Objectives

Familiarize you with:

- Epidemiology of Peds Blunt Head Trauma
- Radiation risks associated with CT scan
- PECARN
- PECARN Prediction Rules for Pediatric BHT
- Sub-analyses of PECARN TBI Study
Epidemiology

- 5,000,000 children with head injuries
- 600,000 Emergency Department
- 250,000 admitted
- ~ 90%: mild TBI/ GCS 14-15
Epidemiology

- Most frequent diagnosis in injured child is: HEAD INJURY
- Every 11 minutes 1 child in the US has a brain injury resulting in permanent disabilities
- Almost 1/2 of winter sports injuries are head injuries

– National Pediatric Trauma Registry
CT Scanning

- Non-contrast head CT
Controversy over CT for Minor BHT

Arguments for liberal use of CT:

- Preventable morbidity/mortality due to unrecognized TBIs
- CT provides visual information about the skull and the brain
- 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 325,000 children evaluated with CT after BHT, fewer than 10% have TBI
- Drawbacks of CT include transport outside the ED, pharmacological sedation, costs (charges $2-3K/patient)
- Most important (theoretical) risk: lethal malignancy risk from CT may be as high as 1:5000

• Substantial variation in the evaluation of children with minor BHT
• Pediatric BHT high priority for AAP, IOM, EMSC…
CT Radiation Risks

 Estimates (theoretical, not observed) of risks of lethal malignancies extrapolated from survivors of WWII atomic explosions:

• 1 per 1250 head CT scans for infants younger than 1 year
• 1 per 5000 for 10 year-olds

Age and size-based radiation-reduction efforts ongoing

CT radiation risks important from a public-health view

• 325,000 CTs for BHT, 2.7 million total pediatric CTs annually
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Background

NEJM 2007, Brenner et al.

- Lifetime cancer mortality risk with single CT head in year 1 of life:
- 1/1250
Background

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- Lifetime cancer mortality risk with single CT head in year 1 of life:
  - 1/1250
Lifetime Cancer Mortality Risk

A. Head CT, 340 mAs

B. Abdominal CT, 240 mAs

C. Head CT, 340 mAs

D. Abdominal CT, 240 mAs
Background

- 4 million pediatric CT scans performed annually in the US (DHHS, 2006)
- Highest rates of increase CT among peds and screening of adults (AJR 2003)
- CT use has increased over past 20 years:
  - 20 fold increase in US
  - 12 fold increase in UK
  - Canada?
PECARN

- 25 centers/ 4 Nodes and CDMCC:
  - CARN – CNMC, UMD, JHU, Howard Cty, HCH
  - GLMS CRN
  - ACORN
  - PEDNET
- Funded by HHS, HRSA, MCHB, EMSC
- Research infrastructure
  - Site PI’s, RC’s, RA’s,
The PECARN Head Injury Study

- **The long-range goal** was to identify the evidence on which to base appropriate ED evaluation of head-injured children.

- **The principal overall objective of the study** was to develop a clinical decision rule for the use of neuroimaging that identifies children at high risk and those at zero risk of TBI needing acute intervention after blunt head trauma.
Outcome Variable Definitions

1. **TBI in need of acute intervention**
   - Death due to TBI
   - Neurosurgical procedure
   - Endotracheal intubation > 24 hours for TBI
   - Hospitalization ≥ 2 nights for head injury

2. **TBI on CT**
   - Intracranial hematoma, hemorrhage, contusion, or edema
   - Depressed skull fracture > width of the skull
PECARN BHT Study

- We prospectively enrolled approx. 44,000 children <18 years old with blunt head trauma at 25 EDs in PECARN from 6/04 to 9/06.
- Head CT obtained at the clinicians discretion. A standardized clinical assessment was recorded onto a case report form prior to CT results
In patients with Glasgow Coma Scale [GCS] score 14-15), clinical variables with a priori likelihood of association with TBI and with at least moderate interobserver agreement were analyzed to develop a decision rule to identify children at very low and high risk of TBI.
PECARN BHT Study

