  – High agreement
Canadian C-Spine Rule

1. No high risk factor, including:
   - Age > 64 years
   - Dangerous mechanism, including:
     - Fall from > 3 meters/5 stairs
     - Axial load to head (diving)
     - High speed vehicular crash (60 MPH, rollover, ejection)
     - Bicycle collision
     - Motorized recreational vehicle
   - Paresthesias in extremities

2. Low-risk factor is present
   - Simple rear end vehicular crash, excluding:
     - Pushed into oncoming traffic
     - Hit by bus/large truck
     - Rollover
     - Hit by high speed vehicle
   - Sitting position in emergency department
   - Ambulatory at any time
   - Delayed onset of neck pain
   - Absence of midline cervical tenderness

3. Able to actively rotate neck (45 degrees left and right)
Comparison

- Canadian-higher potential to improve utilization
- NEXUS simpler to implement
- Canada group reports lower sensitivity for NEXUS
Conclusions

• Two validated instruments
• No good data on either in actual practice
• Does either reduce unnecessary imaging?
  – Compliance?
  – Skill at use?
  – Generalizability?
  – Cost-effectiveness?
Issue 2: What Cervical Spine Imaging is Appropriate in High Risk and Low Risk Patients?
Radiography

• Accurate
  – sensitivity 94%
  – specificity 95%

• Inexpensive
  – complete series $34 to $60

• Available
  – all centers have radiography

• Experience in interpretation
Cervical Spine Radiography
High Risk Patients

• Difficult to perform
  – Backboards
  – Other injuries
  – Non-cooperative

• Time consuming
  – 10 minutes to 1 hour

• Often inadequate or incomplete
Adequacy of Radiography

• Radiographs adeq. 95% (93.6-97.0)
• High risk patients
  – head injury 89% (84.5-94.0)
  – MVC 84% (78.4-89.2)
  – motorcycle 78% (68.1-88.2)

• NEXUS -30% inadequate
• Alberta-ICU patients-82% inadequate
CT Accuracy

- Cohort of 601 consecutive patients
  - 1 year
- Sensitivity
  - for fracture 99% (96-100%)
  - for all injury 95% (90-100%)
- Specificity
  - 93% (91-95%)

<table>
<thead>
<tr>
<th></th>
<th>Radiography</th>
<th>CT Screen</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sensitivity</td>
<td>94%</td>
<td>99%</td>
</tr>
<tr>
<td>Specificity</td>
<td>78-89%</td>
<td>93%</td>
</tr>
<tr>
<td>Time</td>
<td>+++</td>
<td>+</td>
</tr>
<tr>
<td>Cost</td>
<td>+</td>
<td>+++</td>
</tr>
</tbody>
</table>
Cost-Effectiveness Analysis

• Central Assumption:
  – limited pool of health care resources
  – opportunity cost
• Determine value of intervention
  – how many $ per unit of health
• Method of comparing value of competing interventions
Cost-Effectiveness Analysis

• Decision Analysis Model
  – All possible outcomes
  – All possible costs

• Probability estimates
  – HMC data
  – Literature
  – Expert panel
Cost-Effectiveness Analysis: Cervical Spine CT Screening

- High risk of injury (10%)-CT is dominant
- Moderate risk (4%)-CT is cost-effective
  - prevents SCI more sensitive test
  - saves money
    - fewer inadequate exams
    - high cost of spinal cord injury
- Robust to sensitivity analysis

Cost-Effectiveness

• Cost-effectiveness dependent on probability of fracture
• Probability of fracture varies
• Define high risk group
• Clinical criteria
Methods

• Case-control study
• Cases-168 patients evaluated at HMC in 1994-5 with cervical spine fracture
• Controls-304 randomly selected trauma patients
• Excluded: penetrating trauma, transfers, under age 18
# Results

<table>
<thead>
<tr>
<th>Variable</th>
<th>Cases (%)</th>
<th>Controls (%)</th>
<th>OR</th>
<th>95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age over 50</td>
<td>56 (33)</td>
<td>31 (10)</td>
<td>4.4</td>
<td>2.7-7.2</td>
</tr>
<tr>
<td>Sex</td>
<td>116 (69)</td>
<td>213 (70)</td>
<td>1.0</td>
<td>0.7-1.6</td>
</tr>
<tr>
<td>MVA-High Speed</td>
<td>64 (38)</td>
<td>37 (12)</td>
<td>4.5</td>
<td>2.8-7.1</td>
</tr>
<tr>
<td>MVA-Low Speed</td>
<td>7.1 (4)</td>
<td>15 (5)</td>
<td>0.8</td>
<td>0.3-2.1</td>
</tr>
<tr>
<td>Ped. Struck by Car</td>
<td>12 (7)</td>
<td>6 (2.0)</td>
<td>3.8</td>
<td>1.4-10</td>
</tr>
<tr>
<td>Fall</td>
<td>35 (21)</td>
<td>64 (21)</td>
<td>1.0</td>
<td>0.6-1.6</td>
</tr>
<tr>
<td>Motorcycle Accid.</td>
<td>6.0 (3.6)</td>
<td>8 (2.6)</td>
<td>1.4</td>
<td>0.5-5.0</td>
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<tr>
<td>Toxicology Pos.</td>
<td>57 (34)</td>
<td>67 (22)</td>
<td>1.8</td>
<td>1.2-2.8</td>
</tr>
<tr>
<td>Seat Belt</td>
<td>46 (50)</td>
<td>50 (70)</td>
<td>0.4</td>
<td>0.2-0.8</td>
</tr>
</tbody>
</table>

