



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

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Financial Disclosures



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Have You Seen This Face?



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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.



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Whaddya gonna do?



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

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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

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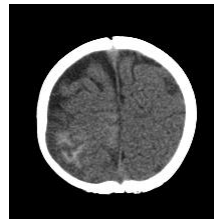
Many Faces of Minor Head Injury



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Many Faces of Minor Head Injury



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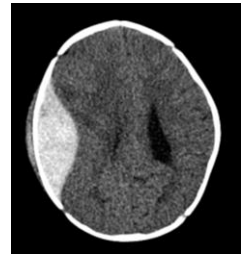
Many Faces of Minor Head Injury



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Many Faces of Minor Head Injury



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Are you going to scan me?



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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

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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

Alves W, Macciocchi SN, Barth JT. Postconcussive symptoms after uncomplicated mild head injury. *J Head Trauma Rehabil.* 1993;8(3):48-59.
Langlois JA, Rutland-Brown W, Thomas KE. Traumatic brain injury in the United States. Atlanta, Georgia: CDC, National Center for Injury Prevention and Control, January 2006.

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The Scope of the Head Injury Challenge

- 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

Swaine BR, Tremblay C, Platt RW et al. Previous Head Injury is a risk factor for subsequent head injury in children: a longitudinal cohort study. *PED* 119(4)April 2007:749-758.

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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*

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Pediatric Minor Head Injuries: Questions for the ED physician

- How can I tell which patients have a brain injury?
- When is head CT indicated ?

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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?

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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

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Definitions

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

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Definitions

- **Minor Head Injury:** Head injury resulting in a near normal-normal neurological condition (i.e. GCS (13-15))

Grade of TBI	GCS
Mild	> 12
Moderate	9-12
Severe	< 9

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Definitions

3rd International Conference on Concussion in Sport:

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

What is missing?

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Definitions

3rd International Conference on Concussion in Sport:

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

Not in the definition:

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

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Definitions

- **Post Concussive Syndrome (PCS)**
 - **Somatic:** headache, dizziness
 - **Emotional:** irritability
 - **Cognitive:** memory, processing
- **Increased Suicidality:** ideation and attempts

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Definitions

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

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Definitions

Second Impact Syndrome:

- Disruption of autoregulation of cerebral vasculature
→ ↑cerebral edema → ↑ICP → brainstem herniation
- 50% mortality

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Pathophysiology

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

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DAI: Diffuse Axonal Injury

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

Bazarian JJ, Blyth B, Cimpello L. Bench to Bedside: Evidence for Brain Injury after Concussion – looking beyond the Computed Tomography Scan ACAD EMERG MED 2006;13:199-214.

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Neuronal Death: Necrosis & Apoptosis

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

Bazarian JJ, Blyth B, Cimpello L. Bench to Bedside: Evidence for Brain Injury after Concussion – looking beyond the Computed Tomography Scan ACAD EMERG MED 2006;13:199-214.

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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

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Tests for TBI

Traditional Tests

- CT
 - Hemorrhages
 - Edema
 - False negatives
- 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

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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

Gorrie C, Oakes S, Doflou, et al. Axonal injury in children after motor vehicle crashes: extent, distribution, and size of axonal swellings using beta-APP immunohistochemistry. *J Neurotrauma*. 2002;19:1171-82.

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

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

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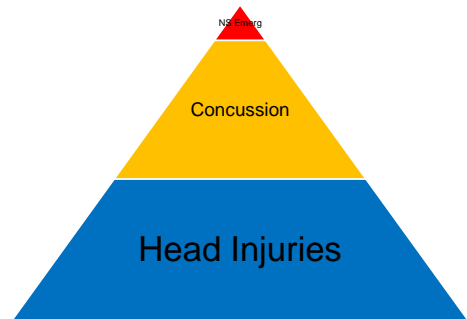
The ER question: To scan...or not to scan



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TBI relationships



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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

Langlois JA, Rutland-Brown W, Thomas KE. Traumatic brain injury in the United States. Atlanta, Georgia: CDC, National Center for Injury Prevention and Control, January 2006.

