Evidence-based Emergency Department Evaluation of Pediatric Blunt Head Trauma

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Disclosure

- No financial relationships or conflict of interests
Today’s Objectives

- Epidemiology of blunt head trauma (BHT) in children
- Evaluation in the ED (minor BHT)
- Indications for CT: the evidence and controversy
- Preverbal patients
- PECARN multicenter study
Case

- 6 year-old falls 4 feet from a ladder
- No LOC
- On exam, GCS 15
- Small forehead hematoma, tender at site

What are you going to do?
Epidemiology of Pediatric Head Trauma

- Trauma the leading cause of death among children > 1 year
- Traumatic brain injury (TBI) the leading cause of death and disability due to trauma (> 70% of deaths)
- On an annual basis in the U.S., BHT in children (to 19 years) results in:
  - 6,000 deaths
  - 60,000 hospitalizations
  - 620,000 ED visits (~50% evaluated with CT scans, and use of CT increasing over the past decade)

*NHAMCS 2006; Blackwell 2007; Centers for Disease Control 2010*
Variation in Care

- Some children with BHT present with overt signs. little controversy in evaluation

- Most BHT patients present with few/subtle signs. much controversy and substantial variation

The evidence for decision-making in evaluating children with minor BHT recently enhanced by large multicenter studies…
Minor Head Trauma in Children

- ~97% of children with BHT evaluated in EDs, and 75% of those evaluated with CT, have “minor” BHT (GCS 14-15)
- ~50% of those with TBI on CT present with GCS 14-15
- Among children with GCS 15 after head trauma, prevalence of TBI is 0-7%, surgical intervention in <1%

Dietrich 1993; Schunk 1996; Quayle 1997; Greenes 1999; Palchak 2003; Oman 2006; Kuppermann 2009; Osmond 2010
Controversy over CT for Minor BHT

Arguments for liberal use of CT:

- Preventable morbidity/mortality due to unrecognized TBIs
- Preverbal children difficult to eval.
- When indicated, benefit of CT greatly outweighs risk, however…
Controversy over CT for Minor BHT

Arguments against liberal use of CT:

- Of the large number of children evaluated with CT after BHT, fewer than 10% have TBI
- Drawbacks of CT include transport outside the ED, pharmacological sedation, costs
- Most important (theoretical) risk: lethal malignancy risk from a single CT may be as high as 1:2500

- Pediatric BHT high priority for AAP, IOM, EMSC…
CT Radiation Risks

- Helical CT scanners have enhanced diagnostic possibilities and reduced need for sedation.
- Radiation exposure, however, not reduced with helical CT.
- Radiation exposure of CT ~200+ times that of CXR.

CT Radiation Risks

- *Estimates* (theoretical, not observed) of risks of lethal malignancies extrapolated from survivors of WWII atomic explosions:
  - 1 per 2500 head CT scans for 5 year-olds
  - 1 per 5000 for 10 year-olds

- Age and size-based radiation-reduction efforts ongoing (*"ALARA"* principle)

- CT radiation risks important from a public-health view
  - ~300,000 CTs for BHT, ~4 million pediatric CTs annually in U.S.
The ED Evaluation of Children with BHT

controversial factors
Blunt Head Trauma in Children

**historical factors**

**History of LOC**
- Most controversial historical finding
- Common driver of CT use
- Common in pediatric BHT
- Reliability of history? Accuracy of report of duration? Amnesia in pre-verbal children?
Blunt Head Trauma in Children

**historical factors**

**History of LOC**

- LOC common in patients with TBI, however…
- LOC absent in 20-30% of patients with TBI

**Is LOC important after adjusting for mental status and other findings?**

- In a few *multivariable* analyses, LOC not found to be an independent predictor of TBI

*Davis 1994; Quayle 1997; Palchak 2003; Smits 2005; Oman 2006; Osmond 2010*
PECARN (enrolled 42,414)

