Pediatric Head Injury

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COI

- I have no relevant financial disclosures

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- 2 year old female
- Witnessed fall from counter top
- No LOC
- Brief shaking after impact, vomited twice, complains of headache
- Notable left frontal hematoma

- *Do you obtain a head CT?*
- *What do you observe for?*

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Outline

- Definitions: TBI vs ciTBI
- An approach to neuroimaging for head injury
- Clinical decision rules
- Application of PECARN
- Observation in the ED
- NS indications

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- Traumatic Brain Injury
  - External force
  - Alteration in brain function or
  - Evidence of brain pathology

  - Mild: GCS 13/14-15
  - Moderate: GCS 9-12/13
  - Severe: GCS $\leq$ 8

- Clinically Important Traumatic Brain Injury (ciTBI)
  - Neurosurgical intervention
  - Intubation
  - Hospital admission
  - Death

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Epidemiology

- Pediatric head trauma in the US, annually
  - 7400 deaths
  - >60K hospital admissions
  - >600K ED visits

- About 50% of children with head injury in EDs undergo CT
  - Between 1995 – 2005, CT use more than doubled
  - Many TBI on CT do not need NS intervention
  - Abnormal CT findings as outcome measures promotes CT use

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Pediatr Radiol (2002) 32: 228–231
DOI 10.1007/s00247-002-0671-1

SESSION I: HELICAL CT AND CANCER RISK

David J. Brenner

Estimating cancer risks from pediatric CT: going from the qualitative to the quantitative

Radiation Dose and Somatic Risk from Computed Tomography

K. Faulkner and B. M. Moores View all authors and affiliations

Volume 28, Issue 4 | https://doi.org/10.1177/028418518702800422

Acta Radiologica

Risk of lethal malignancy from cranial CT scans
* 1/1000 to 1/5000 scans
* increased risk with younger age

The NEW ENGLAND JOURNAL of MEDICINE

SPECIALTIES TOPICS MULTIMEDIA CURRENT ISSUE LEARNING/CME AUTHOR CENTER PUBLICATIONS

REVIEW ARTICLE | CURRENT CONCEPTS

Computed Tomography — An Increasing Source of Radiation Exposure

Authors: David J. Brenner, Ph.D., D.Sc., and Eric J. Hall, D.Phil., D.Sc. Author Info & Affiliations

Published November 29, 2007 | N Engl J Med 2007;357:2277-2284 | DOI: 10.1056/NEJMra072149

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An Approach to Neuroimaging

- Identify ciTBI while limiting radiation
- Most children do not need a CT to rule out ciTBI
- Very few require NS
  - Risks of missing ciTBI is potentially catastrophic
- Clinical decision rules are meant to assist
  - NOT to replace clinical judgment

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Clinical Decision Rules (Pediatric head injury)

- CHALICE
  - Children's Head injury ALgorithm for the prediction of Important Clinical Events
  - English study group
- CATCH
  - Canadian Assessment of Tomography for Childhood Head Injury
  - Pediatric Emergency Research Canada (PERC) study group
- PECARN
  - Pediatric Emergency Care Applied Research Network
  - Multicenter US research consortium

Derivation of the children's head injury algorithm for the prediction of important clinical events decision rule for head injury in children

J Dunning, J Patrick Daly, J-P Lomas, F Lecky, J Batchelor, K Mackway-Jones, on behalf of the children's head injury algorithm for the prediction of important clinical events (CHALICE) study group

Arch Dis Child 2006;**91**:885–891. doi: 10.1136/adc.2005.083980

- Multicenter, 10 hospitals in NW England
- Inclusion: any severity of head injury
- Exclusion: none
- Data collection on 40 clinical variables
- Outcome: death, NS intervention, marked abnormalities on CT
- 22,772 patients enrolled
- Of those scanned, 37.7% abnormal
- 6.4% admitted, 0.6% NS

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The children's head injury algorithm for the prediction of important clinical events rule

A computed tomography scan is required if any of the following criteria are present.

- *History*
  - Witnessed loss of consciousness of >5 min duration
  - History of amnesia (either antegrade or retrograde) of >5 min duration
  - Abnormal drowsiness (defined as drowsiness in excess of that expected by the examining doctor)
  - ⩾3 vomits after head injury (a vomit is defined as a single discrete episode of vomiting)
  - Suspicion of non-accidental injury (NAI, defined as any suspicion of NAI by the examining doctor)
  - Seizure after head injury in a patient who has no history of epilepsy
- *Examination*
  - Glasgow Coma Score (GCS)<14, or GCS<15 if <1 year old
  - Suspicion of penetrating or depressed skull injury or tense fontanelle
  - Signs of a basal skull fracture (defined as evidence of blood or cerebrospinal fluid from ear or nose, panda eyes, Battles sign, haemotympanum, facial crepitus or serious facial injury)
  - Positive focal neurology (defined as any focal neurology, including motor, sensory, coordination or reflex abnormality)
  - Presence of bruise, swelling or laceration >5 cm if <1 year old
- *Mechanism*
  - High-speed road traffic accident either as pedestrian, cyclist or occupant (defined as accident with speed >40 m/h)
  - Fall of >3 m in height
  - High-speed injury from a projectile or an object

If none of the above variables are present, the patient is at low risk of intracranial pathology.

- 14 different criteria requiring CT
- Sensitivity of 98%
- Likely increases the rate of CT
- Many identified that do not require intervention

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- Multicenter, 10 Canadian institutions
- Inclusion:
  - Blunt minor head injury
  - GCS $\geq$ 13
  - Within 24 hours
- Exclusion:
  - Penetrating, depressed fx, acute neurologic deficits, chronic developmental delay, Suspicion of NAT, return visit, pregnancy

- Primary outcomes:
  - Death
  - NS procedure
  - ETT for head injury
- Secondary outcome:
  - TBI on CT
- 3866 enrolled
- 52.8% received CTs
- 4.1% had TBI on CT
- 0.6% required NS

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Box 1: Canadian Assessment of Tomography for Childhood Head injury: the CATCH rule

CT of the head is required only for children with minor head injury* and any one of the following findings:

High risk (need for neurologic intervention)

1. Glasgow Coma Scale score < 15 at two hours after injury
2. Suspected open or depressed skull fracture
3. History of worsening headache
4. Irritability on examination

Medium risk (brain injury on CT scan)

5. Any sign of basal skull fracture (e.g., hemotympanum, "raccoon" eyes, otorrhea or rhinorrhea of the cerebrospinal fluid, Battle's sign)
6. Large, boggy hematoma of the scalp
7. Dangerous mechanism of injury (e.g., motor vehicle crash, fall from elevation ≥ 3 ft [≥ 91 cm] or 5 stairs, fall from bicycle with no helmet)

Note: CT = computed tomography.
*Minor head injury is defined as injury within the past 24 hours associated with witnessed loss of consciousness, definite amnesia, witnessed disorientation, persistent vomiting (more than one episode) or persistent irritability (in a child under two years of age) in a patient with a Glasgow Coma Scale score of 13–15.

