An Evidence Based Approach to Pediatric TBI in the ED

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Objectives
• Review how to use evidence-based medicine in the evaluation and treatment of pediatric head injuries
• Determine who can safely be discharged home and who requires transfer to a Level 1 Trauma Center or admission
• Review research and best practices for the management of acute mild traumatic brain injury

Pediatric Head Trauma: A Significant Burden

Deaths 7,000/yr
Hospitalizations 95,000/yr
ED Visits > 500,000/yr
Primary Care Office Visits Assume numerous, No data

- Hospital care costs alone exceed 1 billion/year
- 29,000 permanent disabilities annually

60%↑ in ED visits in last 10 years

Clinical Challenges in the ED
• Identification of children with significant intracranial injury
• Manage children with moderate and severe TBI
• Improving outcomes of mild TBI

Pathology of Head Trauma

• Primary pathology
  – Injury to the brain tissue
  – Degree of force = extent of injury
    • Mild force: Neuronal dysfunction
    • Moderate force: Axonal injury
    • Results in cerebral edema
  – Usually non-operative lesions
  – Often the CT scan is Negative

• Secondary Pathology
  – Operative Lesions
  – Damage to bridging veins, arteries, and dural sinuses
  – Lesions that can be seen on imaging
Secondary Pathology

- Epidural Hematoma: Better prognosis with mortality rates up to 50%
- Subdural Hematoma: Poor prognosis with mortality rates up to 90%

ED Management of Moderate to Severe TBI
Glascow Coma Scale <12

- Goals = prevent secondary injury
  - Identify operative lesions
  - Manage Airway
  - Manage increased intracranial pressure
  - Prevent Hypoxia / Hypercarbia / Hypoglycemia
  - Prevent Hypotension
  - Adequate Sedation and Analgesia

... no magic bullet

Typical Head Trauma Presentations to the Pediatric ED look like...

- 4 m/o Female
  - Hx: Fall from Dad's shoulders to linoleum
  - Sx: Brief loss of consciousness, but now has no symptoms

- 9 y/o Male
  - Hx: Hit with a baseball bat at recess
  - Sx: No loss of consciousness, headache and vomiting

- 15 y/o Male
  - Hx: Head to head contact during a tackle
  - Sx: No loss of consciousness, but has significant amnesia, Severe Headache and dizziness

What Do We Want To Know?

Does this child have an intracranial injury?

Will this child require emergent surgery?

Do They Have an Intracranial Injury?

<table>
<thead>
<tr>
<th>Study</th>
<th>Setting</th>
<th>n</th>
<th>Age</th>
<th>Type of Injury</th>
<th>GCS</th>
<th>CT Performed as Indication</th>
<th>%</th>
<th>Abnormal Neurologic Exam %</th>
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</thead>
<tbody>
<tr>
<td>Dallas at 14 wks</td>
<td>t+1 pediatric trauma center</td>
<td>1080</td>
<td>0-17</td>
<td>Minor head injury</td>
<td>13-15</td>
<td>Yes</td>
<td>42</td>
<td>0.5</td>
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<td>3966</td>
<td>0-18</td>
<td>Blunt head trauma</td>
<td>14-17</td>
<td>No</td>
<td>2</td>
<td>0</td>
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<td>13-15</td>
<td>No</td>
<td>3</td>
<td>1.2</td>
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<td>102</td>
<td>12-17</td>
<td>Asymptomatic head injury</td>
<td>13-15</td>
<td>No</td>
<td>18</td>
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Will They Require Emergent Surgery?

