

# 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

# 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%)

Hanson, et al, *Emergency Radiology* 2000;7:31-35

# Balance Radiography vs. CT Scan

	Radiography	CT Screen
• Sensitivity	94%	99%
• Specificity	78-89%	93%
• Time	+++	+
• Cost	+	+++

# 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

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

# Results (cont)

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

# 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

# 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

# Radiation Reduction

- Limit to high risk patients
- No children
  - Higher radiosensitivity
  - Lower fracture probability
- Lowest mAs
  - Neck/shoulders

# HMC CT Screen Criteria

- Focal neurological deficit
- Severe head injury
  - unconscious, skull fracture, intracranial hemorrhage
- High energy mechanism
  - MVC speed > 35mph
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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

- Flourosopic 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

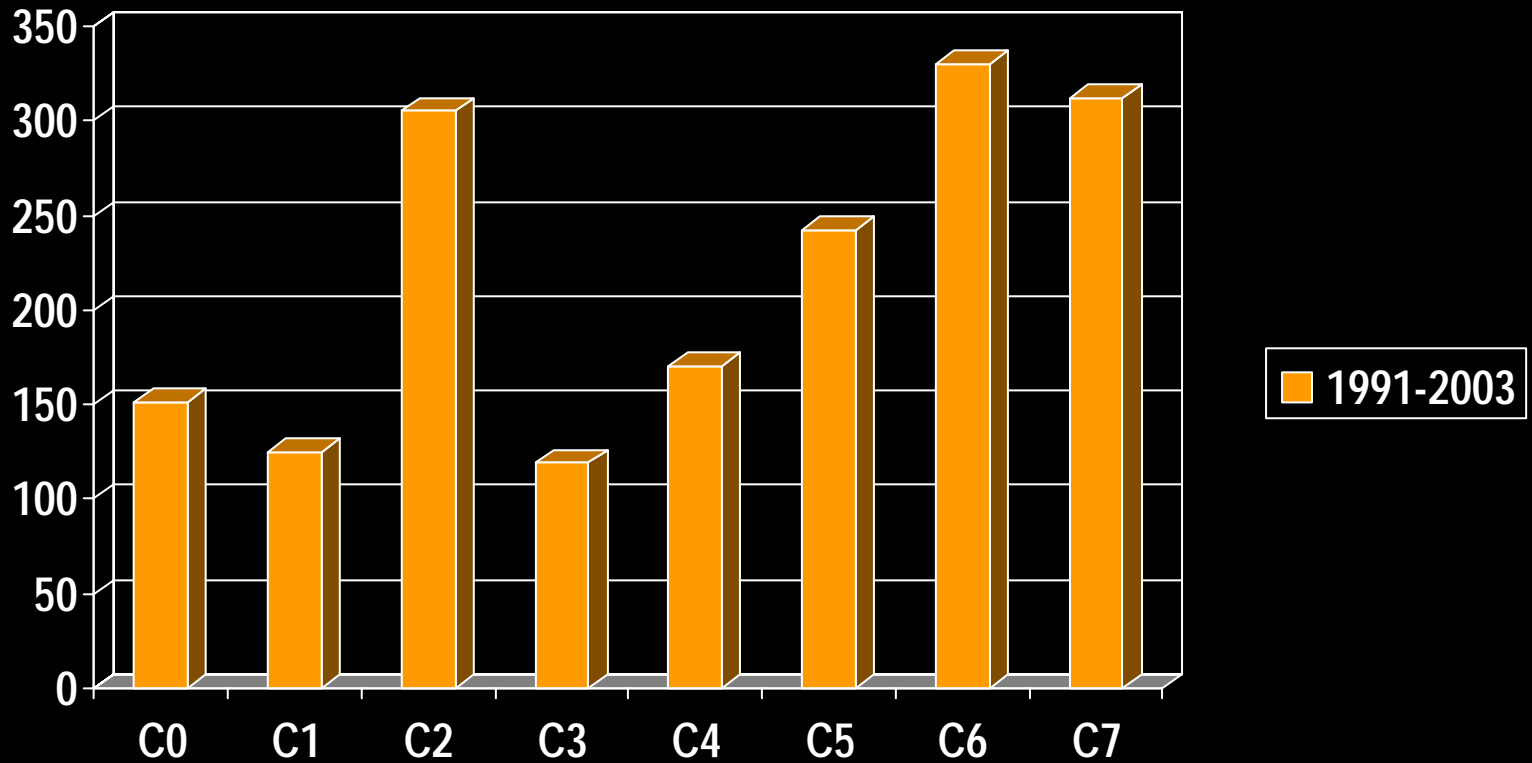
# Issue 4: What Imaging is Appropriate in Elderly Trauma Patients?