- 4 high risk criteria for neurologic intervention
  - 100% sensitivity
- 3 medium risk criteria for TBI on CT
  - 98% sensitivity (high + medium)

- 52% of patients would receive CT
- Most TBI on CT did not require intervention

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Comparisons	CHALICE	CATCH	PECARN
N Enrolled	22,772	3,866	**42,412**
Age	≤ 16 yrs	≤ 16 yrs	**≤ 2 yrs; 2-18 yrs**
Inclusion	All head injury	Symptomatic minor injury, GCS ≥ 13, Injury within 24 hours	**GCS ≤ 14, Injury within 24 hours**
Exclusion	None	Penetrating trauma, obvious depressed fx, neuro deficit, developmental delay, NAT suspicion, return visit, pregnancy	**Trivial mechanisms with only abrasions / lacs, penetrating trauma, known brain tumor, pre-existing neuro d/o, OSH imaging**
Primary Outcome	Death, NS, TBI on CT	Death, NS, ETT; (TBI on CT)	**Identify low risk ciTBI**
Unique CDR Predictors (relative to PECARN)	Amnesia, NAT suspicion, seizure, focal neurologic deficits	No LOC (Vomiting incl in CATCH-2)	-----

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- Each was a derivation study
- PECARN also had a validation arm
- PECARN better discriminates and identifies all patients with ciTBI
- In validation, other studies misclassified some patients with ciTBI as low risk
- PECARN does not increase the rate of neuroimaging

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Accuracy of PECARN, CATCH, and CHALICE head injury decision rules in children: a prospective cohort study

Franz E Babl, Meredith L Borland, Natalie Phillips, Amit Kochar, Sarah Dalton, Mary McCaskill, John A Cheek, Yuri Gilhotra, Jeremy Furyk, Jocelyn Neutze, Mark D Lyttle, Silvia Bressan, Susan Donath, Charlotte Molesworth, Kim Jachno, Brenton Ward, Amanda Williams, Amy Baylis, Louise Crowe, Ed Oakley, Stuart R Dalziel, for the Paediatric Research in Emergency Departments International Collaborative (PREDICT)

Clinical Decision Rule	Validation Sensitivity
PECARN ≤ 2 years	100%
PECARN > 2 years	99%
CATCH	95%
CHALICE	92%

NPV for each CDR was > 99%

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Identification of children at very low risk of clinically-important brain injuries after head trauma: a prospective cohort study

Nathan Kuppermann, James F Holmes, Peter S Dayan, John D Hoyle, Jr, Shireen M Atabaki, Richard Holubkov, Frances M Nadel, David Monroe, Rachel M Stanley, Dominic A Borgialli, Mohamed K Badawy, Jeff E Schunk, Kimberly S Quayle, Prashant Mahajan, Richard Lichenstein, Kathleen A Lillis, Michael G Tunik, Elizabeth S Jacobs, James M Callahan, Marc H Gorelick, Todd F Glass, Lois K Lee, Michael C Bachman, Arthur Cooper, Elizabeth C Powell, Michael J Gerardi, Kraig A Melville, J Paul Muizelaar, David H Wisner, Sally Jo Zuspan, J Michael Dean, Sandra L Wootton-Gorges, for the Pediatric Emergency Care Applied Research Network (PECARN)*

- Previous predictive model limitations
  - Smaller sample sizes
  - Lack of validation
  - No independent assessment of preverbal children (≤ 2 years)
- Aim: Identify children at low risk for ciTBI after blunt head injury
  - CT may therefore be unnecessary
- Pediatric Emergency Care Applied Research Network (PECARN)
  - 25 multicenter sites
  - Prospective cohort study

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Identification of children at very low risk of clinically-important brain injuries after head trauma: a prospective cohort study

*Nathan Kuppermann, James F Holmes, Peter S Dayan, John D Hoyle, Jr, Shireen M Atabaki, Richard Holubkov, Frances M Nadel, David Monroe, Rachel M Stanley, Dominic A Borgialli, Mohamed K Badawy, Jeff E Schunk, Kimberly S Quayle, Prashant Mahajan, Richard Lichenstein, Kathleen A Lillis, Michael G Tunik, Elizabeth S Jacobs, James M Callahan, Marc H Gorelick, Todd F Glass, Lois K Lee, Michael C Bachman, Arthur Cooper, Elizabeth C Powell, Michael J Gerardi, Kraig A Melville, J Paul Muizelaar, David H Wisner, Sally Jo Zuspan, J Michael Dean, Sandra L Wootton-Gorges, for the Pediatric Emergency Care Applied Research Network (PECARN)**

- Inclusion
  - 0 to ≤2 years; 2 to ≤18 years
  - Head injury within 24 hours
  - GCS ≥ 14
- Exclusion
  - Trivial asymptomatic injury
    - Abrasions, lacerations
  - Penetrating trauma
  - Known brain tumor
  - Pre-existing neurologic deficit
  - OSH neuroimaging

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Panel 1: Case report form

Mechanism of injury

- Occupant in motor vehicle crash (with documentation of ejection, rollover, death of other passenger, speed, restraint use)
- Pedestrian struck by vehicle
- Bicycle rider struck by automobile (with documentation of helmet use)
- Bicycle collision or fall (with documentation of helmet use)
- Other wheeled transport crash (with documentation if motorised or not)
- Fall to ground from standing, walking, or running
- Walked or ran into stationary object
- Fall from height (with estimated height)
- Fall down stairs (with number of stairs)
- Sport-related (with documentation of sport type, helmet use)
- Assault
- Head struck by object (unintentional)
- Other mechanism of injury

Clinical variables: history and symptoms

- Post-traumatic amnesia: inability to recall entire traumatic event
- History of loss of consciousness: a period of unconsciousness, categorised by duration (<5 s, 5–60 s, 1–5 min, and >5 min)
- Post-traumatic seizure: tonic and/or clonic jerking activity occurring after the traumatic event, categorised as occurring within or after 30 min of the injury, with duration categorised
- Headache : categorised as currently present or not, severity (mild [barely noticeable], moderate, or severe [intense]), location of headache, and timing of onset
- Vomiting: classified according to the presence or absence of a history of vomiting, number of episodes (once, twice, or more than two episodes), and when vomiting started
- Dizziness: any sensation of vertigo, sense of physical imbalance, or postural instability while in the emergency department
- Parental report of whether the patient is acting normally: whether patient is at baseline or not

