Pediatric Minor Head Injuries: When to Scan & When to Return to Play

Michael Greenwald, MD
mgreenw@emory.edu

Financial Disclosures

Have You Seen This Face?

10:30 pm.
An 15 month old fell out of a shopping cart 1 hr ago.
Mom didn’t see it – just heard the sound as he hit the tile floor.
Cried immediately, became sleepy on the way to the ED.

Whaddya gonna do?

A) Skull X-ray
B) Head CT
C) Obs 1-3 hrs in ED
D) Discharge home with q2hr neuro checks

Objectives

- Know indications for
  - Immediate Head CT
  - CT vs Observation in ED
  - D/C home w/o CT scan
- Describe the risks associated with CT radiation for children
- Know (4) stages of return to activities
  - School
  - Sports
Many Faces of Minor Head Injury

Are you going to scan me?

The Scope of the Head Injury Challenge

What is unique about pediatric head injury?
- High frequency of minor head injury
- Anatomical differences
- Limited Mental Status Exam
- Potential for undisclosed non-accidental trauma

Anatomical differences
- High frequency of minor head injury
- Limited Mental Status Exam
- Potential for undisclosed non-accidental trauma
The Scope of the Head Injury Challenge

- TBI the leading cause of death/disability in children
  - > 7000 pediatric deaths/yr in US
  - 642,000 ED visits/yr
  - 65,000 hospitalizations/yr
- 300,000 to > 3 million concussion/yr
- ¼ post concussive sx > 1 year


Concussion 9% of all high school sports injuries
- Concussions by high school sport
  - Football
  - Girls Soccer
  - Boys Soccer
  - Girls Basketball
- Children with concussion, skull fracture, ICI > 2x likely to sustain subsequent head injury within 12 months


Attention to Head Injury

- Big Hits – Broken Dreams CNN S Gupta January 2012
- imPACT testing/clinic U of Pittsburgh
- Center for the Study of Traumatic Encephalopathy Boston University
- Infant head trauma from abuse doubled during recent recession
  - Apr 29, 2011 Contemporary Pediatrics

Pediatric Minor Head Injuries: Questions for the ED physician

- How can I tell which patients have a brain injury?
- When is head CT indicated?
- Infant head trauma from abuse doubled during recent recession
- Apr 29, 2011 Contemporary Pediatrics

Pediatric Minor Head Injuries: Questions for the ED physician

When I discharge my head injured patient:
- Is it safe to treat vomiting with ondansetron?
- Is it safe to treat headache with ibuprofen?
- Who should manage concussion follow/up?
- When should they return to the ED?

Pediatric Minor Head Injuries: When to Scan & When to Return to Play

- Part 1: ED Evaluation of the Acute Minor Head Injury
- Part 2: Discharge Advice for the Concussion Patient
Definitions

- **Minor Head Injury**
- **Concussion**
- **Post Concussive Syndrome (PCS)**
- **Second Impact Syndrome**

---

3rd International Conference on Concussion in Sport:

- **Concussion**: "complex patho-physiological process affecting the brain, induced by traumatic biomechanical force"

**What is missing?**

- location of injury
- amnesia
- loss of consciousness
- grades

---

**Grade of TBI** | **GCS**
---|---
Mid | > 12
Moderate | 9-12
Severe | ≤ 9

---

**Post Concussive Syndrome (PCS)**

- **Somatic**: headache, dizziness
- **Emotional**: irritability
- **Cognitive**: memory, processing
- Increased Suicidality: ideation and attempts

---

**Second Impact Syndrome**: A catastrophic condition in which a second head injury, often seemingly trivial, causes severe/fatal neurologic injury because of it’s proximity to the prior head injury
**Definitions**

**Second Impact Syndrome:**
- Disruption of autoregulation of cerebral vasculature → ↑cerebral edema → ↑ICP → brainstem herniation
- 50% mortality