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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)

Frush DP, Applegate K. Computed Tomography and radiation: understanding the issues. *J Am Coll Radiol*. 2004;1:113-119.
Smith-Bindman R. Is Computed Tomography Safe? *NEJM* 363;1; July 1, 2010 pp1-3.

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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

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Estimated Medical Radiation Doses for a 5 y/o

Imaging Study	Effective Dose mSv	Equivalent # CXRs
3 view Ankle x-ray	0.0015	1/14
2 view Chest x-ray	0.02	1
2 view Abdominal x-ray	0.05	2.5
VUCG	0.33	16
PET scan	15.3	765
Chest CT	3	150
Head CT	4	200
Abd CT	5	250

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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”*

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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

Lee CI, Hains AH, Monico EP, ET AL. Diagnostic CT scans: assessment of patient, physician and radiologist awareness of radiation dose and possible risks. *Radiology*. 2004;231:393-398.

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So who do we want to scan?

- Significant (?) risk of clinically important TBI (ciTBI)** (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

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2010 Head Injury Workgroup: Goals

- Accurately identify ciTBI
- Standardize approach
 - Optimize resource utilization
 - Minimize stress over practice variation/expectations
- Minimize iatrogenic radiation exposure
- Accurately identify & treat long term effects of concussion

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Creating an Algorithm: Lancet Oct 2009

- Identification of children at very low risk of ciTBI after head injury: a prospective cohort study. *N Kupperman et al (PECARN)*
- 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: $\leq 0.05\%$ risk for ciTBI

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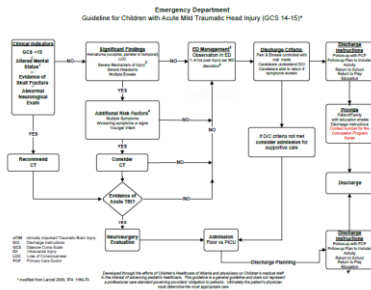
Predicting EmergentTBI: Reviewing the Literature

- | | |
|--|---|
| <p>Independently predictive</p> <ul style="list-style-type: none"> ▪ Altered Mental Status ▪ Skull Fracture ▪ Focal Neurological signs | <p>Not independently Predictive</p> <ul style="list-style-type: none"> • Seizures • Scalp Soft Tissue Injury • Headache • LOC • Vomiting • Amnesia • Premorbid conditions |
|--|---|

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Whaddya gonna do?



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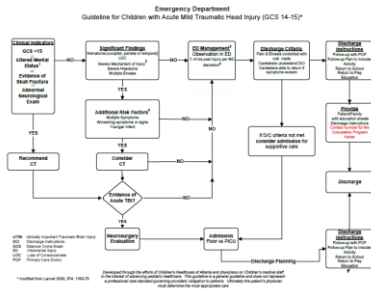


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Whaddya gonna do?



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Unanswered questions for minor head injury

Is ibuprofen safe?

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Unanswered questions for minor head injury

Will Ondansetron (Zofran) mask signs of increased ICP?

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Summary: Who SHOULD be scanned

Acute head injury resulting in:

- Altered Mental Status (GCS < 15)
- Abnormal neurologic finding
- Evidence/strong suspicion for skull fracture

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Summary: Consider scan vs observation

- Non frontal hematoma
- Multiple or worsening symptoms
- Severe mechanism

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Summary: Who DOES NOT NEED a CT scan

- Normal neurologic exam and mental status
- Tolerates PO
- Pain controlled with PO meds
- No premorbid conditions increasing the risk for TBI

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Discharge Advice for the Concussion Patient

Case #2



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Case #2

Star cornerback 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).



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What do you tell the family?

- A) No pass: out from football for 1 week



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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



58

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



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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?

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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

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Principles of Concussion Recovery

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

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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

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Simplified Return to Play Guidelines

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

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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

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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

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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

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Summary

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?

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Resources

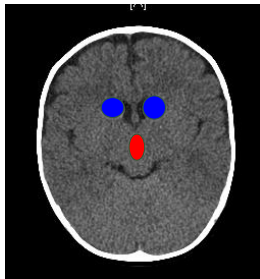
- <http://www.choa.org/concussiontools>
- CHOA Concussion Clinic : 404-785-1111
- http://www.cdc.gov/concussion/HeadsUp/physicians_tool_kit.html

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Thank You!