# Special Populations-Elderly

- Osteopenia
- Biomechanically different
  - Degenerative fusion
- Injury mechanisms (falls)
- Difficult to radiograph

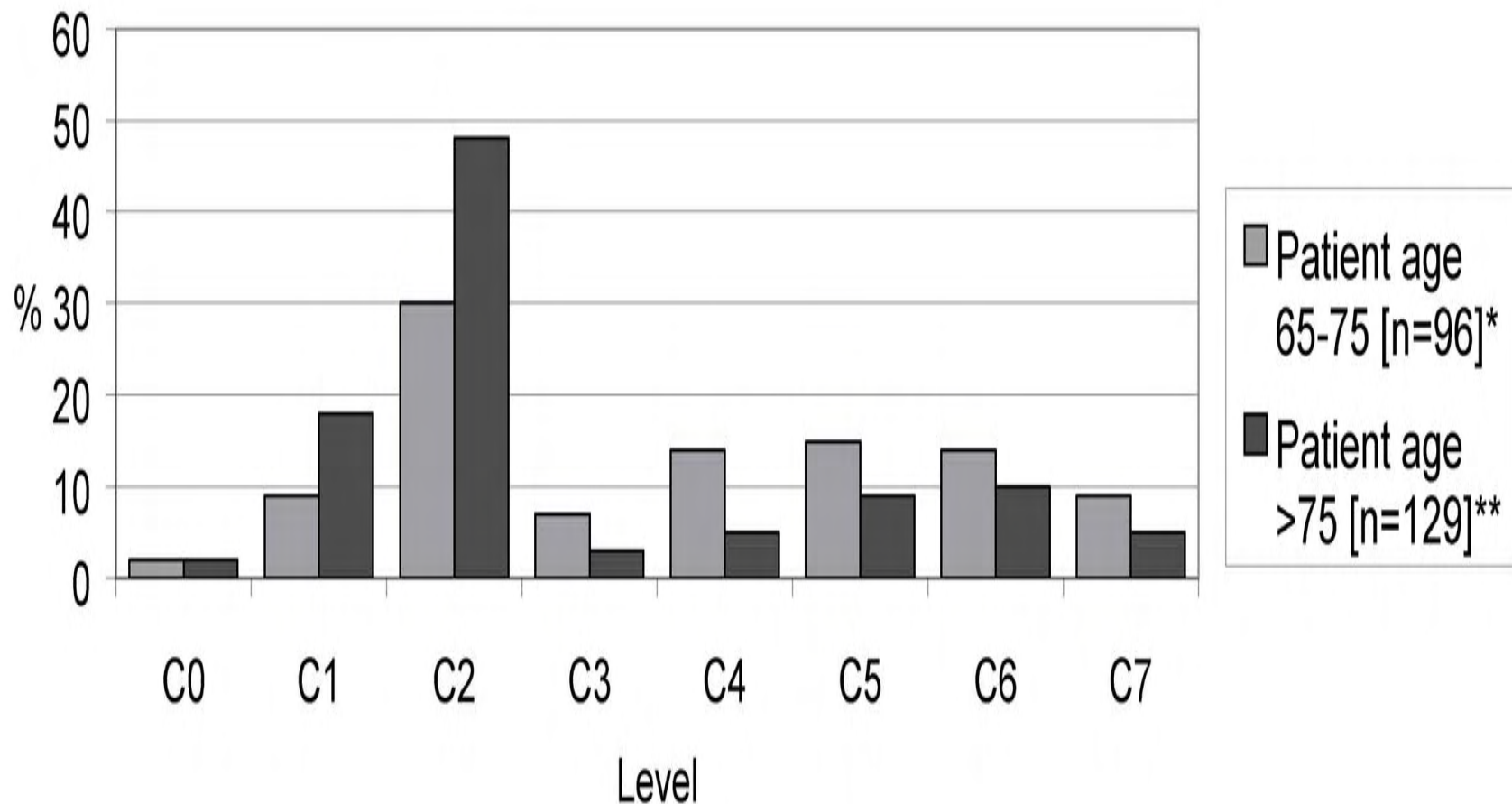


# Location of Fractures



KF Linnau, report in progress