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M. Hospital at Wisconsin
Pediatric Minor Head Injury: 
Goal of Management

- Identify intracranial injuries while limiting unnecessary imaging

Why limit imaging?
- Radiation
- Sedation
- Costs

PECARN Head Injury Study
Methods and Subjects

- Prospective Cohort Study, < 18 yo
- Presented within 24 hrs blunt head injury
- mTBI = GCS 14 -15
- 1° Outcome = “ci TBI” (“clinically important”)
  - Defined as Death, Neurosurgery, Intubation, Hospital admission > 2 nights

PECARN Imaging Guidelines (<2 y/o)

- Normal Mental Status
- No LOC
- No vomiting
- No basilar fracture
- No severe headache

Study Results

- N= 42,412 patients from 25 EDs
  - GCS = 15 in 97%
  - CT performed in 35.3% (n = 14,969)
  - ciTBI in 0.9% (n = 376)
    - Surgery in 0.1% (n = 60)
    - No Deaths


Prediction Rules for No “ciTBI”
Age younger than 2 years

- Normal Mental Status
- No palpable skull fracture
- No scalp hematoma - except frontal
- No LOC or LOC < 5 seconds
- Non-severe injury mechanism
- Acting normally according to parents
  (NPV 100%; Sensitivity 100%)


Prediction Rules for No “ciTBI”
Age 2 years and older

- Normal Mental Status
- No LOC
- No vomiting
- Non-severe injury
- No basilar fracture
- No severe headache
  (NPV 99.95%; Sensitivity 96.8%)

PECARN Subanalyses

Isolated factors NOT predictive of CiTBI
- Severe mechanism
- Loss of consciousness
- Scalp hematomas (>2 y/o)
- Not acting normal per parent

- No need to admit for observation after normal CT
- VP shunt and bleeding disorder alone do not increase risk of CiTBI
- Observation for patients with intermediate risk could save $92 million per year over current practice

Benefits of Brief ED Observation
- In ED observation reported in 5433 (14%) patients in PECARN study
- OBSERVED GROUP:
  - ~4% less likely to get a CT
  - No difference in rate significant TBI
- Observation can reduce CT use
  - Why?: Patients seen immediately, look "sicker" than ones that arrive 1 hr post injury.

How long do we need to observe?
- After 6 hours no risk of significant bleed
  - 8 year retrospective study of ~18 000 pts (<14 y/o)
  - Rate of delayed deterioration (>6 hours)
    - Without altered GCS = 0 (%)
    - With altered GCS = 5 (0.03%)

A Negative CT Does Not Equal Absence of Intracranial Injury.
- CT scans address the tip of the iceberg
- Majority of patients still have persistent symptoms and functional impairment
- Deficits can be detected on fMRI, PET scan and with neurocognitive testing.

Concussion Definition
- Blow to head or indirect force through neck or to body
- Trauma-induced alteration in neurologic function
  - Amnesia (retrograde or anterograde)
  - LOC, dazed, stunned, confused, forgetful
  - Headache, Nausea, Visual changes, Balance, etc...
- Typical Clinical Presentation
  - Rapid short-lived impairment
  - Normal physical examination and neuroimaging
    - Neurometabolic dysfunction, not structural injury
Factors Influencing mTBI Outcomes

**Patient Factors**
- Severity of injury
- Risk factors
- Pre-injury cognition

**Physician Factors**
- Identify injury
- Discharge education
- Appropriate follow up

**Parental Factors**
- Parenting style
- Family Functioning
- Socio-economic status

Addressing the Bottom of the Iceberg

**Improving Concussion Management**
1. Concussion Recognition
2. Assessment of Injury
3. Post-injury Management

Pathophysiology of Head Trauma

1. Release of neurotransmitters and ↓ cerebral blood flow
2. Neuron depolarized
3. Excess K+ in the extracellular space
4. Neurons become refractory
5. Na+/K+ ATP pump activated
6. Increase need for ATP and glucose
7. Mismatch leads to lactate production
8. Cerebral glucose metabolism ↓ to match blood flow.

Neurometabolic Changes in Concussion:
↑ glucose utilization and ↓ CBF

Concussed rats 2 hours post-injury


Concussion Recognition: Immediate Signs/Symptoms

- Loss of consciousness 27%
- Amnesia 44%
- On Field Signs 22%
  - Confusion
  - Dazed or stunned
  - Answers questions slowly
  - Repeating questions

- Symptoms 95%
  - Headache
  - Dizziness/Off-balance
  - Nausea/Vomiting
  - Behavior/Personality Change
  - Vision changes
  - Poor Concentration
  - Poor memory
  - Sensitive to light/sound
  - Numbness/tingling

