Pediatric Head Injury
Past, Present, and Future

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Objectives

- Review old and new literature relevant to minor pediatric head trauma
- Discuss Risks of Significant Intracranial Injury (ICI) with minor head trauma
- Discuss Potential Risks of CT
- Discuss management strategies in terms of imaging versus observation

Literature

- 1997 Diagnostic Testing for Acute Head Injury in Children: When Are Head Computed Tomography and Skull Radiographs Indicated? PEDIATRICS Vol. 99 No. 5 May 1997, p. e11
- 1999 AAP Practice Parameters: Head Injury 2-20 years old
- 2001 AAP Proposed Guidelines: Head Injury < 2 years old
- 2006 Pediatrics Vol. 117 No. 2 February Nexus II

Literature

- 2007 Paediatric Child Health. July; 12(6): 482–484. Canadian Assessment of Tomography for Childhood Head Injury (CATCH) study
- 2008 Archives of Pediatrics AdolescentMedicine.162(5):439-445. Clinical Decision Rule for CT in Minor Head Injury
- 2009 Lancet.;374:1160-1170. Identification of very low risk clinically important brain injuries in children

Overview

- Head injury is a common cause of emergency-department (ED) presentation, accounting for 1 million visits annually.
- Most patients with minor head injury are fine and require no testing or therapy
- The problem is that a small number prove to have clinically significant intracranial injury (ICI).

PEDIATRICS Vol. 117 No. 2 February 2006, pp. e238-e246

Overview

- Because of the risk of unrecognized ICI, clinicians liberally order cranial CT scans:
  - Estimated annual charges of nearly $750 million
  - While revealing significant ICI in < 6%

PEDIATRICS Vol. 117 No. 2 February 2006, pp. e238-e246

Overview

- The overuse of CT may be even more pronounced in children
- Children comprise almost 40% of these patients
- This is probably because of the greater difficulty in assessing neurologic function in the younger child

PEDIATRICS Vol. 117 No. 2 February 2006, pp. e238-e246

Overview

- Children are at a much higher risk from radiation exposure, and there are estimates of importan (theoretical) risk :
  - ***lethal malignancy risk* from CT may be as high as 1:5000**

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Glasgow Coma Scale

Glasgow coma scale

		Score
Eye opening	spontaneously	4
	to speech	3
	to pain	2
	none	1
Verbal response	orientated	5
	confused	4
	inappropriate	3
	incomprehensible	2
	none	1
Motor response	obeys commands	6
	localises to pain	5
	withdraws from pain	4
	flexion to pain	3
	extension to pain	2
	none	1
Maximum score		15

Glasgow Coma Scale Score *modified for infants

Activity	Best response	Score
Eye opening	Spontaneous	4
	To speech	3
	To pain	2
	None	1
Verbal	Oriented * (coos,babbles)	5
	Confused * (irritable cries)	4
	Inappropriate words * (cries to pain)	3
	Nonspecific sounds * (moans to pain)	2
	None	1
Motor	Normal spontaneous movements	6
	Localizes pain * (withdraws to touch)	5
	Withdraws to pain	4
	Abnormal flexion-decorticate rigidity	3
	Abnormal extension-decerebrate rigidity	2
	None	1

Infant Face Scale.

Eye opening	
Spontaneously	4
To verbal stimulation or to touch	3
To pain	2
No response	1
Verbal/facial response	
Cries (grimaces with crying sounds and/or tears) spontaneously, with handling, or to minor pain; alternating with periods of quiet wakefulness when not asleep	5
Cries (grimaces with crying sounds and/or tears) spontaneously, with handling, or to minor pain; alternating with sleep only (no quiet wakefulness maintained)	4
Cries to deep pain only	3
Grimaces only to pain (facial movement without sounds or tears)	2
No facial expression to pain	1
Motor	
Spontaneous normal movements	6
Spontaneous normal movements reduced in frequency or excursion; hypoactive	5
Nonspecific movement to deep pain only	4
Abnormal rhythmic spontaneous movements; seizure-like activity	3
Extension, either spontaneous or to painful stimuli	2
Flaccid	1

GCS

- **GCS = 14-15 *Mild head* injury**
- **GCS = 9-13 *Moderate* head injury**
  - CT and Admit
- **GCS = 3-8 *Severe* head injury**
  - CT scan only after stabilization
  - Early **endotracheal intubation**
  - Pay close attention to cardiovascular status either hypo- or hypertension

Blunt Head trauma in Children Physical Examination

Decreased level of consciousness:

- Risk of TBI if GCS is = 15 is 2-3%
- Risk of TBI if GCS is =14 is 7-8%
- Risk of TBI if GCS is = 13 is **25%** !!!

- GCS is an important predictor in multivariate analyses

1997

Diagnostic Testing for Acute Head Injury in Children: When Are CT Scans and Skull Radiographs Indicated?

PEDIATRICS Vol. 99 No. 5 May 1997, pp. e11

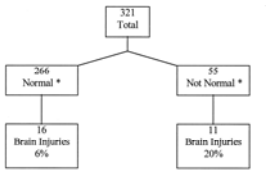
CT versus Skull Films

- 98% percent of all study children underwent head CT, whereas 89% received skull radiographs
- Discrepancies between skull radiographs and head CT in identifying the presence of a linear skull fracture occurred in 10 cases. In 8 children, the skull radiographs demonstrated linear fractures, whereas the CT did not.

PEDIATRICS Vol. 107 No. 5 May 2001, pp. 983-993

1997 Flow Diagram

- Fifty-five children had abnormal neurologic examination results, or altered level of consciousness
- 266 children were described as neurologically normal



*Normal = Alert mental status, no neurologic deficits

1997 Conclusions

In conclusion, independent predictors of intracranial injury include

- Altered mental status
- Focal neurologic deficit
- Signs of a basilar skull fracture
- Seizure
- Skull fracture

1997 Conclusions

- However, intracranial injury may also occur with few or subtle signs and symptoms, especially in infants younger than 1 year.

Recommendations

- We do not recommend skull radiographs for most children,
- However, we do recommend skull radiographs in infants younger than 1 year with hematomas or contusions after head injury, because these infants are at greater risk for skull fracture

PEDIATRICS Vol. 99 No. 5 May 1997, pp. e11

1997

Conclusions

- Intracranial injury may occur with few or subtle signs and symptoms, especially in infants younger than 1 year.
- With Skull Fracture 4 times the risk of ICI

PEDIATRICS Vol. 99 No. 5 May 1997, pp. e11

1997 Conclusions

- The majority of patients with intracranial injury were neurologically intact
- Therefore, CT scans should be considered in children with symptoms such as:
  - Vomiting
  - Headache
  - Drowsiness
  - Amnesia
  - History of loss of consciousness

1997 Clinical Practice

Conclusions

- Most of the patients with ICI were neurologically normal
- CT was a good modality to diagnose ICI.
- Skull films were helpful in children < 1 years old

The Management of Minor Closed Head Injury in Children

AMERICAN ACADEMY OF PEDIATRICS:

- **Committee on Quality Improvement, American Academy of Pediatrics**
- DECEMBER 1999

PEDIATRICS Vol. 104 No. 6 December 1999, pp. 1407-1415

Minor Head Injury Practice Parameter 1999

- A total of 422 articles were identified
- Of these a total of 64 articles were included for review

PEDIATRICS Vol. 104 No. 6 December 1999, pp. 1407-1415

AAP Practice Parameter 1999

- This practice parameter is specifically intended for previously neurologically healthy children 2 through 20 years of age, with isolated minor closed head

PEDIATRICS Vol. 104 No. 6 December 1999, pp. 1407-1415

1999 Management Recommendations

- Observation
- CT
- Skull Radiographs
- MRI

PEDIATRICS Vol. 104 No. 6 December 1999, pp. 1407-1415

Observation

- For children with minor closed head injury and no loss of consciousness, a thorough history and appropriate physical and neurologic examination should be performed.
- Observation in the clinic, office, emergency department, or at home, under the care of a competent caregiver is recommended for children with minor closed head injury and no loss of consciousness.