# Elderly Subjects with Cervical Spine Fractures



# 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



# Elderly

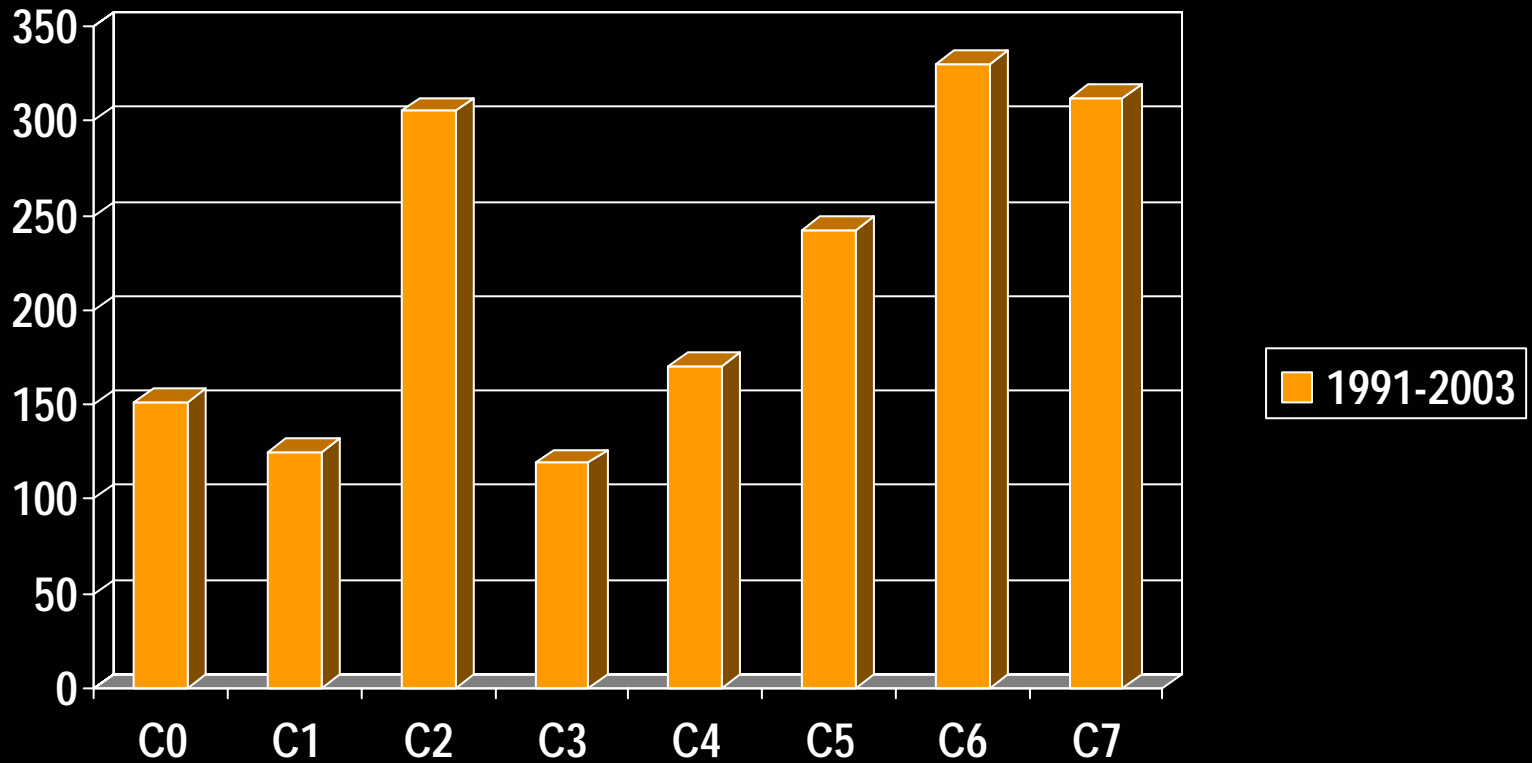
- Same prediction rule
- Low threshold for CT
  - Focal pain/tenderness
  - Limited exam
  - Findings on radiography
- Focus evaluation on C2