(Continues on next column)

(Continued from previous column)

Clinical variables: physical examination findings

- GCS score: applied to patients older than 2 years of age[13]
- Paediatric GCS score: applied to children aged 2 years or younger[14]
- Other signs of altered mental status: defined by agitation, somnolence, repetitive questioning, or slow response to verbal communication
- Bulging anterior fontanelle: if fontanelle open
- Signs of basilar skull fracture: such as retro-auricular bruising (Battle's sign), periorbital bruising (raccoon eyes), haemotympanum, cerebral spinal fluid otorrhoea, or cerebral spinal fluid rhinorrhoea
- Palpable skull fracture: on digital inspection, or unclear on the basis of swelling or distortion of the scalp
- Scalp haematoma: swelling of the scalp (including the forehead),
  recorded by size as small (barely palpable <1 cm), medium (1–3 cm) or large (>3 cm), by location (frontal, temporal–parietal, or occipital), and by character (boggy or firm)
- Neurological deficits: any abnormality of the cranial nerves, motor or sensory examinations, or deep tendon reflexes
- Suspected alcohol or drug intoxication

Other information collected on case report form

- Any signs of trauma above the clavicles (and location): including lacerations, abrasions, and haematomas
- Presence of other substantial (non-cranial) trauma: fractures, intra-abdominal injuries, intrathoracic injuries, or lacerations requiring operating-room repair*
- Was the patient observed in the emergency department after initial evaluation to decide whether to obtain CT?
- Indications for CT scan (if CT obtained)
- Disposition: home, general ward, intensive care unit, operating room, death

*Isolated head trauma is defined by the absence of any of these factors.

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- Primary Outcome Measure
  - Identifying those at low risk for ciTBI

***Panel 2:* Traumatic brain injury outcome definitions**

Clinically-important traumatic brain injury (ciTBI)

Defined by any of the following descriptions:

- Death from traumatic brain injury
- Neurosurgical intervention for traumatic brain injury
  - Intracranial pressure monitoring
  - Elevation of depressed skull fracture
  - Ventriculostomy
  - Haematoma evacuation
  - Lobectomy
  - Tissue debridement
  - Dura repair
  - Other
- Intubation of more than 24 h for traumatic brain injury*
- Hospital admission of 2 nights or more for the traumatic brain injury in association with traumatic brain injury on CT†
  - Hospital admission for traumatic brain injury defined by admission for persistent neurological symptoms or signs such as persistent alteration in mental status, recurrent emesis due to head injury, persistent severe headache, or ongoing seizure management

Traumatic brain injury on CT

Defined by any of the following descriptions:

- Intracranial haemorrhage or contusion
- Cerebral oedema
- Traumatic infarction
- Diffuse axonal injury
- Shearing injury
- Sigmoid sinus thrombosis
- Midline shift of intracranial contents or signs of brain herniation
- Diastasis of the skull
- Pneumocephalus
- Skull fracture depressed by at least the width of the table of the skull‡

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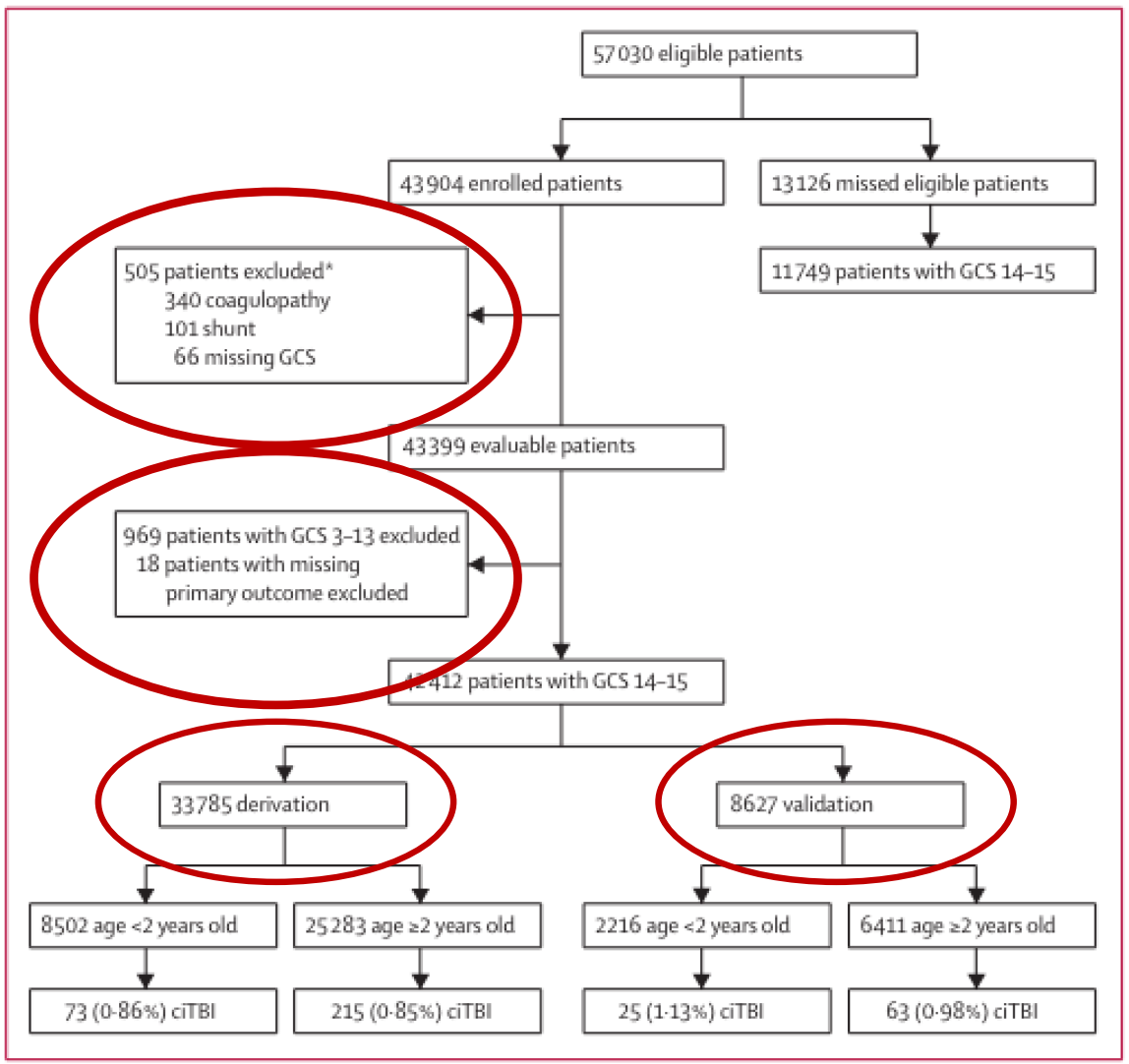

Figure 1: **Flow chart**
GCS=Glasgow Coma Scale. ciTBI=clinically-important traumatic brain injury. *Two patients had more than one exclusion.