**Pathophysiology**

- Deformation of an elastic brain within a rigid skull:
  - Direct blow
  - Acceleration/deceleration
- Injuries:
  - Focal contusions
  - Hematomas
  - Diffuse injury from shear/strain forces

**Neuronal Death: Necrosis & Apoptosis**

- **Necrosis:** rupture of intracellular organelles
  - Mitochondrial failure → ATP depletion
- **Apoptosis:** programmed cell death triggered by caspases

---

**Tests for TBI**

**Traditional Tests**
- CT
  - Hemorrhages
  - Edema
  - Normal
- MRI
  - More sensitive for axonal injury, small hemorrhages
  - 10-57% abnl of nl CTs
- Neuro-Behavioral Tests

**Experimental Tests**
- MR Spectroscopy
- Functional MRI
- SPECT
- PET

**Serum Biomarkers:**
- S-100B
- Enolase

---

**DAI: Diffuse Axonal Injury**

- Trauma to neurofilaments, microtubules
- Proteolysis by calpains
- Release of glutamate → bind NMDA receptors → ↑intracellular Ca^{++} → mitochondria rupture

---

Evidence of Brain Injury after Concussion

- Autopsy studies:
  - Axonal beading & petechiae
  - Axonal (APP) amyloid precursor protein staining
  - Cerebral atrophy
  - Neurofibrillary tangles
  - Senile plaques
  - Degeneration/loss of pigmented cells in substantia nigra

- Dementia Pugilistica: related to # bouts more than # knockouts


What do we need to know? Evaluation of Minor Head Injury

What clinical signs/symptoms can distinguish mild vs moderate/severe TBI?

The ER question:
To scan...or not to scan

TBI relationships

Concussion

Head Injuries

Why not scan ‘em all?

- 10% annual increase in CT use past 2 decades
- 1995 – 2005 Head CT use more than doubled
- Each year 10% of the US population undergoes a CT scan (75 million scans/yr)
- 7 million pediatric CTs/year (11% of total)
- Estimated rate of lethal malignancies from head CT: 1 in 5000 (pediatric)


The Scope of the Head Injury Challenge

- Most head injuries are minor
  - 50-80% CHI patient in ED are GCS 14-15
  - Head CT used 5-50% cases CHI

- Low Yield from Head CT after Minor Head Injury
  - < 4-8% Head CT in minor CHI show TBI
  - < 0.5% children with minor CHI require Neurosurgery

What do we know about radiation risks from CT?

- Increased imaging speed in newer CT scanners has improved resolution and increased radiation doses. Smith-Bindman R Is Computed Tomography Safe? NEJM 363;1;July 1, 2010 pp1-3.
- Age inverse to risk for oncogenic changes:
  - Faster growing tissues/cells at greater risk
  - Longer time to develop mutations
  - CT parameters result in relatively higher dose radiation due to smaller cross sectional area
- Organ sensitivity: lung > liver > muscle

Estimated Medical Radiation Doses for a 5 y/o

<table>
<thead>
<tr>
<th>Imaging Study</th>
<th>Effective Dose mSv</th>
<th>Equivalent # CXRs</th>
</tr>
</thead>
<tbody>
<tr>
<td>3 view Ankle x-ray</td>
<td>0.0015</td>
<td>1/14</td>
</tr>
<tr>
<td>2 view Chest x-ray</td>
<td>0.02</td>
<td>1</td>
</tr>
<tr>
<td>2 view Abdominal x-ray</td>
<td>0.05</td>
<td>2.5</td>
</tr>
<tr>
<td>VCUG</td>
<td>0.33</td>
<td>16</td>
</tr>
<tr>
<td>PET scan</td>
<td>15.3</td>
<td>765</td>
</tr>
<tr>
<td>Chest CT</td>
<td>3</td>
<td>150</td>
</tr>
<tr>
<td>Head CT</td>
<td>4</td>
<td>200</td>
</tr>
<tr>
<td>Abd CT</td>
<td>5</td>
<td>250</td>
</tr>
</tbody>
</table>

What do we know about the oncogenic risk of radiation?