- N=43,995 children,
- 57,158 eligible (77% enrolled)
- MOI: falls (48.1%), occupant in MVC (9.1%), ran into stationary objects (8.5%), object struck head (8.4%), sports (7.3%), assaults (7.3%), pedestrians (3.3%) or bicyclists (1.2%) struck by automobiles, and bicycle crashes (3.5%).
PECARN BHT

- 96.8% had GCS of 14 (3.1%) or 15 (93.7%).
- CTs were obtained in 36.8% (site-specific range: 9.7% - 71.1%), and were positive in 11.2% (30% of these were isolated skull fractures).
- Neurosurgery was performed on 0.5%, and 0.1% died from TBI.
Within PECARN, we developed 2 prediction rules to identify children at very low risk of clinically important Traumatic Brain Injury after blunt head trauma.

Kuppermann/Holmes/Dayan/Hoyle/Atabaki et al, Lancet 2009
PECARN Prediction Rules

Age younger than 2 years

- GCS < 15 or abnormal mental status
- Temporal/parietal/occipital scalp hematoma
- LOC > 5 seconds
- Severe mechanism of injury
- Palpable/suspected skull fracture
- Acting abnormal per parent

Kuppermann/Holmes/Dayan/Hoyle/Atabaki et al 2009
PECARN Prediction Rules

Age 2 years and older

- GCS < 15 or abnormal mental status
- LOC
- History of emesis
- Severe mechanism of injury
- Signs of basilar skull fracture
- Severe headache

Kuppermann/Holmes/Dayan/Hoyle/Atabaki et al 2009
PECARN Prediction Rules

Risk of clinically-important TBI if none of the 6 criteria are met is very low for both age groups

Kuppermann/Holmes/Dayan/Hoyle/Atabaki et al 2009
A

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

- Yes
  - CT recommended
  - 13.9% of population
  - 4.4% risk of ciTBI

- 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
    - Age < 3 months
    - Parental preference

- No
  - CT not recommended¶

- 53.5% of population
- <0.02% risk of ciTBI
B

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

Yes

14.0% of population
4.3% risk of ciTBI

CT recommended

No

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

Yes

27.7% 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
- Parental preference

No

58.3% of population
<0.05% risk of ciTBI

CT not recommended¶
Published abstracts

- Several sub-analyses
Clinician Assessment Versus a Prediction Rule for Identifying Children with Clinically-Important Traumatic Brain Injuries (TBI) after Blunt Head Trauma

S Atabaki, J Hoyle, J Schunk, D Monroe, E Alpern, K Quayle, T Glass, M Badawy, L Dong, P Dayan, J Holmes, N Kuppermann and the TBI Study Group for the PECARN Network

Children’s National Medical Center, George Washington University, Helen DeVos Children’s Hospital, University of Utah, University of Pennsylvania, Washington University, University of Cincinnati, University of Rochester, Columbia University College of Physicians & Surgeons, University of California, Davis School of Medicine

Supported by grant R40MC02461 from the Health Resources and Services Administration / Maternal and Child Health Bureau (HRSA/MCHB) Division of Research, Education, and Training (DRTE) and the Emergency Medical Services for Children (EMSC) Program.
PECARN is supported by cooperative agreements from HRSA/MCHB/EMSC: U03MC00001, U03MC00007, U03MC00006, U03MC00003, U03MC00008
Objectives

In children < 18 years with minor BHT (defined by a GCS 14-15) we sought:

1) To compare test characteristics of clinician suspicion with those of a prediction rule to identify clinically-important traumatic brain injuries (ciTBIs) among children with minor BHT

2) To uncover rationale for CT use among children when clinician suspicion for ciTBI was low (<1%)
Sub-analysis 1

Design:

- Planned secondary analysis
- Prospective 25-center cohort study in PECARN
- Derivation and validation groups

Inclusion Criteria for Sub-study:

- Age < 18 years with BHT and GCS 14-15 meeting inclusion criteria for primary study
- Clinician suspicion for ciTBI documented
Sub-analysis 1