PEDIATRICS Vol. 104 No. 6 December 1999, pp. 1407-1415

Observation

- Observation implies regular monitoring by a competent adult who would be able to recognize abnormalities and to seek appropriate assistance.

PEDIATRICS Vol. 104 No. 6 December 1999, pp. 1407-1415

Observation

- The use of cranial computed tomography (CT) scan, skull radiograph, or magnetic resonance imaging (MRI) is not recommended for the initial evaluation and management of the child with minor closed head injury and no loss of consciousness.

PEDIATRICS Vol. 104 No. 6 December 1999, pp. 1407-1415

Observation/CT

Observation or Cranial CT Scan

- For children with minor closed head injury and brief loss of consciousness (<1 minute), a thorough history and an appropriate physical and neurologic examination should be performed.
- Cranial CT scanning may also be used, in addition to observation, in the initial evaluation and management of children with minor closed head injury with loss of consciousness.

PEDIATRICS Vol. 104 No. 6 December 1999, pp. 1407-1415

Recommendations For CT

CT

- Many investigators have concluded that cranial CT is more sensitive than physical examinations for the diagnosis of intracranial injury.
- CT itself is a safe procedure.
- However, some healthy children require sedation or anesthesia

PEDIATRICS Vol. 104 No. 6 December 1999, pp. 1407-1415

Skull Radiographs/MRI

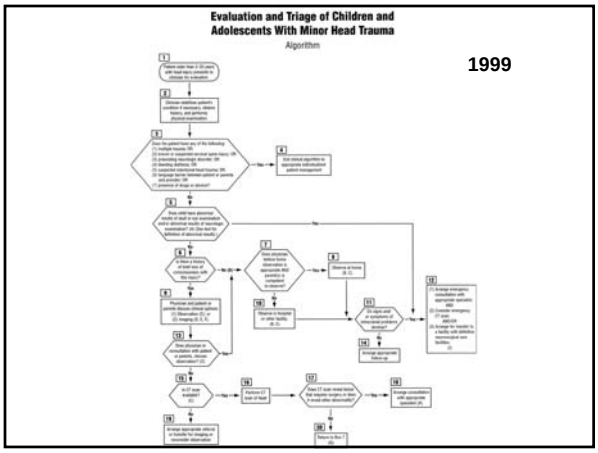
- The use of skull radiographs or MRI in the initial management of children with minor closed head injury and loss of consciousness is not recommended.
- However, there are limited situations in which MRI and skull radiography are options .

PEDIATRICS Vol. 104 No. 6 December 1999, pp. 1407-1415

CT versus MRI

- CT is more sensitive for hyperacute and acute intracranial hemorrhage (especially subarachnoid hemorrhage).
- CT is more quickly and easily performed than MRI, and costs for CT scans generally are less than those for MRI.
- The consensus of the Subcommittee was that cranial CT offered substantial advantages over MRI in the acute care of children with minor closed head injury.

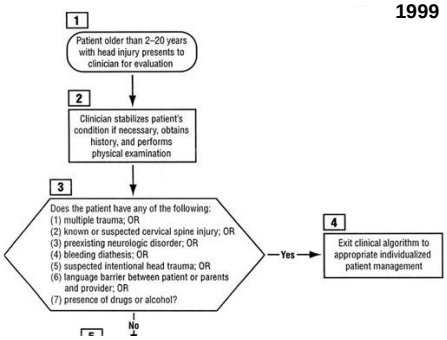
PEDIATRICS Vol. 104 No. 6 December 1999, pp. 1407-1415



1999

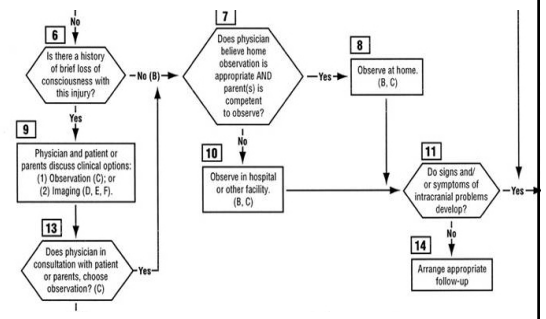
Head Injury Algorithm and Exclusions

1999

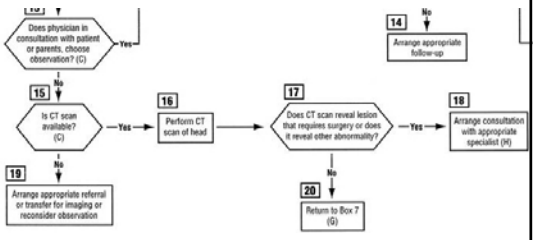


Observation as Part of the Algorithm

1999



If the Parent Wants the CT



1999

AAP Practice Parameter 1999

- It is not intended to replace clinical judgment or establish a protocol for all patients with a minor head injury, **and rarely will provide the *only* appropriate approach to the problem.**

PEDIATRICS Vol. 104 No. 6 December 1999, pp. 1407-1415

Proposed Guidelines AAP 2001

- **Evaluation and Management of Children Younger Than Two Years Old With Apparently Minor Head Trauma: Proposed Guidelines**

PEDIATRICS Vol. 107 No. 5 May 2001, pp. 983-993

AAP Proposed Head Injury Guidelines

Objective

- In children <2 years old, minor head trauma (HT) is a common injury that can result in skull fracture and intracranial injury (ICI).
- We sought to develop guidelines for management based on data and expert opinion that would enable clinicians to identify children with complications of HT and reduce unnecessary imaging procedures.

PEDIATRICS Vol. 107 No. 5 May 2001, pp. 983-993

AAP Head Injury < 2yo

Methods

- *Evidence*: References addressing pediatric HT were generated from a computerized database (Medline).
- 404 articles were reviewed.
- *Consensus Process*: At the meeting, guidelines were formulated based on data and expert consensus.

PEDIATRICS Vol. 107 No. 5 May 2001, pp. 983-993

Clinical Predictors

Clinical predictors of ICI include:

- Skull Fracture
- AMS
- Focal neurologic findings,
- Scalp swelling
- Younger age
- Inflicted injury (child abuse)
- Head injury with no clear history of trauma.