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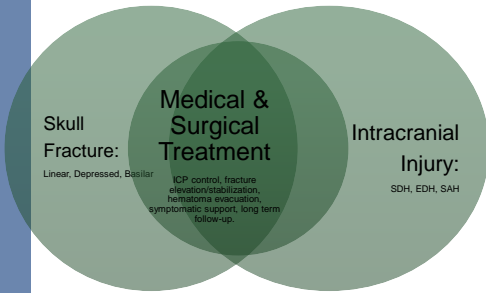
Attention to Head Injury March 18, 2009



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The Head Injury Challenge: Who Needs Treatment?



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Children's Healthcare of Atlanta Head Injury Workgroup: Goals

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

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Skull x-ray in Minor Head Injury

PROs

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

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Exclusion Criteria		
Patient's with one or more existing co-morbidities that would impair an accurate neurological assessment are excluded from this guideline.		
Altered Mental Status Agitation Somnolence Repetitive Questioning Blaw Response to Verbal Communication	Severe Mechanism of Injury Motor Vehicle Crash with Ejection Death of another passenger Rollover Pedestrian or bicyclist who helmet struck by motor vehicle Fall > 3 feet Head struck by high-impact object	Risk of cITBI Exceedingly low, generally lower than risk of CT-induced malignancies. Therefore, CT scans are not indicated for most patients in the group.
Additional Risk Factors Physicians should use clinical judgment based on their understanding of the literature, clinical experience and the parents perspective of changes from baseline/typical behavior. In general, multiple symptoms (e.g., vomiting, LOC) increase risk of cITBI. Patients with isolated findings (i.e., with no other findings suggestive of TBI) such as isolated LOC, headache, vomiting, & scalp hematomas in infants >3mo have a risk of cITBI substantially lower than 1%.		
Observation in the ED Observation in the ED for signs of increasing intracranial pressure (e.g. increased pain, vomiting, decreased alertness or altered mental status) for at least 7 hr up to 4 hrs post injury depending on physician's assessment of risk for cITBI. At present there is not enough published data to judge whether ondansetron's antiemetic effect may mask signs of cITBI. Therefore, neuro-imaging or hospitalization is recommended for any patient who requires an antiemetic for multiple emesis. Phenothiazines are generally discouraged except in cases of migraine headaches and vomiting refractory to ondansetron. Out-patient use of ondansetron following Closed Head Injury should be cautious. Any patient with an increase in symptoms following a head injury should have a re-evaluation. Patients who have not received neuro-imaging may receive acetaminophen for pain. Patients who require IV medications (e.g. opioids) likely require admission for supportive care. Patients who have had a normal head CT or have met discharge criteria may receive NSAIDs such as ibuprofen.		

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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.

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✓ **False:** 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.

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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

79



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- **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

80



What do we know about the oncogenic risk of radiation?

True or False:

The FDA oversees how CTs are used in clinical practice

81



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

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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

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Scorecard on identifying skull fracture and ICI

- 60% head injured patients undergo CT: 5-10% are positive
 - < 30% with ICI require Neuro-Surgical intervention
- Palchak MJ Holmes JF, Vance CW et al. A decision rule for identifying children at low risk for brain injuries after blunt trauma. Ann Emerg Med 2003;42:492-506.
- 23-50% skull fxs missed clinically
- Lloyd DA Carty H. Predictive value skull radiography for intracranial injury in children with blunt head injury. Lancet 1997; 349:821-4.
- 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 1984;59:856-9.

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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

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Lancet Article: Results

- 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

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Skull x-ray in Minor Head Injury

PROs

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

CONS

- Not independently predictive of cITBI

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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

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Lancet Article: Results

Under 2 y/o Predictors

Variable	Risk
AMS	4.0%
Scalp Hematoma	1.6% (non frontal)
LOC > 5s	1.6%
Severe Mech	0.5%
Suspected skull fx	3.6%
Abnl behavior	0.6%

Over 2 y/o Predictors

Variable	Risk
AMS	3.9%
LOC	1.1%
Vomiting	1.1%
Severe Mech	0.6%
Basilar skull fx	7.5%
Severe HA	1.1%

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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

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