Committee of the National Academy of Sciences: Biological Effects of Ionizing Radiation (BEIR) Committee report 2005
- “risk of cancer proceeds in a linear fashion without a lower threshold…”
- “the smallest dose has the potential to cause a small increased risk to humans”

Discussing Radiation Exposure with ED patients

- 7% patients report discussing radiation risks/benefits prior to abd CT
- 9% ED physicians believe lifetime risk cancer potentially increased by CT
- 75% physicians underestimated radiation of CT vs CXR

So who do we want to scan?

- Significant (?) risk of clinically important TBI (cTBI) (i.e. injury that would prompt immediate medical or surgical attention)
- Are we OK not knowing about
  - Small non-displaced skull fractures (?)
  - Small subdural hemorrhages
  - Incidental findings which lead to further (unproductive) testing and anxiety

2010 Head Injury Workgroup: Goals

- Accurately identify cTBI
- Standardize approach
  - Optimize resource utilization
  - Minimize stress over practice variation/expectations
- Minimize iatrogenic radiation exposure
- Accurately identify & treat long term effects of concussion
Creating an Algorithm: Lancet Oct 2009

- Largest pediatric sample size: > 42,000
  - 10,700 under 2 y/o
  - 31,700 2-18 y/o
- 25 N American EDs: June 2004-March 2006
- 3 month follow-up
- Outcome Measure: ≤ 0.05% risk for cTBI

Predicting EmergentTBI: Reviewing the Literature

Independently predictive
- Altered Mental Status
- Skull Fracture
- Focal Neurological signs

Not independently Predictive
- Seizures
- Scalp Soft Tissue Injury
- Headache
- LOC
- Vomiting
- Amnesia
- Premorbid conditions

Whaddya gonna do?

A) Skull X-ray
B) Head CT
C) Obs 1-3 hrs in ED
D) Discharge home with q2hr neuro checks

Whaddya gonna do?

A) Skull X-ray
B) Head CT
C) Obs 1-3 hrs in ED
D) Discharge home with q2hr neuro checks
<table>
<thead>
<tr>
<th><strong>Unanswered questions for minor head injury</strong></th>
<th><strong>Unanswered questions for minor head injury</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Is ibuprofen safe?</em></td>
<td><em>Will Ondansetron (Zofran) mask signs of increased ICP?</em></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Summary: Who SHOULD be scanned</strong></th>
<th><strong>Summary: Consider scan vs observation</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Acute head injury resulting in:</strong></td>
<td><em>Non frontal hematoma</em></td>
</tr>
<tr>
<td>• Altered Mental Status (GCS &lt; 15)</td>
<td><em>Multiple or worsening symptoms</em></td>
</tr>
<tr>
<td>• Abnormal neurologic finding</td>
<td><em>Severe mechanism</em></td>
</tr>
<tr>
<td>• Evidence/strong suspicion for skull fracture</td>
<td></td>
</tr>
</tbody>
</table>

| **Summary: Who DOES NOT NEED a CT scan** | **Discharge Advice for the Concussion Patient** |
|------------------------------------------|-------------------------------------------------
| • Normal neurologic exam and mental status |                                                  |
| • Tolerates PO                            |                                                  |
| • Pain controlled with PO meds           |                                                  |
| • No premorbid conditions increasing the risk for TBI |   |
Case #2

Star corner w/2 prior concussions. Head on collision in practice last night: confusion + brief retrograde amnesia. Normal neurologic exam. Family is anxious to see him play on Friday’s playoff game (scouts from SEC will be there).

What do you tell the family?

A) No pass: out from football for 1 week
B) He can play if he passes mental status exam @ game time
C) He can play if he passes mental status exam after 2 minutes cardiovascular exercise
D) Punt that question to the PCP

What are the real questions?