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Clinical Predictors

- Loss of consciousness (LOC) and vomiting have not been shown to be predictors of ICI.
- Of note is that many young children with ICI had no signs or symptoms of brain injury.
- Asymptomatic, or occult, ICI is significantly more prevalent in younger aged children, particularly those <3 to 6 months old.

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What are indications for CT? Evidence

- CT is considered the standard for diagnosis of acute ICI.
- The incidence of ICI among young children with minor HT is ~3%-6% The few studies that subdivide by age show a higher incidence in younger infants.

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Indications for Skull Radiographs (SR)

- **What are indications for SRs?**
- SRs can diagnose Skull Fractures.
- Skull Fractures is one of the strongest predictors for ICI, and may lead to complications such as an enlarging cephalohematoma

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Clinical Predictors of Skull Fracture

Incidence of SF in Outpatients Less Than Two Years Old Presenting for Evaluation

- Younger age and **scalp hematoma** (particularly temporal and parietal) are predictors for skull fracture.
- The presence of scalp hematoma is 80%-100% sensitive for associated skull fractures.

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Skull Fracture and ICI

If a fracture is noted on SR, should CT be obtained?

- In most studies of children with SF, an associated ICI was present in 15%-30%
- So, Skull Fracture is a predictor for ICI!

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General Principles in Head Injury

AGE

- The younger the child, the lower the threshold should be for obtaining imaging studies
- Younger patients have a higher incidence of complications and a higher incidence of asymptomatic ICI
- The youngest patient is difficult to assess clinically.

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General Principles in Head Injury

3 Months

- Infants <3 months old are at the highest risk.
- The youngest infants (<3 months old) also require sedation less often for CT than do older infants and young children.

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General Principles in Head Injury

There is no magic Formula

- Discrete cut-offs cannot be provided for signs and symptoms along the continuum.

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General Principles in Head Injury

Mechanism of Injury

- The greater the forces involved (such as those experienced in motor vehicle collisions, falls from greater heights or onto harder surfaces)

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General Principles in Head Injury

Physical Findings

- The greater the severity and number of historical symptoms and physical signs, the stronger the consideration should be for obtaining an imaging study.
- The more pronounced the physical findings such as scalp swelling, and the younger the age, the greater the risk of ICI.

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General Principles in Head Injury

Non Accidental Trauma

- Although not directly addressed by this article, all children with head trauma should be evaluated for extra-cranial injuries.
- Likewise, the possibility of intentional injury or neglect must be considered when a young child is evaluated for head trauma.

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Management Strategy
Imaging Recommendations

- Because these guidelines are intended for use by physicians in a variety of clinical settings, several options are offered in certain areas.
- The most appropriate strategy should be based on the clinical findings of the individual patient and the resources available.

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Most Importantly

PHYSICAL EXAM - CLINCAL EVALUATION

- It is assumed that the physician is qualified and performs a thorough and age-appropriate clinical evaluation.
- It is not the purpose of this document to detail the standards regarding the performance of a history and physical examination in an infant or young child with head trauma.

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Management Strategy
Imaging Recommendations

- The management strategy, subdivides children with minor blunt HT into 4 groups:
- 1) those at high risk for ICI, in whom CT is indicated
- 2) those at some risk for ICI with potential indicators of brain injury in whom CT and/or observation is indicated
  3) those without symptoms of brain injury who are at some risk for SF or ICI in whom CT and/or SRs or observation is indicated
- 4) those at low risk for ICI, for whom imaging is not necessary.

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High Risk Group
Significant Findings Predictive of ICI

- Depressed or Altered Mental Status
- Focal Neurologic Findings
- Skull fracture – basilar, depressed, linear
- Irritability
- Bulging Fontanel

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Vomiting, Seizure, LOC
NOT predictive of ICI

Available data do **not** demonstrate that either seizure, vomiting, LOC are independent predictors for ICI

- Seizure(3 studies)
- Vomiting(5 studies)
- LOC(4 studies)

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Expert Consensus on Vomiting

- However, panel consensus was that a CT should be obtained for any child with:
- Vomiting 5 or more times or persisting longer than 6 hours
- Or progressively worsening vomiting

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Expert Opinion on Seizure and LOC

- However, expert consensus was that a child with a seizure, or LOC as judged by caretakers as longer than 1 minute should undergo CT.

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Expert Consensus on Age < 3 months

- The expert consensus was that a low threshold should be adopted for CT of young infants (particularly those <3 months old) because of their relatively high incidence of ICI (including occult ICI), and the difficulties inherent in their assessment.

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High Risk Group Significant Findings Predictive of ICI and Expert Consensus

- Depressed or Altered Mental Status
- Focal Neurologic Findings
- Skull fracture – basilar, depressed, linear
- Irritability
- Bulging Fontanel
- Vomiting 5 or more times or persisting longer than 6 hours or progressively worsening
- Seizure

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High Risk Imaging Recommendations

- CT is indicated

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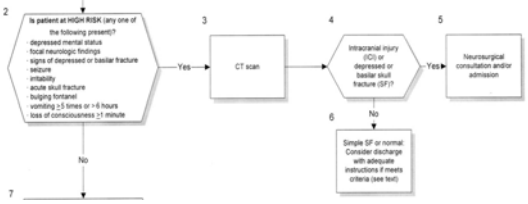
High Risk Group



Intermediate Risk Group

- This group consists of infants and children at some risk for a complication of head injury, in whom imaging or observation is indicated.
- This group is comprised of two subgroups of patients.

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Intermediate Risk Imaging Recommendations

The two Groups are:

- A) potential indicators of brain injury in whom CT and/or observation is indicated
- B) those without symptoms of brain injury who are at some risk for SF or ICI in whom CT and/or SRs or observation is indicated

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Intermediate Risk Group A
With Clinical Symptoms of Brain Injury

- 3 to 4 episodes of vomiting
- Transient LOC (<1 minute)
- History of lethargy or irritability (resolved by time of evaluation)
- Behavior not at baseline as reported by caretakers
- Nonacute SF (>24 hours old).

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Intermediate Risk Group A
With Clinical Symptoms of Brain Injury

- First group either CT or observation are valid clinical options

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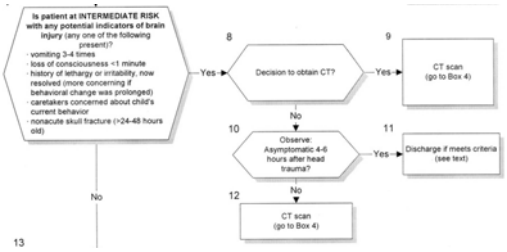
Intermediate Risk Group A
With Clinical Symptoms of Brain Injury



Intermediate Risk Group B
Without Clinical Symptoms of Brain Injury

- Second group an imaging procedure (CT and/or Skull Radiographs) or observation are valid clinical options.