- 42,412 enrolled
  - Received CT: 35.3%
  - TBI on CT: 5.2%
  - ciTBI: 0.9%
  - NS intervention: 0.14%

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	ciTBI (n=98)	No ciTBI (n=10 620)	Difference
Severity of injury mechanism			
Mild	4/92, 4·3% (1·2 to 10·8)	1567/10 518, 14·9% (14·2 to 15·6)	−10·6% (−14·8 to −6·3)
Moderate	42/92, 45·7% (35·2 to 56·4)	6658/10 518, 63·3% (62·4 to 64·2)	−17·6% (−27·9 to −7·4)
Severe	46/92, 50·0% (39·4 to 60·6)	2293/10 518, 21·8% (21·0 to 22·6)	28·2% (18·0 to 38·4)
History of LOC			
Known or suspected	20/80, 25·0% (16·0 to 35·9)	521/10 218, 5·1% (4·7 to 5·5)	19·9% (10·4 to 29·4)
LOC duration			
No LOC	60/77, 77·9% (67·0 to 86·6)	9697/10 138, 95·7% (95·2 to 96·0)	−17·7% (−27·0 to −8·5)
<5 s	2/77, 2·6% (0·3 to 9·1)	79/10 138, 0·8% (0·6 to 1·0)	1·8% (−1·7 to 5·4)
5–60 s	8/77, 10·4% (4·6 to 19·5)	211/10 138, 2·1% (1·8 to 2·4)	8·3% (1·5 to 15·1)
1–5 min	4/77, 5·2% (1·4 to 12·8)	99/10 138, 1·0% (0·8 to 1·2)	4·2% (−0·7 to 9·2)
>5 min	3/77, 3·9% (0·8 to 11·0)	52/10 138, 0·5% (0·4 to 0·7)	3·4% (−0·9 to 7·7)
Acting abnormally according to parent	38/82, 46·3% (35·3 to 57·7)	1401/10 212, 13·7% (13·1 to 14·4)	32·6% (21·8 to 43·4)
GCS score			
14	33/98, 33·7% (24·4 to 43·9)	425/10 620, 4·0% (3·6 to 4·4)	29·7% (20·3 to 39·0)
15	65/98, 66·3% (56·1 to 75·6)	10 195/10 620, 96·0% (95·6 to 96·4)	−29·7% (−39·0 to −20·3)
Altered mental status*	50/97, 51·5% (41·2 to 61·8)	1160/10 552, 11·0% (10·4 to 11·6)	40·6% (30·6 to 50·5)
Palpable skull fracture (or unclear exam)	34/98, 34·7% (25·4 to 45·0)	334/10 600, 3·2% (2·8 to 3·5)	31·5% (22·1 to 41·0)
Scalp haematoma	64/97, 66·0% (55·7 to 75·5)	4849/10 582, 44·8% (43·1 to 45·8)	22·0% (12·5 to 31·4)
Location of scalp haematoma			
No haematoma	33/97, 34·0% (24·7 to 44·3)	5913/10 511, 56·3% (55·3 to 57·2)	−22·2% (−31·7 to −12·8)
Frontal	7/97, 7·2% (2·8 to 14·3)	396/10 511, 3·8% (3·5 to 4·1)	3·4% (−2·6 to 9·5)
Temporal or parietal	47/97, 48·5% (38·2 to 58·8)	1012/10 511, 9·6% (9·1 to 10·2)	38·8% (28·9 to 48·8)
Occipital	10/97, 10·3% (5·1 to 18·1)	624/10 511, 5·9% (5·5 to 6·4)	4·4% (−1·7 to 10·4)

Data are n/N, percentage (95% CI). ciTBI=clinically-important traumatic brain injury. LOC=loss of consciousness. GCS=Glasgow Coma Scale. *Defined as GCS=14 or: agitation, somnolence, repetitive questioning, or slow response to verbal communication.

Table 2: **Bivariable analysis of tree predictor variables of ciTBI for children younger than 2 years**

	ciTBI (n=278)	No ciTBI (n=31416)	Difference
Severity of injury mechanism			
Mild	17/275, 6·2% (3·6 to 9·7)	5518/31 214, 17·7% (17·3 to 18·1)	−11·5% (−14·4 to −8·6)
Moderate	155/275, 56·4% (50·3 to 62·3)	21 875/31 214, 70·1% (69·6 to 70·6)	−13·7% (−19·6 to −7·8)
Severe	103/275, 37·5% (31·7 to 43·5)	3821/31 214, 12·2% (11·9 to 12·6)	25·2% (19·5 to 30·9)
History of LOC			
Known or suspected	139/241, 57·7% (51·2 to 64·0)	5606/30 154, 18·6% (18·1 to 19·0)	39·1% (32·8 to 45·3)
LOC duration			
No LOC	102/161, 63·4% (55·4 to 70·8)	24 548/28 034, 87·6% (87·2 to 88·0)	−24·2% (−31·7 to −16·7)
<5 s	7/161, 4·3% (1·8 to 8·8)	819/28 034, 2·9% (2·7 to 3·1)	1·4% (−1·7 to 4·6)
5–60 s	21/161, 13·0% (8·3 to 19·2)	1582/28 034, 5·6% (5·4 to 5·9)	7·4% (2·2 to 12·6)
1–5 min	26/161, 16·1% (10·8 to 22·8)	936/28 034, 3·3% (3·1 to 3·6)	12·8% (7·1 to 18·5)
>5 min	5/161, 3·1% (1·0 to 7·1)	149/28 034, 0·5% (0·4 to 0·6)	2·6% (−0·1 to 5·3)
Headache	163/222, 73·4% (67·1 to 79·1)	12 512/27 273, 45·9% (45·3 to 46·5)	27·5% (21·7 to 33·4)
Severity of headache			
No headache	59/189, 31·2% (24·7 to 38·4)	14 761/26 305, 56·1% (55·5 to 56·7)	−24·9% (−31·5 to −18·3)
Mild	25/189, 13·2% (8·7 to 18·9)	5223/26 305, 19·9% (19·4 to 20·3)	−6·6% (−11·5 to −1·8)
Moderate	81/189, 42·9% (35·7 to 50·2)	5541/26 305, 21·1% (20·6 to 21·6)	21·8% (14·7 to 28·9)
Severe	24/189, 12·7% (8·3 to 18·3)	780/26 305, 3·0% (2·8 to 3·3)	9·7% (5·0 to 14·5)
History of vomiting	97/273, 35·5% (29·9 to 41·5)	3895/31 203, 12·5% (12·1 to 12·9)	23·1% (17·4 to 28·7)
Number of vomiting episodes			
0	176/266, 66·2% (60·1 to 71·8)	27 308/31 026, 88·0% (87·6 to 88·4)	−21·9% (−27·6 to −16·2)
1	40/266, 15·0% (11·0 to 19·9)	1372/31 026, 4·4% (4·2 to 4·7)	10·6% (6·3 to 14·9)
2	13/266, 4·9% (2·6 to 8·2)	787/31 026, 2·5% (2·4 to 2·7)	2·4% (−0·3 to 5·0)
>2	37/266, 13·9% (10·0 to 18·7)	1559/31 026, 5·0% (4·8 to 5·3)	8·9% (4·7 to 13·1)
GCS score			
14	74/278, 26·6% (21·5 to 32·2)	809/31 416, 2·6% (2·4 to 2·8)	24·0% (18·9 to 29·2)
15	204/278, 73·4% (67·8 to 78·5)	30 607/31 416, 97·4% (97·2 to 97·6)	−24·0% (−29·2 to −18·9)
Altered mental status*	174/278, 62·6% (56·6 to 68·3)	4103/31 169, 13·2% (12·8 to 13·5)	49·4% (43·7 to 55·1)
Signs of basilar skull fracture	37/275, 13·5% (9·6 to 18·1)	193/31 121, 0·6% (0·5 to 0·7)	12·8% (8·8 to 16·9)