## Results (cont)

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<tr>
<th>Variable</th>
<th>Cases (%)</th>
<th>Controls (%)</th>
<th>OR</th>
<th>95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intracranial Heme.</td>
<td>32 (19)</td>
<td>9 (3.0)</td>
<td>7.8</td>
<td>3.6-16</td>
</tr>
<tr>
<td>Brain Contusion</td>
<td>26 (15)</td>
<td>6 (2.0)</td>
<td>9.1</td>
<td>3.6-23</td>
</tr>
<tr>
<td>Skull Fracture</td>
<td>24 (14)</td>
<td>5 (1.6)</td>
<td>9.9</td>
<td>3.7-26</td>
</tr>
<tr>
<td>Unconscious</td>
<td>38 (23)</td>
<td>6 (2.0)</td>
<td>14</td>
<td>6.0-35</td>
</tr>
<tr>
<td>Facial Fracture</td>
<td>18 (11)</td>
<td>16 (5.3)</td>
<td>2.1</td>
<td>1.1-4.3</td>
</tr>
<tr>
<td>Mandible Fx.</td>
<td>5.0 (3.0)</td>
<td>4 (1.3)</td>
<td>2.3</td>
<td>0.6-8.8</td>
</tr>
<tr>
<td>Facial Laceration</td>
<td>79 (47)</td>
<td>91 (30)</td>
<td>2.1</td>
<td>1.4-3.1</td>
</tr>
<tr>
<td>Scalp Laceration</td>
<td>57 (34)</td>
<td>67 (22)</td>
<td>5.1</td>
<td>3.1-8.4</td>
</tr>
<tr>
<td>Focal Neurol. Def.</td>
<td>31 (18)</td>
<td>2 (0.7)</td>
<td>34</td>
<td>8-145</td>
</tr>
</tbody>
</table>

HMC CT Screen Criteria

- Focal neurological deficit
- Severe head injury
  - unconscious, skull fracture, intracranial hemorrhage
- High energy mechanism
  - MVC speed > 35mph
  - auto vs. pedestrian
  - death at scene
  - pelvic fracture

Hanson, et al, AJR 2000:174:713-718
Validation of Prediction Rule

• HMC cohort
  – 4285 patients/ 601 CT screen
  – 6 months

• Fracture yield
  – 12.8% for CT screen
  – 0.2% if did not get CT

• Criteria select high-risk group

Hanson, et al, AJR 2000:174:713-718
Radiation Reduction

• Limit to high risk patients
• No children
  – Higher radiosensitivity
  – Lower fracture probability
• Lowest mAs
  – Neck/shoulders
HMC CT Screen Criteria

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Hanson, et al, AJR 2000:174:713-718
Issue 3: What imaging is appropriate in obtunded or comatose patients?
Special Populations- Head Injury

- Imaging limited for ligaments
- Unstable injury without fracture
  - Pain, tenderness
- Unexaminable patients
  - Head injury, intubation
  - Collar (morbidity)
- MRI, flouroscopy, upright radiography, nothing
- No good data
Guidelines

• Eastern Association for Surgery of Trauma
  – Fluoroscopic guided flexion and extension radiography
  – No evidence

• Harborview Medical Center
  – Upright lateral radiograph out of collar
  – No evidence

• MRI
  – Limited evidence
MRI

• MRI vs. CT
  – MRI lower sensitivity for posterior fracture (CT)
  – MRI higher sensitivity for ligamentous injury

• False positives
  – Soft tissue injury/edema is common
  – 25% will have abnormality
  – Significance of injuries not seen at CT is not known
Imaging Options

• Fluoroscopic flex/ext
  – High resource use
  – Unproven efficacy

• Upright lateral radiograph
  – Low resource use
  – Unproven efficacy

• MRI
  – High resource use
  – High sensitivity
  – High false positive rate
Issue 4: What Imaging is Appropriate in Elderly Trauma Patients?
Special Populations-Elderly