- Standardized history and PE before CT
- CT obtained at ED faculty discretion
- Clinician suspicion of ciTBI before CT
  - <1%, 1-5%, 6-10%, 11-50%, >50%
- Clinician suspicion documented
- Prediction rule and clinician suspicion compared
  - on validation set
Sub-analysis 1

ciTBI defined as:

• Death from TBI
• Neurosurgery
• Intubation for TBI > 24 hrs
• Hospitalization for TBI ≥ 2 nights
Results

43,904

42,412 (GCS 14,15)

33,785 Derivation

8,627 Validation

8,496 suspicion ciTBI recorded
Results

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## CT Imaging

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<th>Clinician suspicion ciTBI</th>
<th>CT obtained n (%)</th>
<th>ciTBI</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;1%</td>
<td>2117/7688 (27.5%)</td>
<td>32/7688 (0.4%)</td>
</tr>
<tr>
<td>1-5%</td>
<td>637/686 (92.9%)</td>
<td>28/686 (4.1%)</td>
</tr>
<tr>
<td>6-10%</td>
<td>85/85 (100%)</td>
<td>16/85 (18.8%)</td>
</tr>
<tr>
<td>11-50%</td>
<td>29/30 (96.7%)</td>
<td>8/30 (26.7%)</td>
</tr>
<tr>
<td>&gt; 50%</td>
<td>7/7 (100%)</td>
<td>3/7 (42.9%)</td>
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## CT Imaging

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Results: ciTBI

<table>
<thead>
<tr>
<th>ciTBI = 25</th>
<th>Patients &lt; 2 years (n=2185)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Prediction rule</td>
</tr>
<tr>
<td>Sensitivity (95% CI)</td>
<td>100% (86.3%, 100%)</td>
</tr>
<tr>
<td>Specificity (95% CI)</td>
<td>53.7% (51.5%, 55.8%)</td>
</tr>
</tbody>
</table>
# Results: ciTBI

<table>
<thead>
<tr>
<th>ciTBI = 62</th>
<th>Patients ≥ 2 years (n=6311)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Prediction rule</strong></td>
<td><strong>Clinician suspicion ≥1%</strong></td>
</tr>
<tr>
<td><strong>Sensitivity (95% CI)</strong></td>
<td>96.8% (88.8%, 99.6%)</td>
</tr>
<tr>
<td><strong>Specificity (95% CI)</strong></td>
<td>59.8% (58.5%, 61.0%)</td>
</tr>
</tbody>
</table>
Conclusions

- Prediction rules for ciTBI in children < 2 years and those ≥ 2 years had greater sensitivity than clinician suspicion, but lower specificity
- Despite suspicion of ciTBI < 1%, clinicians frequently obtained CT scans
- ~ 20% of neurosurgeries were associated with a clinician suspicion for ciTBI of <1%
Association of TBI in Children after BHT with Degree of Isolated HA or Isolated Vomiting

Objective: Are isolated Vomiting (i-V) or isolated HA (i-HA) with 1) TBI on CT or 2) TBI requiring intervention

For 43,485 children with i-V or i-HA only 1 required neurosurgery.
Conclusion

- For children with i-V and i-HA after BHT the risk of TBI on CT is low.

- Clinicians should individualize the use of CT in such cases.
## Does Isolated LOC Predict TBI in Children after BHT?

<table>
<thead>
<tr>
<th></th>
<th>Any LOC (N=6,847)</th>
<th>No LOC (N=34,746)</th>
<th>Isolated LOC N=790</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Undergoing CT</strong></td>
<td>5,545 (81%)</td>
<td>8,964 (25.8%)</td>
<td>465 (58.9%)</td>
</tr>
<tr>
<td><strong>Positive CT</strong></td>
<td>521 (9.4%, 95% CI 8.6, 10.2%)</td>
<td>471 (5.3%, 95% CI 4.8, 5.8%)</td>
<td>4 (0.9%, 95% CI 0.2, 2.2%)</td>
</tr>
<tr>
<td><strong>TBI acute intervention (denominator total N)</strong></td>
<td>438 (6.4%, 95% CI 5.8, 7.0%)</td>
<td>195 (0.6%, 95% CI 0.5, 0.7%)</td>
<td>1 (0.1%, 95% CI 0, 0.7%)</td>
</tr>
</tbody>
</table>
Conclusion