Data are n/N, percentage (95% CI). ciTBI=clinically-important traumatic brain injury. LOC=loss of consciousness. GCS=Glasgow Coma Scale. *Defined as GCS=14 or: agitation, somnolence, repetitive questioning, or slow response to verbal communication.

Table 3: **Bivariable analysis of tree predictor variables of ciTBI for children aged 2 years and olde**

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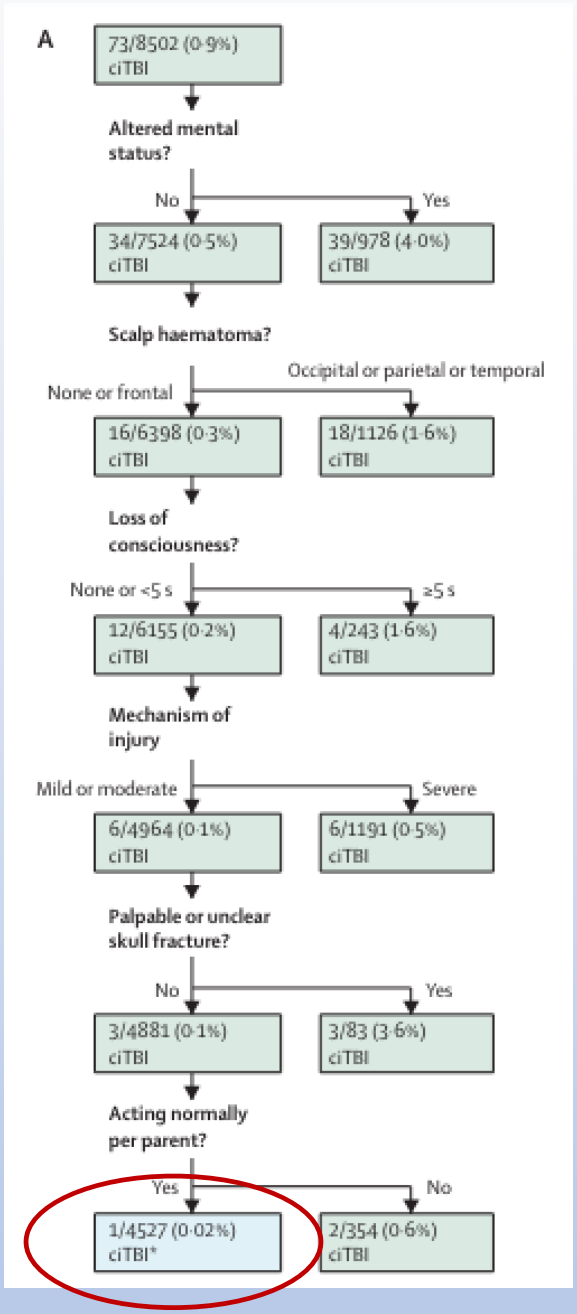

Prediction tree for ciTBI
In children younger than 2 years

	Derivation			Validation		
	ciTBI	No ciTBI	Total	ciTBI	No ciTBI	Total
Any predictor present	72	3903	3975	25	1016	1041
No predictor present	1	4526	4527	0	1175	1175
Total	**73**	**8429**	**8502**	**25**	**2191**	**2216**

	Derivation	Validation
Prediction rule sensitivity (95% CI)	98·6% (92·6–99·97)	100·00% (86·3–100·00)
Prediction rule specificity (95% CI)	53·7% (52·6–54·8)	53·6% (51·5–55·7)
Negative predictive value (95% CI)	99·9% (99·88–99·999)	100·00% (99·7–100·00)
Positive predictive value (95% CI)	1·8% (1·4–2·3)	2·4% (1·6–3·5)
Negative likelihood ratio (95% CI)	0·03 (0·001–0·14)	0·0 (0–0·26)