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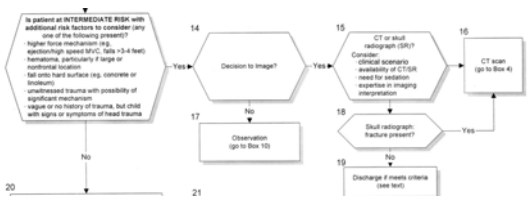
Intermediate Risk Group B

Without Clinical Symptoms of Brain Injury



Observation Period

- Even with trivial mechanisms, the risk of having or developing an ICI **is not zero**, so an observation period (4-6 hours)for onset of signs and symptoms of ICI is still warranted.
- If the child has reliable caretakers, this observation may occur at home, after appropriate discharge instructions are given.

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Management
Simple Skull Fracture

DISCHARGE

- Children with isolated simple skull fractures may be considered for discharge if the fracture is:
- A single fracture that has margins separated by <3 mm, is not depressed
- Restricted to a single bone
- No associated ICI noted on CT (see below).
- And they meet discharge criteria

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Low-Risk Group

- The low-risk group consists of patients with head trauma whose injuries are trivial and who have a very low likelihood of an ICI.
- These children do not require any imaging

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Low-Risk Group

- This category includes children with low-energy mechanisms (eg, fall <3 feet) who have no signs or symptoms at least 2 hours after the injury.

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Low-Risk Group

- These children do not require any imaging

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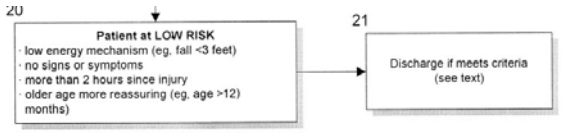
Low Risk Group



Low-Risk Group

- If the child has reliable caretakers, this observation may occur at home, after appropriate discharge instructions are given.

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Discharge Criteria

Discharge may be considered (after appropriate evaluation, with imaging, observation, or neurosurgical consultation as indicated) if:

1. The child has no significant extracranial injuries or other indications (eg, unremitting vomiting) for admission

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Discharge Criteria

2. The child easily alerts and has a normal neurologic examination;
3. There is no suspicion of abuse or neglect
4. The child lives in relatively close proximity to health care and has reliable caretakers who are able to return if necessary.

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Adult Literature

- Mower WR, Hoffman JR, Herbert M, et al, for the Nexus II Investigators. National Emergency X-Radiography Utilization Study. Developing a clinical decision instrument to rule out intracranial injuries in patients with minor head trauma: methodology of the NEXUS II investigation. ***Ann Emerg Med.*** **2002;40 :505 –514**
- Mower WR, Hoffman JR, Herbert M, et al, for the NEXUS II Investigators. Identification of high yield criteria for use in assessing blunt head injury patients for intracranial injuries. ***J Trauma.*** **2005;59:954-959**

Bean Bash

- B Behavior abnormal
  E Emesis intractable
  A Age > 65 years
  N Neurologic deficit
- B Bleeding disorder
  A Altered mental status
  S Skull fracture
  H Hematoma scalp

•***J Trauma.*** **2005;59:954-959**

Recent Literature

- **Performance of a Decision Rule to Predict Need for Computed Tomography Among Children With Blunt Head Trauma**
- National Emergency X-Radiography Utilization Study II (NEXUS II)
- PEDIATRICS Vol. 117 No. 2 February 2006, pp. e238-e246

National Emergency X-Radiography Utilization Study II (NEXUS II)

- **OBJECTIVE.** To assess the ability of the NEXUS II head trauma decision instrument to identify patients with clinically important intracranial injury (ICI) from among children with blunt head trauma.

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National Emergency X-Radiography Utilization Study II (NEXUS II)

METHODS

- An analysis was conducted of the pediatric cohort involved in the derivation set of a prospective, observational, multicenter study of all patients who had blunt head trauma and underwent cranial computed tomography (CT) imaging at 1 of 21 emergency departments.
- We determined the test performance characteristics of the 8-variable NEXUS II decision instrument, derived from the pediatric cohort (0–18 years of age)
- Also in the very young children (<3 years).

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National Emergency X-Radiography Utilization Study II (NEXUS II)

METHODS

- Clinically important ICI was defined as ICI that required neurosurgical intervention (craniotomy, intracranial pressure monitoring, or mechanical ventilation) or was likely to be associated with significant long-term neurologic impairment.

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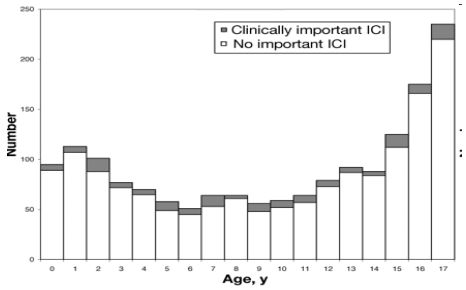
Age Distribution



Age distribution of the 1666 pediatric blunt trauma victims. A total of 138 children had clinically important ICI that was identified on CT imaging.

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RESULTS

- NEXUS II enrolled 1666 children
- 138 (8.3%) of whom had clinically important ICI.
- The decision instrument correctly identified 136 of the 138 cases and classified 230 as low risk.
- A total of 309 children were younger than 3 years, among whom 25 had ICI.
- The decision instrument identified all 25 cases of clinically important ICI in this subgroup.

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CT Findings Representing Clinically Important ICI

- Substantial epidural or subdural hematoma (>1.0 cm in width or causing mass effect)
- Substantial cerebral contusion (>1.0 cm in diameter or >1 site)
- Extensive subarachnoid hemorrhage
- Mass effect or sulcal effacement
- Signs of herniation
- Basal cistern compression or midline shift
- Hemorrhage in the posterior fossa
- Intraventricular hemorrhage
- Bilateral hemorrhage of any type
- Depressed or diastatic skull fracture
- Pneumocephalus
- Diffuse cerebral edema
- Diffuse axonal injury

PEDIATRICS Vol. 117 No. 2 February 2006, pp. e238-e246

BEN BASH for Pediatrics

- B Behavior abnormal
  E Emesis intractable
  N Neurologic deficit (GCS < 15)
- B Bleeding disorder
  A Altered mental status
  S Skull fracture
  H Hematoma scalp

CONCLUSIONS

- The decision instrument derived in the large NEXUS II cohort performed with similarly high sensitivity among the subgroup of children who were included in this study.
- Clinically important ICI were rare in children who did not exhibit at least 1 of the NEXUS II risk criteria.

PEDIATRICS Vol. 117 No. 2 February 2006, pp. e238-e246

Conclusions: For Minor Head Injury CT or Not?

- Cranial CT imaging seems unlikely to detect clinically important ICI in children who do not exhibit at least 1 of the following risk criteria:

PEDIATRICS Vol. 117 No. 2 February 2006, pp. e238-e246

Nexus II Conclusion Significant ICI

- (1) evidence of significant skull fracture (diastatic, depressed, open, or basilar)
- (2) altered level of alertness
- (3) neurologic deficit
- (4) persistent vomiting
- (5) presence of scalp hematoma
- (6) abnormal behavior
- (7) coagulopathy

PEDIATRICS Vol. 117 No. 2 February 2006, pp. e238-e246

Missed ICI with Nexus II Criteria

- The number of injuries missed by the instrument was 2 in 1666 evaluations.
- Neither of the children who were missed by the decision instrument in our derivation cohort had an abnormal neurologic examination or developed delayed clinical deterioration.