- Is my patient at risk for Second Impact Syndrome?
- How much rest does he need to recover from a concussion?
- At what point do you prohibit collision activities?
Recovery from Concussion

- Concussion involves injury to brain cells:
  - Metabolic derangements
  - Axonal (structural) injury
- Resolution of injury & symptoms may take hours-days-weeks
- Premature return will prolong symptoms
- Return to normal activities should be gradual

Principles of Concussion Recovery

- Cognitive Rest
- Physical Rest
- Protection from re-injury

Pediatric Minor Head Injuries: When to Scan & When to Return to Play

- When can a head injured patient safely return to
  - School
  - Exercise
  - Competitive sports
  - Collision sports

Simplified Return to Play Guidelines

<table>
<thead>
<tr>
<th>Stage</th>
<th>Cognitive Activity</th>
<th>Physical Activity</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 (+ symptoms)</td>
<td>Hydration; minimal stimulation</td>
<td>None: rest at home</td>
</tr>
<tr>
<td>2 (no symptoms at rest)</td>
<td>Cautious return to school</td>
<td>Light aerobic</td>
</tr>
<tr>
<td>3 (no symptoms @ stage 2)</td>
<td>Full activities</td>
<td>Moderate aerobic: no competition/contact</td>
</tr>
<tr>
<td>4 (no symptoms @ stage 3)</td>
<td>Full activities</td>
<td>Competition w/o contact</td>
</tr>
</tbody>
</table>

Follow-up Options

- PCP in 2-3 days depending on
  - severity of symptoms
  - history of prior concussions
  - collision activities
- Persistent Symptoms:
  - Concussion Clinic
  - Neurologist
  - Neuro-Psychiatrist

What do you tell the family?

A) No pass: out from football for 1 week
B) He can play if he passes mental status exam @ game time
C) He can play if he passes mental status exam after 2 minutes cardiovascular exercise
D) Punt that question to the PCP
Summary: Management of Acute Minor Head Injury

- Variables that raise the risk of ciTBI include:
  - AMS
  - skull fracture,
  - focal neurological signs
- Presence of multiple variables, progression of symptoms and very young age increases risk for ciTBI
- Radiation risk is likely and inversely related to age

Summary

- Concussion is defined by any altered neurologic function after head injury
- Recovery from concussion is facilitated by gradual return to activities and requires
  - Cognitive Rest
  - Physical rest
- Premature return to normal activities may result in
  - Prolonged recovery time
  - Second Impact Syndrome

Challenges in assessing TBI in pediatric patients

- Difficult to assess higher functions
- Vulnerable population

Unknowns

- Will Ondansetron mask signs of increased ICP?
- What biochemical markers can predict ciTBI?
- Can MRI (or other) replace CT?

Resources

- http://www.choa.org/concussiontools
- CHOA Concussion Clinic: 404-785-1111

mgreenw@emory.edu

Thank You!
### The Head Injury Challenge: Who Needs Treatment?

**Skull Fracture:**
- Linear, Depressed, Diastatic

**Medical & Surgical Treatment**
- ICP control, fracture management, stabilization, hematoma evacuation, symptomatic support, long term follow-up.

**Intracranial Injury:**
- SDH, EDH, SAH

### Children’s Healthcare of Atlanta Head Injury Workgroup: Goals

- **Accurately identify ciTBI at the least possible cost:**
  - Minimize injury to patient
  - Immediate sequelae
  - Long term sequelae
  - Minimize cost to families ($, anxiety)
  - Minimize cost to providers (medico-legal risk, anxiety)
  - Minimize cost to system: ($, staffing)

### Skull x-ray in Minor Head Injury

**PROs**
- Sensitive test for skull fracture
- Less radiation
- No sedation needs

### What do we know about radiation risks from CT?

**True** or **False:**

Technical advances in CT such as increased imaging speed have lowered radiation doses.

---

Smith Bindman R Is Computed Tomography Safe? NEJM 363;1;July 1, 2010 pp1-3.
### What do we know about the oncogenic risk of radiation?