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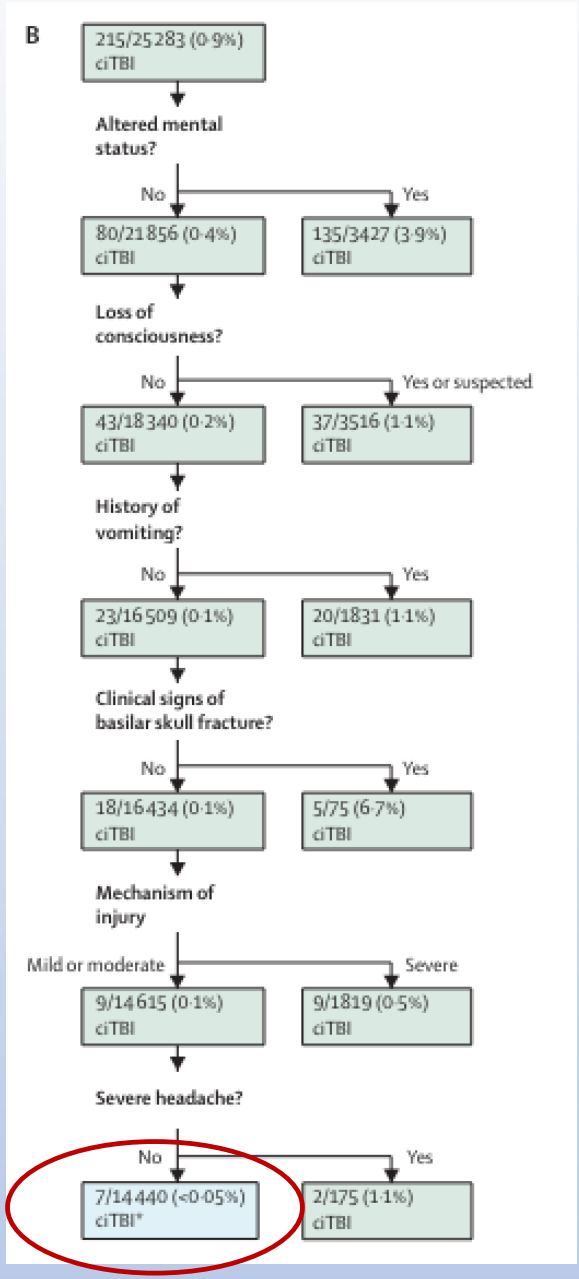

Prediction tree for ciTBI
In children 2 years and older

	Derivation			Validation		
	ciTBI	No ciTBI	Total	ciTBI	No ciTBI	Total
Any predictor present	208	10635	10843	61	2652	2713
No predictor present	7	14433	14440	2	3696	3698
Total	**215**	**25068**	**25283**	**63**	**6348**	**6411**

	Derivation	Validation
Prediction rule sensitivity (95% CI)	96·7% (93·4–98·7)	96·8% (89·0–99·6)
Prediction rule specificity (95% CI)	57·6% (57·0–58·2)	58·2% (57·0–59·4)
Negative predictive value (95% CI)	99·95% (99·9–99·98)	99·95% (99·80–99·99)
Positive predictive value (95% CI)	1·9% (1·7–2·2)	2·2% (1·7–2·9)
Negative likelihood ratio (95% CI)	0·06 (0·03–0·12)	0·05 (0·01–0·19)

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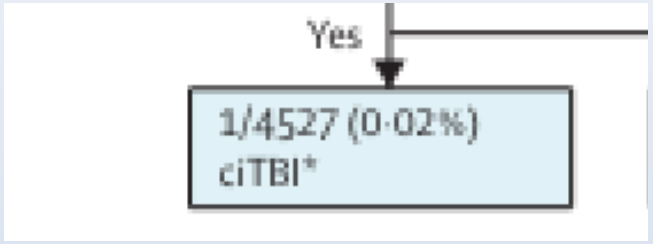

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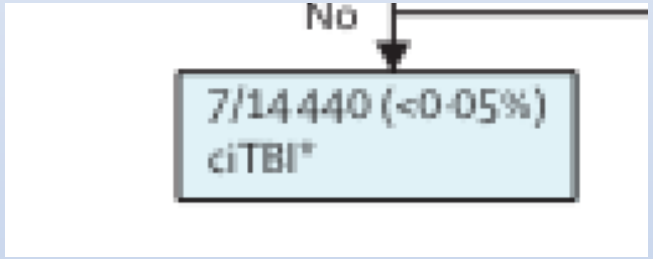

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- The risk of ciTBI when all 6 predictors are absent is less than the risk of lethal malignancy from cranial CT

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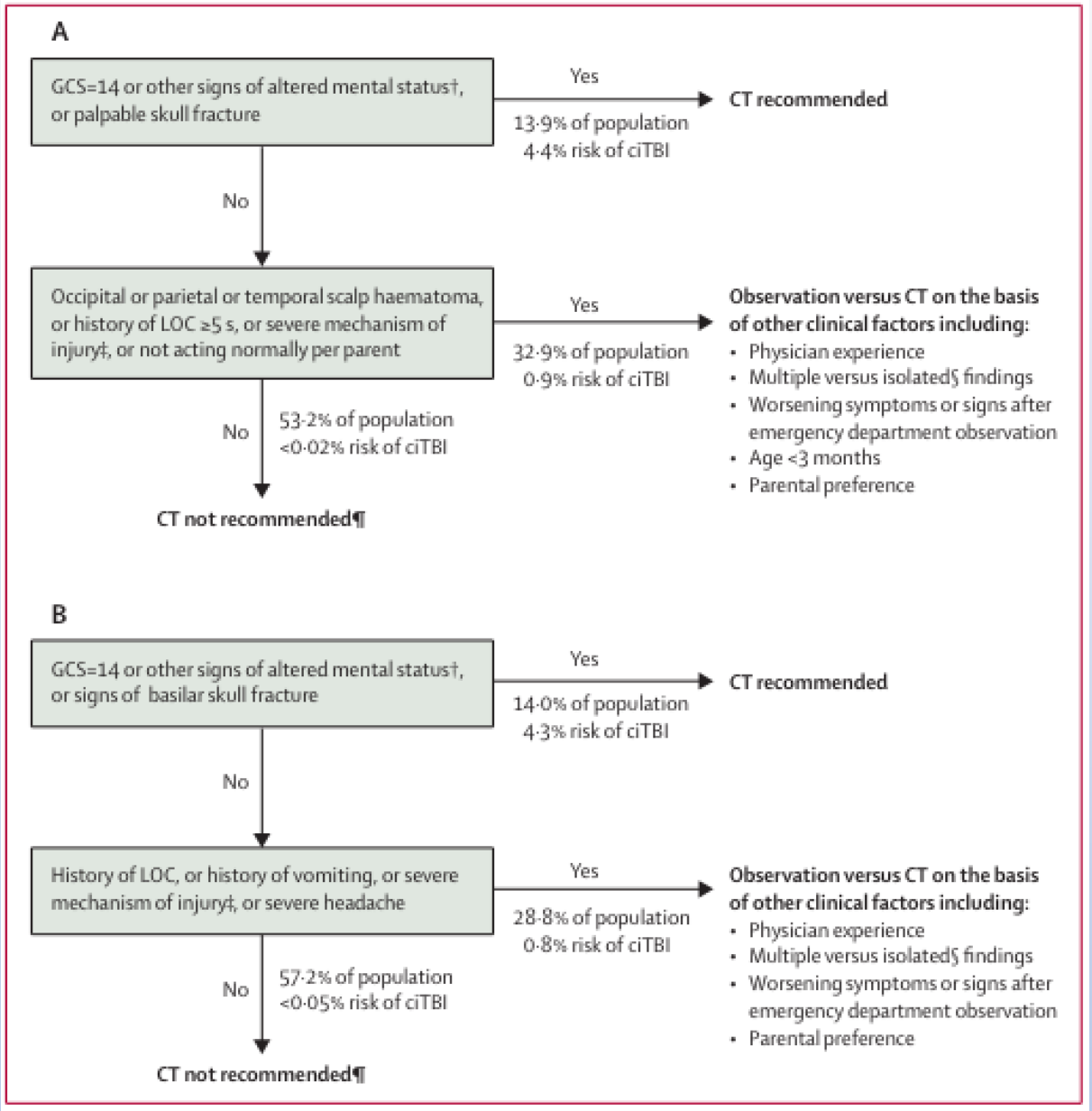