- **TBI occurs more often in children with LOC than those without a hx of LOC post BHT.**

- **For children with isolated LOC the risk of TBI on CT is small.**

- **LOC should be considered in conjunction with other signs and symptoms and not drive the decision for cranial CT when it occurs in isolation.**
Practice Pattern Variation in Cranial CT Use in BHT

- Practice pattern variation in head CT use in children with minor blunt head trauma evaluated in the emergency department (ED): Is there an association with physician training?
- N=14,883 patients with GCS 14-15 who had a CT scan by physician order
## PPV

<table>
<thead>
<tr>
<th>Physician training (#of pts)</th>
<th>CT rate (%)</th>
<th>Adjusted OR (95% CI)</th>
<th>Adjusted OR (95% CI)</th>
<th>Rate of positive CT scan</th>
</tr>
</thead>
<tbody>
<tr>
<td>PEM</td>
<td>36.8%</td>
<td>1.0</td>
<td>1.0</td>
<td>5.8%</td>
</tr>
<tr>
<td>26,625</td>
<td></td>
<td></td>
<td></td>
<td>567/9787</td>
</tr>
<tr>
<td>EM only</td>
<td>44.8%</td>
<td>1.39</td>
<td>1.12</td>
<td>3.8%</td>
</tr>
<tr>
<td>4,760</td>
<td></td>
<td></td>
<td></td>
<td>82/2131</td>
</tr>
<tr>
<td>Peds and EM</td>
<td>46.3%</td>
<td>1.49</td>
<td>1.34</td>
<td>3.3%</td>
</tr>
<tr>
<td></td>
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</table>
Conclusion

- Variation Exists in CT use in children with minor BHT in the ED by MDs of different training
Use of sedation is infrequent (3.3% GCS 14-15) n= 497/14,881

Multiple agents of varying effectiveness were used

Complications of sedation except failed sedation were rare 6.3% n=31/497

Most common complication vomiting
  • vomiting only occurred with chloral hydrate
Objective

Decrease use of unnecessary cranial CT in mild TBI and related iatrogenic morbidity.
INCLUSION CRITERIA

Recent history of closed head injury with Glasgow Coma Scale of 13-15

NOTE: Exclude pt w/Glasgow coma Scale < 13, trauma STAT

1. Evaluate patient
   • Clear c-spine if possible (If unable to clear, see C-Spine Algorithm)
   • Assess for High Risk criteria for TBI
   • Assess for other injuries
2. Consider CT scan, if High Risk criteria for TBI met
3. Consult Neurosurgery, if neurologic examination or CT abnormal

High Risk Criteria for Traumatic Brain Injury (TBI)
1. Age < 2 Years
2. Altered Mental Status
   • GCS < 15
   • Loss of consciousness
   • Lethargy/Confusion
3. Altered Neuro Status
   • Focal neurologic deficit
   • Ataxia, dizziness
   • Postural instability
4. Abnormal Physical Findings
   • Bulging fontanel
   • Parietal hematoma in age < 2 years
   • Unequal pupils
   • Depressed skull fracture/skeletal deformity
   • Basilar skull fracture suspected due to
     • - Raccoon eyes
     • - Blood behind eardrum
     • - Blood +/- CSF draining from nose/ear
5. Altered Vital Signs
   • Hypertension
   • Bradycardia
6. Concerning Mechanism Of Injury
   • Fall > 10 feet
   • Fall > 3 feet in patients age < 2 years
   • MVC > 20 mph
   • Bicyclist (fall, crash)
   • Suspicious circumstances/mechanism

- Highlights high-risk criteria for TBI in children with blunt head trauma and a GCS 13-15
Methods

- Incorporate elements from a decision rule for cranial CT identifying patients at near zero risk for intracranial injury into the CPOE order set.
- The modification will include items to be completed by MD/LIP as order for CT is being placed.

- Compare rate of CT scan against rate of intracranial injury identified by CT scan for patients with a GCS 14-15 before and after CPOE TBI Care set/Pathway modification