**True or False:**

Oncogenic risks from radiation are the same regardless of organ or age of exposure

- **False:** age is inversely related to risk for oncogenic changes.
  - Faster growing tissues/cells at greater risk
  - Longer time to develop mutations
  - CT parameters result in relatively higher dose radiation due to smaller cross sectional area
  - Organ sensitivity: lung > liver > muscle

### What do we know about the oncogenic risk of radiation?

**True or False:**

The FDA oversees how CTs are used in clinical practice

- **False:** The FDA approves CT scanners but not how they are used in clinical practice. It collects only limited data on routine doses.
  - Feb 2010 the FDA launched an initiative to reduce unnecessary radiation from medical imaging: [www.fda.gov/radiation-emittingproducts/radiationsafety/radiationdosereduction/UCM199904](http://www.fda.gov/radiation-emittingproducts/radiationsafety/radiationdosereduction/UCM199904)

### What do we know about radiation equivalency?

One head CT provides a similar dose of radiation to:

- A) 10 ankle series radiographs
- B) 200 chest radiographs
- C) 100 abdominal radiographs
- D) 2 abdominal CTs

### Scorecard on identifying skull fracture and ICI

- 60% head injured patients undergo CT: 5-10% are positive
- < 30% with ICI require Neuro-Surgical intervention
- 23-50% skull fx missed clinically
- Significant head injuries are clinically apparent within 6 hrs of injury


*Sainsbury CP, Silbert JR. How long do we need to observe head injuries in the hospital? Arch Dis Child 1997; 74:902-4.*
Lancet Article: Results

Under 2 y/o Prediction rules: NPV 100%
- Normal mental status
- No scalp hematoma (except frontal)
- No LOC
- Non-severe mechanism
- No palpable skull fracture
- Acting normally

Over 2 y/o Prediction rules: NPV 99.95%
- Normal mental status
- No LOC
- Non-severe mechanism
- No severe headache
- No vomiting
- No signs basilar skull fracture

Skull x-ray in Minor Head Injury

PROs
- Sensitive test for skull fracture
- Less radiation
- No sedation needs

CONS
- Not independently predictive of cTBI

When to obtain skull x-ray?

- Neurologically normal patient at risk for a fracture (correlates with young age, large & non-frontal hematoma) when knowing about a non-displaced skull fracture is important information:
  - Suspected abuse (looking for evidence)
  - Young infant
  - Collision sports/activities

Lancet Article: Results

Under 2 y/o Predictors

<table>
<thead>
<tr>
<th>Variable</th>
<th>Risk</th>
</tr>
</thead>
<tbody>
<tr>
<td>AMS</td>
<td>4.0%</td>
</tr>
<tr>
<td>Scalp Hematoma</td>
<td>1.6% (non frontal)</td>
</tr>
<tr>
<td>LOC &gt; 5s</td>
<td>1.6%</td>
</tr>
<tr>
<td>Severe Mech</td>
<td>0.5%</td>
</tr>
<tr>
<td>Suspected skull fx</td>
<td>3.6%</td>
</tr>
<tr>
<td>Abnl behavior</td>
<td>0.6%</td>
</tr>
</tbody>
</table>

Over 2 y/o Predictors

<table>
<thead>
<tr>
<th>Variable</th>
<th>Risk</th>
</tr>
</thead>
<tbody>
<tr>
<td>AMS</td>
<td>3.9%</td>
</tr>
<tr>
<td>LOC</td>
<td>1.1%</td>
</tr>
<tr>
<td>Vomiting</td>
<td>1.1%</td>
</tr>
<tr>
<td>Severe Mech</td>
<td>0.6%</td>
</tr>
<tr>
<td>Basilar skull fx</td>
<td>7.5%</td>
</tr>
<tr>
<td>Severe HA</td>
<td>1.1%</td>
</tr>
</tbody>
</table>

Shortcomings of the Lancet article

- Is it too conservative?
  - AMS loosely defined & not timed
  - Inconsistent with previous studies on poor correlation with vomiting and LOC

- No evaluation of
  - Amnesia
  - Seizures
  - pre-existing CNS d/o
  - coagulopathy