- 14% of patients should get CT
  - 4.3-4.4% risk of ciTBI
- 56% should not
  - <0.02-0.05% risk of ciTBI
- 30% favor observation over imaging
  - 0.8-0.9% risk of ciTBI
  - Observation of 4-6 hours

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Observation over immediate imaging

- Consider
  - Clinical experience
  - Isolated vs multiple findings
  - Age (< 3 months)
  - Parental preference
  - Clinical worsening during observation period

- PECARN Observation Factors
  - Severe mechanism
  - LOC
  - Severe headache
  - Vomiting
  - Acting abnormal
  - Scalp hematoma*

- Other CDR factors
  - Amnesia
  - Seizure*
  - Increased anterior fontanelle**
  - Neurologic deficits**

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The Infant Scalp Score: A Validated Tool to Stratify Risk of Traumatic Brain Injury in Infants With Isolated Scalp Hematoma

Sara A. Schutzman, MD[1,2], Lise E. Nigrovic, MD, MPH[1,2], and Rebekah Mannix, MD, MPH[1,2]

Risk Points	Patient Age, mo	Hematoma Size	Hematoma Location
0	≥12	None	Frontal
1	6–11	Small (barely palpable)	Occipital
2	3–5	Medium (easily palpable)	Temporal/parietal
3	0–2	Large (very easily palpable)	

- PECARN database
- Patients < 1 year
- Score ≥ 4
  - 100% sensitivity for ciTBI (n=12)
  - 100% sensitivity for TBI (n=59)
- Score ≥ 5
  - 100% sensitivity for ciTBI
  - Missed 3 TBI (no NS intervention)

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Prevalence of Brain Injuries and Recurrence of Seizures in Children With Posttraumatic Seizures

Mohamed K. Badawy, MD, Peter S. Dayan, MD, MSc, Michael G. Tunik, MD, Frances M. Nadel, MD, Kathleen A. Lillis, MD, Michelle Miskin, MS, Dominic A. Borgialli, DO, MPH, Michael C. Bachman, MD, Shireen M. Atabaki, MD, MPH, John D. Hoyle, Jr., MD, James F. Holmes, MD, MPH, Nathan Kuppermann, MD, MPH, for the Pediatric Emergency Care Applied Research Network (PECARN)

- PECARN database
  - Post-traumatic sz (PTS): 536
  - CT obtained: 466

- TBI on CT in 15.5%
- 20 required NS
- 15 had recurrence of sz

- Conclusion
  - PTS have a high likelihood of TBI on CT
  - PTS frequently require NS intervention
  - PTS frequently have recurrence

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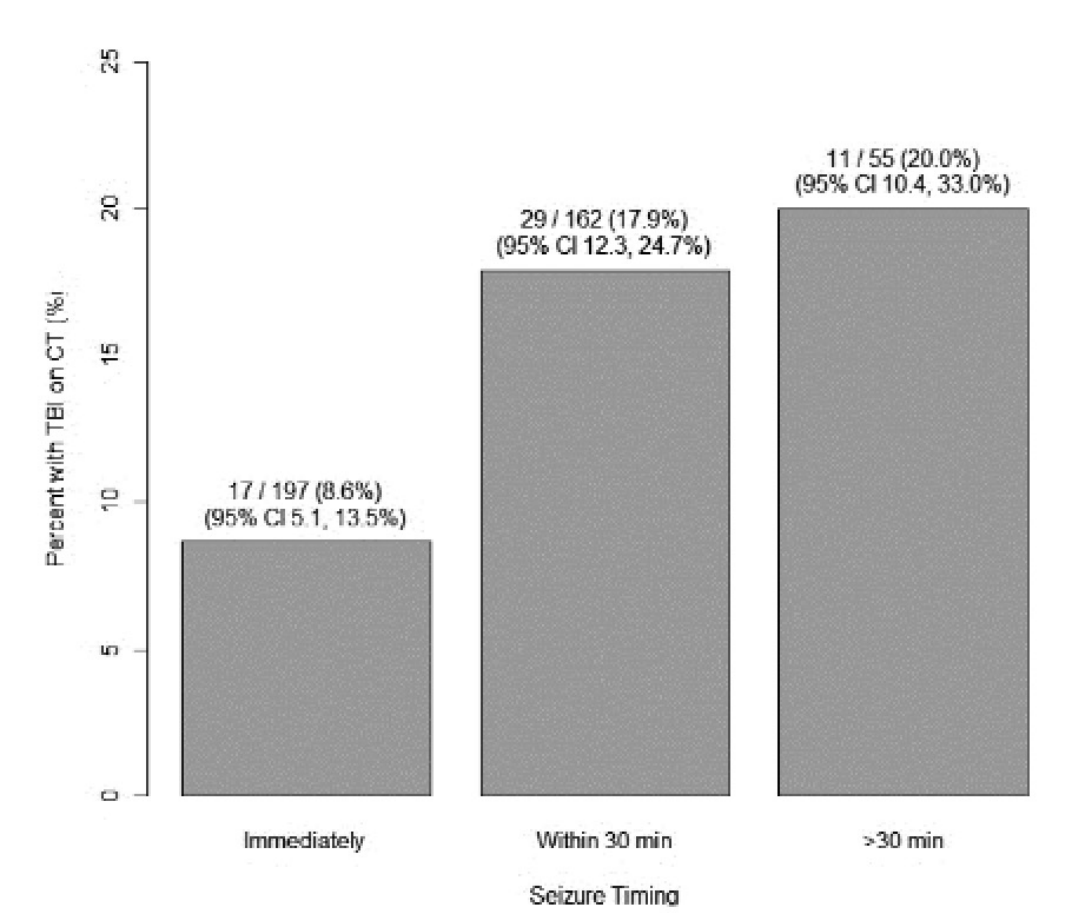