PEDIATRICS Vol. 117 No. 2 February 2006, pp. e238-e246

Missed ICI with Nexus II Criteria

- This false-negative rate is of a magnitude slightly greater than the potential lethal malignant transformation rate (1 in 1000) associated with the liberal use of CT scanning.

PEDIATRICS Vol. 117 No. 2 February 2006, pp. e238-e246

CT and the Risk of Malignancy

- CT is an exquisite means of detecting potentially dangerous intracranial injuries, but it exposes particularly vulnerable populations to ionizing radiation and the potential for lethal malignant transformation.

Brenner DJ. Estimating cancer risks from pediatric CT: going from the qualitative to the quantitative Pediatr Radiol. 2002;32:228-231

Estimated Risks

- Estimates (theoretical, not observed) of risks of lethal malignancies extrapolated from survivors of WW II atomic explosions:
  - 1/2000 head CT scans for children younger than 1 yr.
  - 1/5000 for 10 yo
- Age and size based radiation reduction efforts are ongoing
  - 4/5th of CT studies in children are not managed by pediatric radiologists.

Brenner DJ. Estimating cancer risks from pediatric CT: going from the qualitative to the quantitative Pediatr Radiol. 2002;32:228-231

CT and the Risk of Malignancy

- It has been estimated that 600,000 abdominal and head CT examinations were performed annually in children under the age of 15 years with an estimated LAR(lifetime attribituble risk) of 500 deaths from cancer, and that the number of CT studies is growing rapidly.

Brenner DJ. Estimating cancer risks from pediatric CT: going from the qualitative to the quantitative Pediatr Radiol. 2002;32:228-231

CT and the Risk of Malignancy

- The U.S. Food and Drug Administration estimates that a CT examination with an effective dose of 10 mSv (eg, 1 CT of the abdomen) may be associated with the increase in the possibility of fatal cancer of approximately 1 chance in 2000.

Whole body scanning using computed tomography (CT). What are the radiation risks from CT? Available on the U.S. Food and Drug Administration Web site: www.fda.gov/cdrh/ct/risks.html. Accessed February 2007.
Mettler FA Jr, Wiest PW, Locken JA, Kelsey CA. CT scanning: Patterns of use and dose.J Radiol Prot.2000;20:353-359.

CT and the Risk of Malignancy

- The pediatric population is more vulnerable to the risks of CT radiation, and an estimate of the lifetime cancer mortality risk attributable to the radiation exposure from a single abdominal CT examination in a 1-year-old child is approximately 1 in 550

Brenner DJ. Estimating cancer risks from pediatric CT: going from the qualitative to the quantitative Pediatr Radiol. 2002;32:228-231

CT and the Risk of Malignancy

- Additional concern derives from the potential for use of suboptimal CT technique and excessive exposures in smaller pediatric patients: at the same technique factors, pediatric doses are substantially higher.

Brenner DJ. Estimating cancer risks from pediatric CT: going from the qualitative to the quantitative Pediatr Radiol. 2002;32:228-231

Radiation Risks - FDA

November 2, 2001

David W. Feigal, Jr., MD, MPH

Director Center for Devices and Radiological Health

Radiation Risks - FDA

November 2, 2001

David W. Feigal, Jr., MD, MPH

Director Center for Devices and Radiological Health

1 David J. Brenner et al., “Estimated Risks of Radiation-Induced Fatal Cancer from Pediatric CT.” *AJR* Vol. 176, pp. 289-296, Feb 2001.

2 "One Size Does Not Fit All: Reducing Risks from Pediatric CT." *ACR Bulletin* Vol. 57, Issue 2, pp.20-23, Feb 2001.

Radiation Risks - FDA

- This Notification is to emphasize the importance of keeping radiation doses during CT procedures as low as reasonably achievable, especially for pediatric and small adult patients, who may sometimes receive more radiation than needed to obtain diagnostic images.
- To prevent this, we want to stress the importance of adjusting CT scanner parameters appropriately for each individual’s weight and size, and for the anatomic region being scanned.

Radiation Risks - FDA

This is particularly important when the patient is a child, since children exposed to radiation are at a relatively greater risk than adults.

The American College of Radiology has noted, “Because they have more rapidly dividing cells than adults and have longer life expectancy, the odds that children will develop cancers from x-ray radiation may be significantly higher than adults.

Radiation Risks - FDA

It has been estimated by the National Research Council's Committee on the Biological Effects of Ionizing Radiation that children less than 10 years of age are several times more sensitive to radiation than middle-aged adults.

FDA Recommendations

- Optimize CT Settings
- Reduce tube current
- Develop and use a chart or table of tube-current settings based on patient weight or diameter and anatomical region of interest
- Eliminate inappropriate referrals for CT.

Canadian Assessment of Tomography for Childhood Head Injury (CATCH) study

Neuroimaging for paediatric minor closed head injuries

- Sanjay Mehta, MD MEd FRCPC FAAP FACEP
- Paediatr Child Health. 2007 July; 12(6): 482–484.

CATCH Study

- Multicenter study included 3,866 consecutive children
- Mean age 9.2 years, who entered emergency departments with blunt head trauma

CATCH Inclusion Criteria

- Inclusion criteria included one or more of the following:
- GCS score between 13 and 15,
- LOC,
- Amnesia,
- Disorientation,
- Two episodes of vomiting or more,
- Irritability (if two years of age or younger).

CATCH Study

- Emergency department staff completed a standardized assessment form for each child prior to any CT scan.
- Twenty-eight items were asked to be identified on a pre-CT scan assessment, with intra-observer evaluations encouraged whenever possible.
- Telephone follow-up was conducted at 14 days for no (or mild) headache, vomiting, memory, concentration, seizures or focal motor problems, and return to normal daily activities.

CATCH Study

Glasgow Coma Scale,

- 2.5 percent of patients presented with an initial score of 13
- 7.3 percent of patients had a score of 14
- 90.2 percent of patients had a score of 15.

CATCH Study

- Researchers found that CT revealed ICI in 4.1 percent of patients
- 0.6 percent of patients underwent neurologic intervention.

CATCH

(Canadian Assessment Tomography Childhood Head Injury)

- A clinical decision rule was derived with high-risk factors for power in predicting neurosurgical intervention, and medium-risk factors for power in detecting brain injury.

Paediatr Child Health. 2007 July; 12(6): 482–484.

CATCH High Risk Factors

High-risk factors included a

- GCS score lower than 15 within 2 h of injury
- Suspected open skull fracture
- Worsening headache
- Irritability on examination.

Paediatr Child Health. 2007 July; 12(6): 482–484.

CATCH Medium Risk Factors

Medium-risk factors included:

- Large, boggy scalp hematoma
- Signs of basal skull fracture
- Dangerous mechanism of injury (such as falling from a height greater than three times the patient's height).

Paediatr Child Health. 2007 July; 12(6): 482–484.

Results

- If only high-risk factors were applied, the rule would be:
- 100% sensitive and 70.4% specific for neurosurgical intervention
- Only 29.6% of patients would undergo CT scans.

Paediatr Child Health. 2007 July; 12(6): 482–484.