Isolated LOC

6,132 with any LOC

576 (9.4%) with isolated LOC

326 (56.6%) CT performed

3 TBI on CT (0.9%, 95% CI 0.2, 2.7)

1 Clinically-important TBI (ciTBI) (0.2%, 95% CI 0, 1.0)

Lee/Kuppermann 2014
Blunt Head Trauma in Children

*historical factors*

Other possible predictors: vomiting and headache

- Frequently seen with TBI, however, frequently not “statistically significant” in (small) studies…
- In multivariate analyses, patients with TBI “missed” by the models frequently have vomiting and/or headache
- Recent large studies using vomiting/headache as CT criteria missed no “important” TBIs (*Palchak 2003, Haydel 2003, Oman 2006, Dunning 2006, Kuppermann 2009*)
- Isolated vomiting and isolated headache and risk of ciTBI:
  - Isolated vomiting – 2/815 (0.2%; 95% CI 0, 0.9%)
  - Isolated headache – 0/2,462 (0%; 95% CI 0, 0.1%)

*Dayan/Kuppermann 2014*
Blunt Head Trauma in Children

**physical examination**

**Decreased level of consciousness**

<table>
<thead>
<tr>
<th>Eye Opening</th>
<th>Verbal Response</th>
<th>Motor Response</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spontaneous</td>
<td>Oriented (coos/smiles) 5</td>
<td>Follows (spontaneous) 6</td>
</tr>
<tr>
<td>To voice</td>
<td>Confused (fussy/cries) 4</td>
<td>Localizes pain 5</td>
</tr>
<tr>
<td>To pain</td>
<td>Inappropriate (screams) 3</td>
<td>Withdraws to pain 4</td>
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<tr>
<td>None</td>
<td>Incomprehens. (grunts) 2</td>
<td>Decorticate posture 3</td>
</tr>
<tr>
<td></td>
<td>None</td>
<td>Decerebrate posture 2</td>
</tr>
</tbody>
</table>

- Definition of minor BHT varies (GCS ≥13? ≥14? 15?)
Blunt Head Trauma in Children

physical examination

Decreased level of consciousness

- Risk of TBI if GCS = 15 is ~2-3%
- Risk of TBI if GCS = 14 is ~7-8%
- Risk of TBI if GCS = 13 is ~25%
- GCS an important predictor in multivariable analyses

Blunt Head Trauma in Children

**physical examination**

Clinical evidence of skull fracture

- ~20% of children with basilar skull fx and GCS=15 have TBI
- Signs of depressed skull fx highly associated with TBI
- In *multivariable* analyses, signs of basilar skull fx and signs/presence of *any* skull fx highly associated with TBI

*Kadish 1995; Quayle 1997; Palchak 2003; Oman 2006, Dunning 2006, Tunik 2010*
Gaps in Knowledge about Pediatric BHT

problematic issues with earlier studies

- Differing methodologies, variable definitions
- Inadequate power (wide confidence intervals)
- Lack of validation
- (Historical) lack of large multicenter study
Preverbal Children
Blunt Head Trauma in Children

*infants (≤ 2 years) are different*

- Mechanism typically is a fall
- The younger the infant, the greater the risk of TBI
- **Head injury from abuse:** 25-30% of infants ≤ 2 years hospitalized with BHT are abused and up to 10% of all infants evaluated in ED for head trauma
- High risk of abuse if “no history” of trauma
- Investigation of several biomarkers (neuron-specific enolase [NSE], myelin-basic protein [MBP], s100B) for identifying infants at risk for inflicted TBI
Blunt Head Trauma in Infants ≤2 Years

**clinical evaluation**

- 45% will present with scalp hematomas
- Infants ≤2 years with TBI may have subtle signs
- ~50% of those with TBI are asymptomatic, however…
- Scalp hematomas present in:
  - >90% of otherwise asymptomatic infants with TBI
  - >95% of infants with skull fx

Shane 1997; Greenes 1997, 1999; Schutzman 2001; Dayan/Kuppermann 2014
Blunt Head Trauma in Infants ≤2 Years: *scalp hematomas*

- *In this age range*, scalp hematoma is one of the most sensitive clinical predictors of TBI
- If scalp hematoma and SF present, ~30% TBI risk
- If scalp hematoma present w/o SF, <1% risk of TBI
- Large size and non-frontal location increase the risk
- “Isolated” scalp hematoma and risk of ciTBI:
  - 12/2,998 (0.4%; 95% CI 0.2, 0.7%)
  - None required neurosurgery

Greenes 1997, 1999, 2001; Schutzman 2001; Dayan/Kuppermann 2014
Clinical Prediction Rules

- Help clinicians optimize decision-making process
- Decrease errors of omission and commission
- Decision rules may help ED clinicians cope with diagnostic, therapeutic, medico-legal uncertainty
- ED physicians strongly support the development of decision rules (including for head CT use after trauma)