• Osteopenia
• Biomechanically different
  – Degenerative fusion
• Injury mechanisms (falls)
• Difficult to radiograph
Location of Fractures

KF Linnau, report in progress
Elderly Subjects with Cervical Spine Fractures

From Lomoschitz, AJR 2002, 178, 573-577
Predictors in Elderly

- Case-Control study
- Predictors of fracture
- Recursive partitioning
- Compare to adult prediction rule
Elderly

• Same risk factors
  – Other injuries
  – High energy mechanism
• Fall from standing common
  – 11% of fractures
  – harder to predict
• Type 2 dens fractures

Bub, RADIOLOGY, IN PRESS
Lomoschitz, AJR, 178: 573-577
Elderly

• Same prediction rule
• Low threshold for CT
  – Focal pain/tenderness
  – Limited exam
  – Findings on radiography
• Focus evaluation on C2
Issue 5: What Imaging is Appropriate in Children?
Special Populations-Children

- Increased radiation sensitivity
- Lower injury incidence
  - <1%
- Different injury patterns
- Adult data not relevant
  - Best imaging approach not clear
Location of Fractures

KF Linnau, report in progress
Cervical Spine Injuries in Children

Adapted from Kuhns
Pediatric CT

- CT
  - Increased imaging cost
  - Higher radiation dose
  - No change in medication/sedation

- No solid accuracy data on CT v. radiography
Pediatric Protocol

- Under 4 years
  - AP and lateral radiographs
- 4-8 years
  - AP, lateral, open mouth, (swimmers)
- 9 and over=adult
- Attending (surgeon/ER/radiology) required for CT under 9
  - Unless fracture identified
Issue 6: What Thoracolumbar Spine Imaging is Appropriate in Trauma Patients?
Thoracolumbar Spine

- Incidence 640-1170 per million
  - Elderly osteoporotic fractures
- Admitted trauma patients 2-4% T/L fracture
- No good data on cost
Clinical Predictors of Thoracolumbar Fracture

- Prospective validation
  - NEXUS group (Holmes)
  - Single center
- 2404 consecutive subjects
  - 152 (6.3%) fracture
- Sensitivity 100%
- Specificity 3.9%
- Limited data on children
Thoracolumbar Spine Predictors

- Thoracolumbar spine pain
- Thoracolumbar spine tenderness on midline palpation
- Decreased level of consciousness
- Abnormal peripheral nerve examination
- Distracting injury
- Intoxication.
CT Scan

• Multi-detector CT
  – Faster
    • More patients
    • Less motion artifact
    • Reformations

• CT reconstructed from Chest/ Abdomen/ Pelvic CT
  – High accuracy

• Standard protocol in trauma
CT v. Radiography

- Limited evidence
  - Higher accuracy than radiography
  - Sensitivity CT: 78-97%
  - Sensitivity Xray: 32-74%
- Clinical significance???
- CT “free”
  - Time
  - Radiation
Conclusions: Thoracolumbar Spine

- CT (axial and sagittal)
  - from CT C/A/P
  - If available
- Radiography
  - CT if questions
- MRI if neuro deficit
Issue 7: What Cerebrovascular Imaging is Appropriate in Patients with Cervical Trauma?
Cervical Vascular Injury

• Incidence
  – Prior to 1995: Rare
  – After screening initiated: More common
  – 0.1% to 1.55%

• Outcomes improving
  – ? Detection of less severe/important disease
  – ? Treatment of important disease
Screening Criteria

• Denver
  – Symptomatic (hemorrhage/stroke)
  – At risk
    • Severe hyperextension/rotation
      – Facial fracture/mandible fracture
      – Head injury/DAI
    • Near hanging
    • Seat belt abrasion
      – Swelling/altered mental status
    • Carotid canal fracture
    • Vertebral body fracture or distraction
Screening Criteria

• Tennessee
  – Symptomatic
  – At risk:
    • Cervical spine fracture
    • LeFort II or III
    • Skull base to foramen lacerum
    • Neck soft tissue injury (seat belt injury or hanging)
Modality

- Angio considered gold standard
  - Complications in (1%)
- CTA
  - Miller (2002) sens 47%
    - Single slice helical, hard copy
  - Berne (2004) sens 100%
    - 4/16 slice helical
  - Hollingworth review (2003) sens 95%
    - Used atherosclerotic plaque as surrogate for injury
    - No data on intimal plaque
Clinically Important Disease?

• Denver
  – 90% of subjects with stroke were symptomatic prior to imaging
  – 4 strokes in 171 patients after imaging
    • Confounded by other injuries
Questions

• Criteria to screen
  – Not well defined
  – Must be high yield if using angio
• Modalities
  – CT promising, but data controversial
• Screening
  – Are we finding clinically relevant disease?