Results

- If only medium-risk factors were applied:
- The rule would be 98.3% sensitive and 50.1% specific for brain injury,
- With 49.9% of patients undergoing CT scans.

Paediatr Child Health. 2007 July; 12(6): 482–484.

CATCH Commentary on Vomiting

- The CATCH study shows that vomiting may not be as important an indication for neuro-imaging as previously thought.
- This is supported in a prospective case-control study of 162 case subjects by **Da Dalt et al**, who found that post-traumatic vomiting is significantly related to personal or familial predisposition to vomiting rather than to the presence of intracranial lesions.

CATCH Conclusions

- For children with a minor closed head injury and brief or no loss of consciousness.
- If the patient's condition appeared normal on examination, no additional tests were needed and the child could be safely discharged to the care of a responsible caregiver.

CATCH Conclusions

- Observation implies regular monitoring by a competent adult who would be able to recognize abnormalities and to seek appropriate assistance.

CATCH Conclusions

- There was no evidence to show that immediate neuro-imaging of asymptomatic children produced demonstrable benefits compared with initial observations alone.

Another Clinical Decision Rule

A Clinical Decision Rule for Cranial Computed Tomography in Minor Pediatric Head Trauma

- Shireen Atabaki, et al
- *Archives of Pediatrics Adolescent Medicine.* 2008;162(5):439-445.

Clinical Decision Rule for CT in Minor Pediatric Head Trauma

Objectives

- To develop a sensitive clinical decision rule with a high negative predictive value for the use of cranial computed tomography (CT) in minor pediatric head trauma,
- To identify clinical features predictive of neurosurgical intervention
- **To assess clinicians' predictive abilities to determine the presence or absence of intracranial injury based on history and physical examination alone.**

•*Archives of Pediatrics Adolescent Medicine.* 2008;162(5):439-445.

Clinical Decision Rule for CT in Minor Pediatric Head Trauma

- **Design** Prospective observational study.
- **Setting** Four level I pediatric trauma centers.
- **Participants** 1000 patients younger than 21 years with minor head trauma undergoing cranial CT.
- **Main Outcome Measure** Intracranial injury as demonstrated by CT and neurosurgical intervention.

•*Archives of Pediatrics Adolescent Medicine.* 2008;162(5):439-445.

Clinical Decision Rule for CT in Minor Pediatric Head Trauma

Results

- 1000 patients in the study
- Mean age was 8.9 years
- 64.1% were male

•*Archives of Pediatrics Adolescent Medicine.* 2008;162(5):439-445.

Study Group

Table 1. Characteristics of the Entire Study Group vs the Patients With Intracranial Injury

Characteristic	No. (%) of Study Group (N=1000)	No. (%) of Patients With Intracranial Injury (n=65)
Age, y		
<2	188 (18.8)	27 (41.5)
≥2	812 (81.2)	38 (58.5)
Male sex	641 (64.1)	40 (61.5)
Method of arrival		
Ambulance	445 (44.5)	32 (49.2)
Helicopter	101 (10.1)	8 (12.3)
Other	454 (45.4)	25 (38.5)

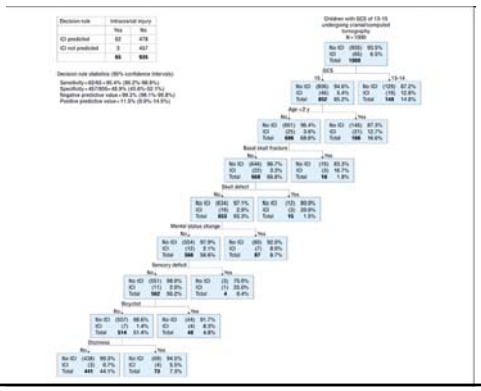
•*Archives of Pediatrics Adolescent Medicine.* 2008;162(5):439-445.

Eight Criteria

- Dizziness,
- Sensory deficit
- GCS less than 15
- Mental status change
- Bicycle-related injury
- Age younger than 2 years
- Skull defect on examination
- Evidence of a basilar skull fracture (Battle sign, rhinorrhea, hemotympanum, periorbital ecchymosis, or cerebrospinal fluid otorrhea).

•*Archives of Pediatrics Adolescent Medicine.* 2008;162(5):439-445.

Pediatric Head CT Decision Rule



The Three Missed Patients

Positive ICI with Negative Decision Rule

Table 4. Patients With Positive Intracranial Injury Findings on Computed Tomography in Whom the Decision Rule Was Negative[a]

Age, y	Computed Tomographic Findings	Mechanism of Injury	Symptoms
13.9	Small interhemispheric subdural hemorrhage above and below the tentorium and posterior falx	Fall	Amnesia, loss of consciousness, or headache
2.1	Subarachnoid hemorrhage	Fall	Emesis or behavior change
6.5	Small focus of increased density in the occipitoparietal region representing a small contusion or an artifact	Motor vehicle crash, pedestrian struck	Behavior change

[a] None required neurosurgical intervention.

•*Archives of Pediatrics Adolescent Medicine.* 2008;162(5):439-445.

Clinicians Ability To Predict Intracranial Injury

Table 5. Clinician's Ability to Predict Intracranial Injury[a]

Variable	Intracranial Injury	
	Yes (n=54)	No (n=866)
Clinician's prediction of the likelihood of intracranial injury		
Likely	8	64
Unlikely	46	802
Sensitivity	14.8% (95% confidence interval, 7.1%-27.7%)	
Specificity	92.6% (95% confidence interval, 90.6%-94.2%)	
Positive predictive value	11.1% (95% confidence interval, 5.3%-21.3%)	
Negative predictive value	94.6% (95% confidence interval, 85.8%-98.3%)	

[a]Values do not sum to 920 because the clinicians completing the data collection survey did not complete this item.

•*Archives of Pediatrics Adolescent Medicine.* 2008;162(5):439-445.

Clinical Decision Rule for CT in Minor Pediatric Head Trauma

Results

- 6.5% (65 of 1000) had positive findings on CT
- 9.2% (6 of 65) of these required neurosurgical intervention..

•*Archives of Pediatrics Adolescent Medicine.* 2008;162(5):439-445.

CT Findings of ICI

Table 2. Cranial Computed Tomographic Findings in the Patients With Intracranial Injury[a]

Finding	No. (%) of Patients With Intracranial Injury (n=65)
Subdural hematoma	26 (40.0)
Contusion	18 (27.7)
Subarachnoid hematoma	15 (23.1)
Epidural hematoma	11 (16.9)
Cerebral edema	2 (3.1)
Other intracranial injury	8 (12.3)

[a]Some patients had more than 1 intracranial injury.

•*Archives of Pediatrics Adolescent Medicine.* 2008;162(5):439-445.

Clinical Decision Rule for CT in Minor Pediatric Head Trauma

Results

For detection of intracranial injury, the decision rule had a:

- Sensitivity of **95.4%** (95% confidence interval [CI], 86.2%-98.8%)
- Specificity of **48.9%** (95% CI, 46.6%-52.1%)
- Negative predictive value of **99.3%** (95% CI, 98.1%-99.8%).

•*Archives of Pediatrics Adolescent Medicine.* 2008;162(5):439-445.