*Thomas 2011

Neurometabolic Changes in Concussion:
↓ glucose utilization over time

### Improving Concussion Recognition

- **Acute Concussion Evaluation (ACE) and ACE Care Plan**
  - Validated to identify mTBI
  - Provides discharge instructions for children and adults
- **Available free on CDC website in 2007**

### ACE Form

- **Description of the injury**
  - How, location on the head and type of force.
- **Presence of amnesia and its duration**
- **Loss of consciousness, Seizures Early signs (dazed, repeating questions, etc)**

### ACE Care Plan

- **Evidence based discharge instructions**
- **Specific recommendations regarding**
  - Return to school
  - Return to work
  - Sports and exertion
  - Follow up plan

### ACE ED: Intervention

- **Pediatric Emergency Medicine National Expert Panel**
  - to developed ACE ED form
- **Embedded into electronic health record**
- **Clinician and Nurse Concussion Education**
- **Improve Discharge instructions**
  - **Emphasized keys to recovery**
    - Resting the brain
    - No additional forces to head/brain
    - Managing/ facilitating physiological recovery

### Use of Modified Acute Concussion Evaluation Tools in the Emergency Department

- **Improved Rate of Diagnosis & Concussion-Specific Discharge Instruction Administration**
- **More patients recalled received concussion specific, sports-related, and school-related discharge instructions**
- **Increased follow up with PCP up to 30%**

Zuckerbraun et al. Pediatrics 2014
ACE ED and ACE Care form

- Available free on CDC website
- Can be adapting it for ED use
- Improves patient identification in the ED

Unfortunately, ACE ED does not assess the severity of a patient's concussion.

Improving Assessment of Injury:

**Utility**
- Useful higher level neurocognitive testing can take over an hour to complete
- Efficient products may lack predictive utility
- Better assessment of Balance and Visual motor control
- Better assessment of risk factors for prolonged recovery

**Efficiency**

Acute Balance Assessment

- ~36% of concussed athletes will have a balance problem in first 24 hrs post-injury
- How to assess
  - BESS
  - Tandem Gait

Vestibular/Oculomotor Assessment

- Emerging evidence suggests up 50% may experience dizziness post-injury

- How to assess
  - Vestibular Ocular-Motor Screening (VOMS)
    1. Smooth pursuits
    2. Saccades
    3. Vestibular ocular reflex
    4. Visual motion sensitivity
    5. Near-point-of-convergence distance

Risk factor assessment

- Many conflicting risk factors for recovery have been reported.
  - Older children with loss of consciousness, headache, and/or nausea/vomiting, initial dizziness, and premorbid conditions
- Zemek et al. conducted the 5P study
  - Multicenter derivation and validation model
  - Recruited 3063 patients 5-17 years with concussion
  - Subject completed a survey of predictive factors
  - Primary outcome: (31% , N=801)
    - Proportion with persistent concussion symptoms at 1 month

5P Clinical Risk Score

- Risk increases:
  - Age
  - Gender
  - Past Concussion*
  - H/o Migraine
  - Answers questions slowly
  - BESS errors
  - Headache
  - Sensitivity to noise
  - Fatigue
Symptom Management

- There is no standardized approach to the management of acute concussion symptoms.

- Sleep and Rest may be the most effective strategy to acute symptom management.

Sleeping your way to the top…

- Fatigue/sleepiness immediately follows mTBI suggests that it serves some biologic purpose
- mTBI is metabolic mismatch
- Sleep has restorative benefits
  - Decreased synaptic activity (Cirelli et al)
  - Increased ATP stores (Dworak et al)

Post Concussive Symptoms

- Headache
  - Oral analgesics
    - NSAID (ibuprofen, naproxen)
    - Acetaminophen
    - Opiates
  - IV ED Migraine Pathway
    - IV fluid bolus
    - NSAID (e.g. Ketorolac)
    - Dopamine receptor antagonist (e.g. Prochlorpromazine, metoclopramide)
    - Ergotamine, Triptans, Opiates

- Nausea / Vomiting
  - Oral antiemetics
    - Ondansetron
    - Prochlorpromazine