Laupacis 1997; Stiell 1999; Graham 1998
Pediatric Emergency Care Applied Research Network (PECARN)

Supported in full by Project #U03 MC00001-01 from the Maternal and Child Health Bureau, Health Resources and Services Administration, Department of Health and Human Services
Ongoing PECARN Research Development

- Patient safety and error reduction
- Quality of PEM care
- **Evaluation of head trauma**
- C-Spine immobilization
- Steroids in acute bronchiolitis
- The burden of mental illness and psychiatric emergencies in PED
- RCT of fluids for DKA
- Magnesium for sickle cell pain
- Therapeutic hypothermia in pediatric cardiopulmonary arrest
- Diagnostic categorization of illnesses and injuries in the PED
- Management of status epilepticus
- **Evaluation of abdominal trauma**
- Screening for alcohol abuse
- Probiotics for AGE
- **Knowledge translation of TBI rules**
- RNA transcription biosignatures to diagnose febrile infants
The PECARN Head Injury Study

**Goal**: to derive a clinical decision rule to accurately identify children at near zero risk of clinically important traumatic brain injury after blunt trauma with high accuracy and wide generalizability.
Methods

◆ **Design:**
  • Prospective multicenter study over 28 mo. (6/04 – 9/06) in 25 sites in PECARN

◆ **Inclusion Criteria:**
  • Age < 18 years with head trauma evaluated in ED

◆ **Exclusion Criteria:**
  • Ground-level mechanisms and no symptoms or signs of TBI
  • Penetrating trauma
  • Injury > 24 hours old
  • Pre-existing neurological disease impeding assessment
  • Transfer with neuroimaging already performed
Outcome Definition

Clinically-important TBI (ciTBI)

• Death from TBI
• Neurosurgical procedure
• Intubation for > 24 hours for head injury
• Positive CT in association with hospitalization ≥ 2 nights
Variables Considered

- Age in years
- 3-level mechanism severity
  - High risk
    - MVC - ejection, rollover, death
    - Ped or unhelmeted bicyclist struck by motorized vehicle
    - Fall > 5 feet (> 3 feet if < 2 years)
    - High impact / projectile
- Amnesia
- LOC (duration)
- Seizure
- Acting normal per parent
- Headache (severity, location)
- Emesis (number, timing)
- GCS (14 vs. 15)
- Other mental status
  - Agitated
  - Sleepy
  - Slow to respond
  - Repetitive
- Palpable skull fx signs
- Basilar skull fx signs
- Bulging fontanelle
- Scalp hematoma (location, size, quality)
- Focal neurological deficit
- Other system injuries
- Evidence of intoxication
Variable Modification for Children < 2 Years

- Headache and amnesia not evaluated
- Age dichotomization at < 3 months
- Any scalp trauma considered
Results

57,030 eligible

2,869 GCS <14 or other exclusion

54,161 GCS 14-15

42,412 (78.3%)

Not enrolled

11,749 (21.7%)

Enrolled

42,412 (78.3%)

Derivation 33,785

Validation 8,627

288 ciTBI (0.9%)

88 ciTBI (1.0%)
Identification of children at very low risk of clinically-important brain injuries after head trauma: a prospective cohort study


Summary

Background CT imaging of head-injured children has risks of radiation-induced malignancy. Our aim was to identify children at very low risk of clinically-important traumatic brain injuries (ciTBI) for whom CT might be unnecessary.

Methods We enrolled patients younger than 18 years presenting within 24 h of head trauma with Glasgow Coma Scale scores of 14–15 in 25 North American emergency departments. We derived and validated age-specific prediction rules for ciTBI (death from traumatic brain injury, neurosurgery, intubation >24 h, or hospital admission ≥2 nights).
The PECARN TBI Rules (derived and validated)

Children are at very low risk of clinically-important traumatic brain injury (TBI) if they meet all criteria in age-specific rule:

**Children < 2 years**
1. Severe mechanism of injury
2. History of LOC ≥ 5 sec
3. GCS = 14 or other signs of altered mental status
4. Not acting normally per parent
5. Palpable skull fracture
6. Occipital/parietal/temporal scalp hematoma