Clinical Decision Rule Shireen et al.

- In this decision rule, pediatric patients who meet GCS definitions for minor head trauma and have at least 1 of the historical or clinical criteria listed are at higher risk for ICI. Children without any of these risk factors are unlikely to have ICI.

•*Archives of Pediatrics Adolescent Medicine.* 2008;162(5):439-445.

Clinical Decision Rule for CT in Minor Pediatric Head Trauma

- **Conclusions**
- We developed a sensitive clinical decision rule with a high NPV for detection of intracranial injury in minor pediatric head trauma.
- If validated, this rule could provide a useful adjunct to the physician's clinical assessment by reducing variations in practice and unnecessary cranial CT.

•*Archives of Pediatrics Adolescent Medicine.* 2008;162(5):439-445.

PECARN Study

(**P**ediatric **E**mergency **C**are **A**pplied **R**esearch **N**etwork)

- Identification of children at very low risk of clinically-important brain injuries after head trauma: a prospective cohort study.
- Kupperman N, Holmes JF, Dayan PS, et al.
- Lancet. 2009;374:1160-1170.

Study Characteristics

- 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.

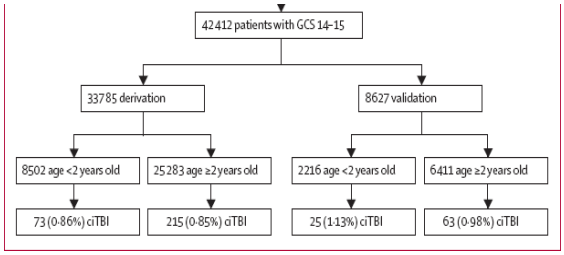
•Lancet. 2009;374:1160-1170.

Study Characteristics

- We enrolled and analyzed 42,412 children
- 8502 and 2216 younger than 2 years and 25 283 and 6411 aged 2 years and older (Derivation and validation populations:,).

•Lancet. 2009;374:1160-1170.

Study Overview



•Lancet. 2009;374:1160-1170.

Study Characteristics

- We derived and validated age-specific prediction rules for ciTBI (death from traumatic brain injury, neurosurgery, intubation >24 h, or hospital admission >or=2 nights).

•Lancet. 2009;374:1160-1170.

Idenfication of Very Low Risk Head Injury Patients

Children aged **2 years and older** are classified as low risk if they exhibit :

- Normal mental status
- No loss of consciousness
- No vomiting
- Non-severe injury mechanism
- No signs of basilar skull fracture
- No severe headache.

•Lancet. 2009;374:1160-1170.

Idenfication of Very Low Risk Head Injury Patients

Children **younger than 2 years of age** are considered low risk if they exhibit :

- Normal mental status
- No scalp hematoma except frontal
- No loss of consciousness or loss of consciousness for less than 5 seconds
- Non-severe injury mechanism
- No palpable skull fracture
- Acting normally according to parents.

•Lancet. 2009;374:1160-1170.

Findings

- We obtained CT scans on 14 969 (35.3%)
- Clinically important Traumatic Brain Injuries (ciTBIs) occurred in 376 (0.9%)
- 60 (0.1%) underwent neurosurgery

•Lancet. 2009;374:1160-1170.

Prediction Rule Findings < 2 years old

Clinical Findings

- normal mental status
- no scalp hematoma except frontal
- no loss of consciousness or loss of consciousness for less than 5 secs
- non-severe injury mechanism
- no palpable skull fracture

Results

- Negative predictive value for ciTBI of 1176/1176 (**100.0%,** 95% CI 99.7-100 0)
- Sensitivity of 25/25 (**100%,** 86.3-100.0).
- 167 (24.1%) of 694 CT-imaged patients younger than 2 years were in this low-risk group.

Prediction Rule Findings > 2 years old

Clinical Findings

- Normal mental status
- No loss of consciousness
- No vomiting
- Non-severe injury mechanism
- No signs of basilar skull fracture
- No severe

Results

- Negative predictive value of 3798/3800 (99.95%, 99.81-99.99)
- Sensitivity of 61/63 (96.8%, 89.0-99.6).
- 446 (20.1%) of 2223 CT-imaged patients aged 2 years and older were in this low-risk group.

Prediction Rule Findings

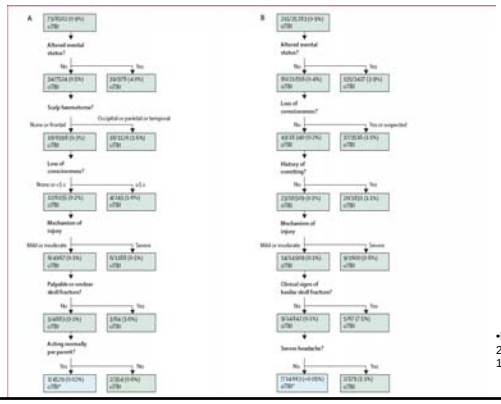
- Neither rule missed neurosurgery in validation populations

ICI in Two Missed Patients in > 2 year old Group

- Non helmeted bicyclist with pulmonary contusion, large frontal hematoma and small subdural noted on CT
- Non helmeted in line skater who fell down 10 steps with a moderate headache and large frontal scalp hematoma. CT showed frontal lobe contusions and a linear fracture. Hospitalized 2 days without any intervention.

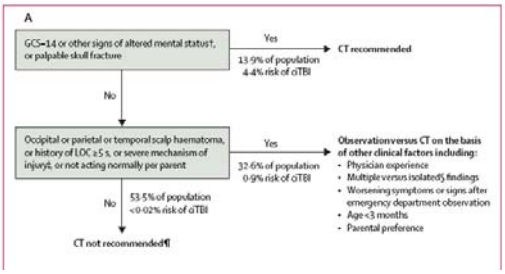
•Lancet. 2009;374:1160-1170.

Prediction Tree for Age < 2 (A) or > 2(B)



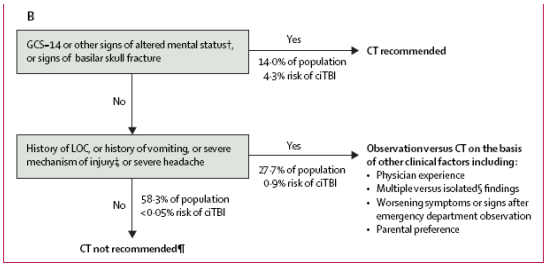
•Lancet. 2009;374:1160-1170.

Age < 2 yrs and GCS 14-15



•Lancet. 2009;374:1160-1170.

Age > 2 yrs and GCS 14-15



•Lancet. 2009;374:1160-1170.

Excellent Negative Predictive Value

- In clinical application the rule was found to have a negative predictive value greater than 99.95%, and correctly identified clinically important injuries in 86 of 88 children (97.7%).

•Lancet. 2009;374:1160-1170.

The Rule Could Decrease CT Imaging

- The rule assigned low-risk status, and would have omitted imaging, for about 21% of the children who underwent imaging on the basis of clinical judgment.

•Lancet. 2009;374:1160-1170.