Post-Injury Management

- Decreasing post-concussive symptoms
- Prevent cumulative effects of injury
- Prevent complications
  - Post-Concussion Syndrome
  - Second Impact Syndrome
- Risk can be reduced by ensuring proper recovery prior to return to full activity

Post-Concussive Symptoms

4 Major Categories

- Physical
  - Headache
  - Nausea and vomiting
  - Balance problems
  - Blurred vision
  - Sensitivity to light
  - Sensitivity to sound
  - Fatigue or lack of energy

- Thinking and remembering
  - Difficulty concentrating
  - Difficulty remembering
  - Feeling confused
  - Feeling disoriented

- Mood disruption
  - More emotional
  - More irritable
  - More depressed

- Sleep
  - Sleeping more or less than usual
  - Waking up feelingt tired
  - Feeling fatigued on wakening

Vulnerable during the Post-Concussive Period

- 4 X more likely to have another concussion
- Dangers of Second Concussion
  - Post-concussion syndrome
    - More severe and prolonged recovery (> 14 days)*
  - Second Impact Syndrome?
    - Occurs in young athletes with prior concussion following often relatively minor second impact
    - Catastrophic increase in intracranial pressure

**Dangers of Repeat Concussion**

Bowden et al. 2003 *Catastrophic TBI in Football*

- 97% occurred at the high school level
- ~60% had previous head injury before catastrophic event
- ~40% were playing with residual neurologic symptoms.

**Risks of Exertion During Recovery**

- Risks associated with return to sports
- Animal models show early physical and mental exertion impairs healing
- Few human studies suggest exertion may have negative effects.

**Effect of Exertion on Recovery**

- 5 point activity scale coded on chart review
- Athletes with moderate levels of post-injury activity had the best performance at follow-up
- Athletes with highest and lowest levels of cognitive and physical activity had more symptoms and worse neurocognitive performance

**Concussion Management**

- Based on expert consensus*
- Recommend:
  - 24-48 hours of rest
  - Gradual step-wise return to activity
- Some clinicians advocate “Cocoon Therapy”

**Results: Compliance**

- Both groups exhibited ~20% decrease in energy expenditure and physical activity level in the first 5 days post injury
- Intervention group reported less school and after school activity for days 2-5 post concussion (3.8 vs. 6.7 hours total, p < 0.05)
Results: Efficacy

- No significant difference between groups in neurocognitive or balance scores at 3 or 10 days
- Intervention group reported more daily PCSS and slower symptom resolution

Results: Total and daily PCSS

- Intervention group reported greater symptoms over the course of the study (187.9 vs 131.9, p <0.03)
- Difference in mean daily PCSS was significant at Day 4

Time To Symptom Resolution (PCSS ≤ 7)

- It took 4 days longer for 50% of the intervention group to report symptom resolution

Study Conclusions

- First study to test recommending strict activity limits as an intervention to improve acute concussion outcomes
- Strict activity limits immediately after mTBI offer no benefit over current standard of care
- Adolescents’ symptom reporting may be influenced by limiting activity

Concussion Is Treatable

Individualized approach is key!
- Step 1: “When in doubt, sit them out”
- Step 2: Resume Activities of Daily living
- Step 3: Get back to school (+/- support)
- Step 4: Get back to sport (w/ clearance)

Not recovering fast enough, see a specialist
- Tx: Rehab, PT, OT, CBT, Medications

ED Discharge Instructions

- Inform patients on Red flag symptoms
- Inform patients of common post-concussive symptoms
- Encourage academic and physical rest no more than 1-2 days
- Encourage step-wise return to activity
- Encourage follow up for formal clearance
Improving Post-injury Management: Stepwise return-to-play for high risk activities

1. Rest until asymptomatic
   - No signs or symptoms at rest
2. Stepwise return to play
   1. Light aerobic activity (e.g. walking, stationary bike)
   2. Sport-specific activity (e.g. running in soccer, skating in hockey)
   3. Non-contact training drills
   4. Full-contact practice training
   5. Game Play


Other Considerations in Concussion Management

- Support outside the athletic arena
  - Alert and educate key school personnel
  - Gradual reintegration back to school
  - Educational Support
- Informal accommodations for most
- Formal interventions in few cases

Questions?