**Children 2-18 years**
1. Severe mechanism of injury
2. History of LOC
3. GCS = 14 or other signs of altered mental status
4. History of vomiting
5. Severe headache in the ED
6. Signs of basilar skull fracture
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<thead>
<tr>
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<th>Derivation</th>
<th>Validation</th>
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<tr>
<td></td>
<td>cITBI</td>
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<td>Prediction rule sensitivity (95% CI)</td>
<td>98.6% (92.6-99.97)</td>
<td>100.00% (86.3-100.00)</td>
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<tr>
<td>Prediction rule specificity (95% CI)</td>
<td>53.7% (52.6-54.8)</td>
<td>53.6% (51.5-55.7)</td>
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<tr>
<td>Negative predictive value (95% CI)</td>
<td>99.9% (99.88-99.999)</td>
<td>100.00% (99.7-100.00)</td>
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<tr>
<td>Positive predictive value (95% CI)</td>
<td>1.8% (1.4-2.3)</td>
<td>2.4% (1.6-3.5)</td>
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<td>Negative likelihood ratio (95% CI)</td>
<td>0.03 (0.001-0.14)</td>
<td>2.4 (0.0-0.26)</td>
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<td>10635</td>
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<td>58.2% (57.0-59.4)</td>
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<td>99.95% (99.80-99.99)</td>
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<tr>
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<td>2.2% (1.7-2.9)</td>
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<tr>
<td>Negative likelihood ratio (95% CI)</td>
<td>0.06 (0.03-0.12)</td>
<td>0.05 (0.01-0.19)</td>
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</table>
Recommendations for children younger than 2

- **GCS=14 or other signs of altered mental status†, or palpable skull fracture**
  - Yes: CT recommended
  - No:
    - Occipital or parietal or temporal scalp haematoma, or history of LOC ≥5 s, or severe mechanism of injury‡, or not acting normally per parent
      - Yes: Observation versus CT on the basis of other clinical factors including:
        - Physician experience
        - Multiple versus isolated§ findings
        - Worsening symptoms or signs after emergency department observation
      - No: 53.2% of population, <0.02% risk of ciTBI
    - No: CT not recommended¶
Recommendations for children younger than 2

A

GCS = 14 or other signs of altered mental status†, or palpable skull fracture

Yes

13.9% of population
4.4% risk of ciTBI

CT recommended

No

Occipital or parietal or temporal scalp haematoma, or history of LOC ≥ 5 s, or severe mechanism of injury‡, or not acting normally per parent

Yes

32.9% of population
0.9% risk of ciTBI

Observation versus CT on the basis of other clinical factors including:
- Physician experience
- Multiple versus isolated§ findings
- Worsening symptoms or signs after emergency department observation
- Age < 3 months
- Parental preference

No

53.2% of population
< 0.02% risk of ciTBI

CT not recommended¶

Suggestions
Recommendations for children 2 years and older

The Rule

- GCS=14 or other signs of altered mental status†, or signs of basilar skull fracture
  - Yes: CT recommended
    - 14.0% of population
    - 4.3% risk of ciTBI
  - No: History of LOC, or history of vomiting, or severe mechanism of injury; or severe headache
    - Yes: Observation versus CT on the basis of other clinical factors including:
      - Physician experience
      - Multiple versus isolated findings
      - Worsening symptoms or signs after emergency department observation
      - Parental preference
    - No: CT not recommended
      - 57.2% of population
      - <0.05% risk of ciTBI
Recommendations for children 2 years and older

GCS=14 or other signs of altered mental status†, or signs of basilar skull fracture

If No:

History of LOC, or history of vomiting, or severe mechanism of injury‡, or severe headache

If No:

CT not recommended¶

If Yes:

14.0% of population
4.3% risk of ciTBI

CT recommended

If Yes:

28.8% of population
0.8% risk of ciTBI

Observation versus CT on the basis of other clinical factors including:
- Physician experience
- Multiple versus isolated findings
- Worsening symptoms or signs after emergency department observation
- Parental preference

Suggestions
Case

- 6 year-old falls 4 feet from a ladder
- No LOC
- On exam, GCS 15
- Small forehead hematoma, tender at site

What are you going to do?
Pediatric Blunt Head Trauma

**summary**

- The study of pediatric head trauma is important
- Pressing issues include indications for emergency CT
  - **Benefits**: early identification of TBI
  - **Drawbacks**: radiation-induced malignancies
- Current data re: indications for CT in children are limited
- Definitive decision rule requires large, multicenter study
  - *Then need to translate the research into practice!*
- Multicenter networks can help improve the foundation of evidence for CT use after pediatric BHT
Selected References

19. Hettler J, Greenes D. Can the initial history predict whether a child with a head injury has been abused? Pediatrics 111:602-607, 2003
How to get clinicians to use the prediction rules?
Knowledge Translation Pipeline

The research-to-practice pipeline. New research, of varying soundness, is added to the expanding pool and enters practice both directly or is reviewed, summarised, and systematised (delay) before entering practice, with leakage occurring at each of several stages between awareness and patient outcome. Different knowledge translation disciplines focus on different parts of the pipeline (1–4).