Decision Rule Might Actually Increase Imaging Rates in Certain Cases

- On the other hand, the overall performance of the rule is inferior to clinical judgment
- Strict application would have increased overall imaging rates from 35% to about 42%, without increasing sensitivity.

•Lancet. 2009;374:1160-1170.

Limitations of Clinical Decision Rules

Commentary

- To achieve high sensitivity, developers are forced to sacrifice specificity, and the vast majority of "non-low-risk" patients do not harbor injuries.
- As a consequence, these instruments are relatively poor at determining which children do need imaging.

Lancet. 2009;374:1160-1170.

Limitations of Clinical Decision Rules

Commentary

- Indiscriminate imaging of non-low-risk children typically increases overall imaging rates, with concomitant increased radiation exposure, but offers little advantage over clinical judgment in detecting clinically important injuries.

Lancet. 2009;374:1160-1170.

What Rules Should Guide Imaging Decisions in Injured Children?

From Medscape Emergency Medicine Ask the Experts

- **What Rules Should Guide Imaging Decisions in Injured Children?**

William R. Mower, MD

Authors and Disclosures

Posted: 02/23/2010

In response to Lancet. 2009;374:1160-1170

Limitations of Clinical Decision Rules

Commentary

- While it may be convenient to have decision tools that dictate imaging requirements for all children, it is unlikely that such tools are feasible.

William R. Mower, MD

02/23/2010

One Tool Does Not Fit All

Commentary

- Many children present with findings that exclude them from low-risk classification, but do not exhibit high-risk findings.

William R. Mower, MD

02/23/2010

Clinical Judgement

- Imaging decisions in these children should be based on clinical impressions, and it is likely that clinical judgment will continue to play an important role in the foreseeable future in the treatment of many children who have sustained blunt head injury.

William R. Mower, MD

02/23/2010

Summary

- Decision Rules will always have limitations but they are very good at predicting ciTBI if they are completely normal
- The more sensitive the decision rule is, the greater the probability that imaging might be used
- Clinical decision making is very good, however, like decision rules are not perfect

Summary

- The overwhelming majority of children who have a GCS of 14-15 and who look well two hours post injury will not have an ciTBI.
- Vomiting is NOT a good independent indicator of ciTBI
- Good follow up and observation are still excellent tools to evaluate minor head trauma with and without imaging

Summary

- CT is an excellent method to diagnose clinically important Traumatic Brain Injury (ciTBI)
- CT does have a risk of causing a malignancy, more so in the younger child
- CT scans in adult facilities may expose children to much higher doses of radiation than pediatric facilities

Summary

- Younger children are more difficult to diagnose with ICI than older children
- Very young infants are the most difficult to diagnose and so imaging either with skull radiographs or CT is indicated

Summary

- Children with multisystem trauma should have a lower threshold for CT scanning
- Children who may be abuse or non-accidental trauma victims should be strongly considered for CT scanning

Summary

- Skull films are reasonable in children less than 1 year of age, especially with scalp hematomas

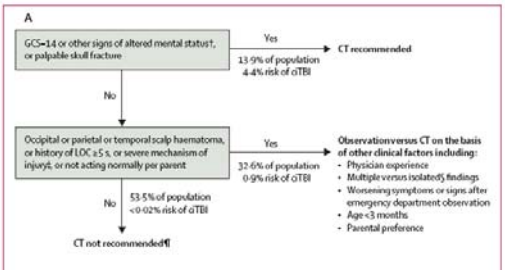
Bottom Line

- Children with minor head injuries with normal GCS without significant physical finding of trauma who are back at baseline probably do not need a CT scan
- Very young children (< 6 months) are the most difficult to assess and may require imaging
- Skull films are useful, particularly with scalp hematomas to diagnose skull fractures

Bottom Line

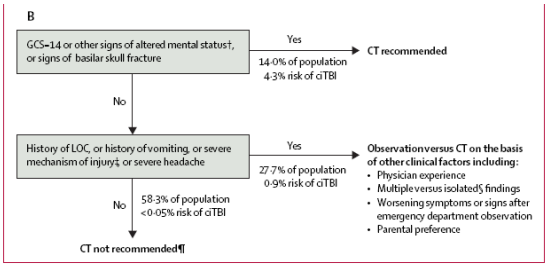
- Children with skull fractures should get a CT scan
- Observation is a valid and reasonable alternative to imaging
- Discussion with parents about potential risks of radiation versus risks of missing a clinically important tramatic brain injury

SUMMARY SLIDE
Age < 2 yrs and GCS 14-15



•Lancet. 2009;374:1160-1170.

SUMMARY SLIDE
Age > 2 yrs and GCS 14-15



•Lancet. 2009;374:1160-1170.

Case A

- 6 month old male GCS 15 with large cephalo-hematoma on his head from falling out of his crib 2 days ago

Case B

- 2 month old ejected from a car, still in his car seat with no visible marks on him, including his head with a GCS of 15

Case C

- 3 year old with a history of febrile seizures who slipped on the kitchen floor and struck the back of his head two hours ago. Mother reports immediate crying and a 20 second seizure that resolved spontaneously. The child has a GCS of 15 and is running around the room and playing. His physical shows no signs of trauma

Case D

- A 5 years old who fell of his bunk bed and hit his head. His brother reported a brief LOC of < 10 seconds, and he has vomited three times. His GCS is 15 and he complains of a mild headache. He has since tolerated an oral challenge and is 4 hours post injury

Case E

- An 4 month old infant who has no visible marks on him except a small bruises on his back and shoulder, but is irritable and his GCS is 14.

Case A

- 6 month old male GCS 15 with large cephalo-hematoma on his head from falling out of his crib 2 days ago
- Consider a skull film and if negative may not need the CT
- CT
- Skull film positive then definitely obtain CT

Case B

- 2 month old ejected from a car, still in his car seat with no visible marks on him, including his head with a GCS of 15
- Obtain CT
- Mechanism of action is too high energy and clinical exam in this age is unreliable

Case C

- 3 year old with a history of febrile seizures who slipped on the kitchen floor and struck the back of his head two hours ago. Mother reports immediate crying and a 20 second seizure that resolved spontaneously. The child has a GCS of 15 and is running around the room and playing. His physical shows no signs of trauma
- Unlikely to need any imaging
- Observation and close follow up
- Discuss with parents

Case D

- A 5 years old who fell of his bunk bed and hit his head. His brother reported a brief LOC of < 10 seconds, and he has vomited three times. His GCS is 15 and he complains of a mild headache. He has since tolerated an oral challenge and is 4 hours post injury
- Unlikely to have significant ICI
- Discuss option of CT with parent and decide whether radiation risk is worth the very small risk of missing a ciTBI
- Close observation and follow up

Case E

- An 4 month old infant who has no visible marks on him except a small bruises on his back and shoulder, but is irritable and his GCS is 14.
- Child needs a CT
- Non accidental trauma is a concern and often with a shaken baby it is very difficult to diagnose a significant ciTBI

Case F

- 9 year old hit in the head with a thrown brick. Has a laceration on his scalp and a GCS of 13-14. No vomiting but complains of a headache.
- With a depressed GCS, a significant mechanism of injury and the physical finding of a laceration a CT should definitely be done.

Head Injury