# Issue 5: What Imaging is Appropriate in Children?

# Special Populations-Children

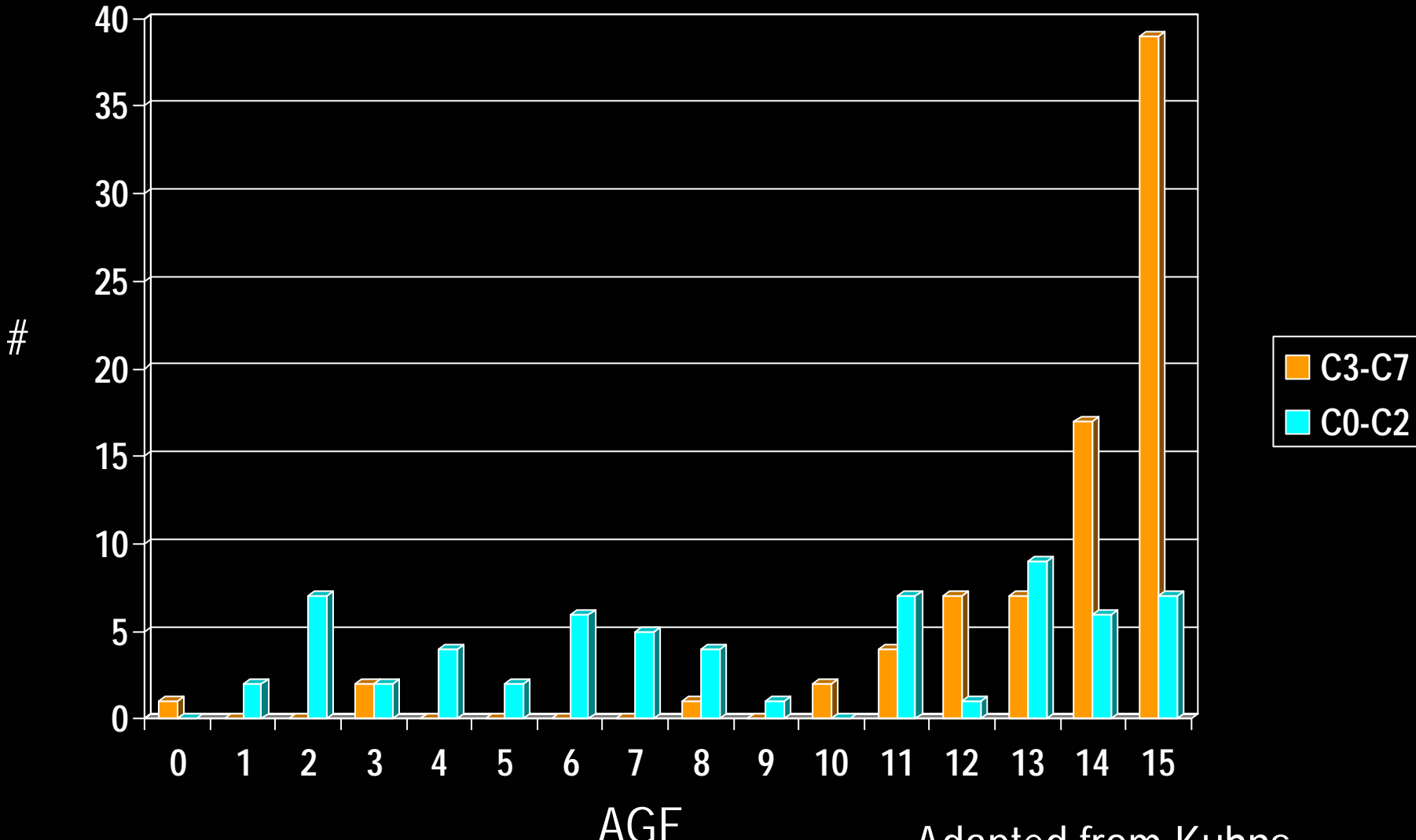
- Increased radiation sensitivity
- Lower injury incidence
  - <1%
- Different injury patterns
- Adult data not relevant
  - Best imaging approach not clear

# Location of Fractures



KF Linnau, report in progress

# Cervical Spine Injuries in Children



# 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?