Glasziou and Haynes, 2005
Translating Research into Practice

What works

Clinical decision support more successful when:

- Automatic provision of support in workflow
- Recommendations given rather than risks
- Support given at the time and location of decision-making
- Support is computer based

Kawamoto, BMJ, 2005
Translating Research into Practice

What PECARN is doing...

Funded by the American Recovery and Reinvestment Act – Office of the Secretary: Grant #S02MC19289-01-00
Specific Aims

1. To develop and pilot test an integrated EHR blunt head trauma data collection template and computer-based CDS system to implement the PECARN TBI prediction rules for children with minor head trauma.

2. To assess whether implementing the two age-specific PECARN TBI clinical prediction rules via CDS integrated with the EHR, decreases the number of (unnecessary) cranial CTs obtained by clinicians in the ED in children with minor blunt head trauma at very low risk of clinically-important TBIs.
Methods

Computer-Based Decision Support Development and Pilot

- Perform focus groups
- Perform ED work flow assessments
- Develop EHR blunt head injury template
- Develop CDS
- Pilot testing
## Blunt Head Trauma Assessment

**Blunt Head Trauma Assessment**

- **Blunt head trauma?**
  - Yes - less than 24 hours ago
  - Yes - more than 24 hours ago

- **Loss of consciousness?**
  - Yes - less than 5 seconds
  - Yes - 5 seconds up to one minute
  - Yes - 1 minute or longer

- **Vomiting since injury?**
  - No
  - Once
  - Twice
  - Three or more times

- **Acting normally per caregiver?**
  - Yes
  - No

- **Severe mechanism of injury?**
  - No
  - Yes

- **Current headache?**
  - No
  - Mild
  - Moderate

- **Other signs of altered mental status?**
  - No
  - Yes

- **Temporal, parietal, or occipital scalp hematoma?**
  - No
  - Yes

---

**Other signs of altered mental status?**

**Row Information:**

Other signs of altered mental status defined as any of the following:

- Agitation
- Somnolence
- Repetitive questioning
- Slow response to verbal communication

**Temporal, parietal, or**

---

**GCS**

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<tr>
<th>Eye Opening</th>
<th>4</th>
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<tr>
<td>Motor Response</td>
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<td>5</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>Total GCS</td>
<td></td>
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</tbody>
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Courtesy: Peter S. Dayan, MD, PECARN
**Traumatic Brain Injury Risk: Child less than 2 years**

**RECOMMENDATION:** A head CT is not recommended for this patient based on the absence of any of the PECARN prediction rule variables.

**Risk Estimate:** The risk of **clinically-important traumatic brain injury** for patients less than 2 years is < 1/5000

Importantly, the PECARN rules were based on attending initial evaluations (not based on subsequent evaluations over time).

The age-specific PECARN rule findings documented are:

- Loss of consciousness?: No
- Acting normally per caregiver?: Yes
- Mechanism of injury?: Mild
- Total Glasgow Coma Scale score: 15
- Other signs of altered mental status?: No
- Scalp hematoma?: None
- Palpable skull fracture or unclear on the basis of swelling or distortion of the scalp?: No

If the above clinical findings are incorrect, please revise.

Note: The PECARN prediction rules do not apply to patients with: bleeding diatheses, ventricular (e.g. “VP”) shunts, known brain tumors, or pre-existing neurological disorders complicating your clinical assessment.

[Click here to view the PECARN prediction rule manuscript (Lancet)]

[5 Click to provide a revised risk assessment]
Methods – design

Interrupted Time Series Trial with Concurrent Controls

Month of Trial

- Pre-intervention phase
- Intervention implemented
- Intervention maintained (post-intervention phase)
- Main Comparisons: Pre to post int.

Intervention Group Measurement (receives CDS)

Baseline rate of CT use → Post-intervention rate of CT use

Control Group Measurement (standard of care)

Rate of CT use measured throughout the study period