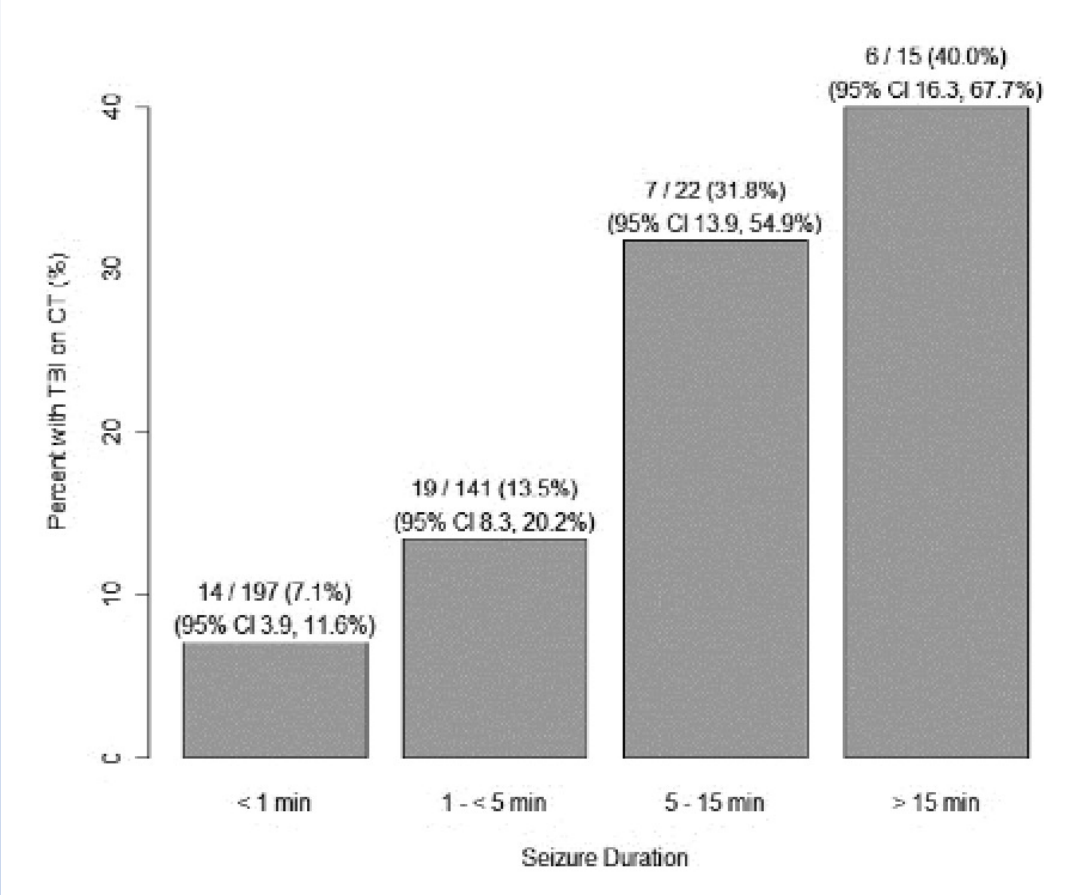

TBI had a statistically significant association with PTS interval after trauma and duration

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TBI and ciTBI

- Diffuse brain injury
  - Most common cause of TBI death
  - Impact, acceleration, and deceleration forces
  - Mild = concussion
  - Severe = Diffuse axonal injury
    - Tissue shearing at grey-white matter interface
- Focal brain injury
  - Contusion
  - Intraparenchymal hemorrhage
  - Subdural hematoma*
  - Epidural hematoma*
  - Subarachnoid hemorrhage

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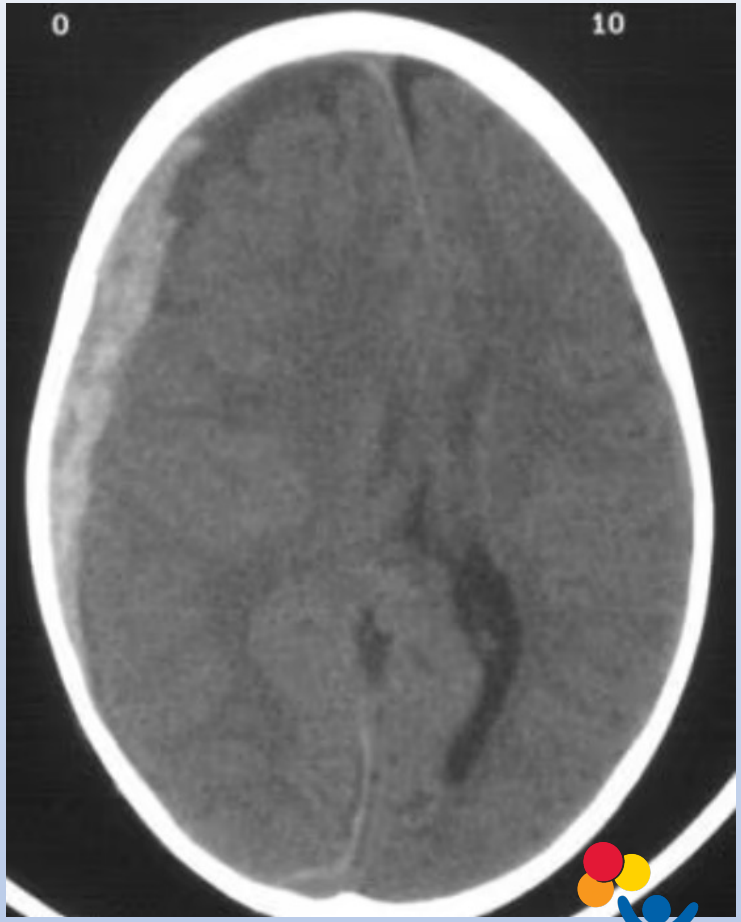
Subdural Hematomas

- Potential space between dura and arachnoid membranes
- Bridging blood vessels + direct cerebral cortical hemorrhage
- NAT accounts for the majority of SDH in infants
- Classically crescent shaped (crosses suture margins)



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Indications for NS intervention

- No clear criteria
- Variable presentations – may be hours to weeks after injury
- Risk of marked change when acute
  - Admit for observation
  - Possible reimaging
- Surgical evacuation
  - Acute SDH
  - Neurologic impairment
  - Midline shift

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Epidural Hematomas

- Dura is stripped from the bone
- Disrupted arteries and veins
- Fractures can lacerate vessels
- Temporoparietal is most common location
  - Middle meningeal artery
- Generally does not cross suture lines
- Classically appears biconvex and displaces brain tissue

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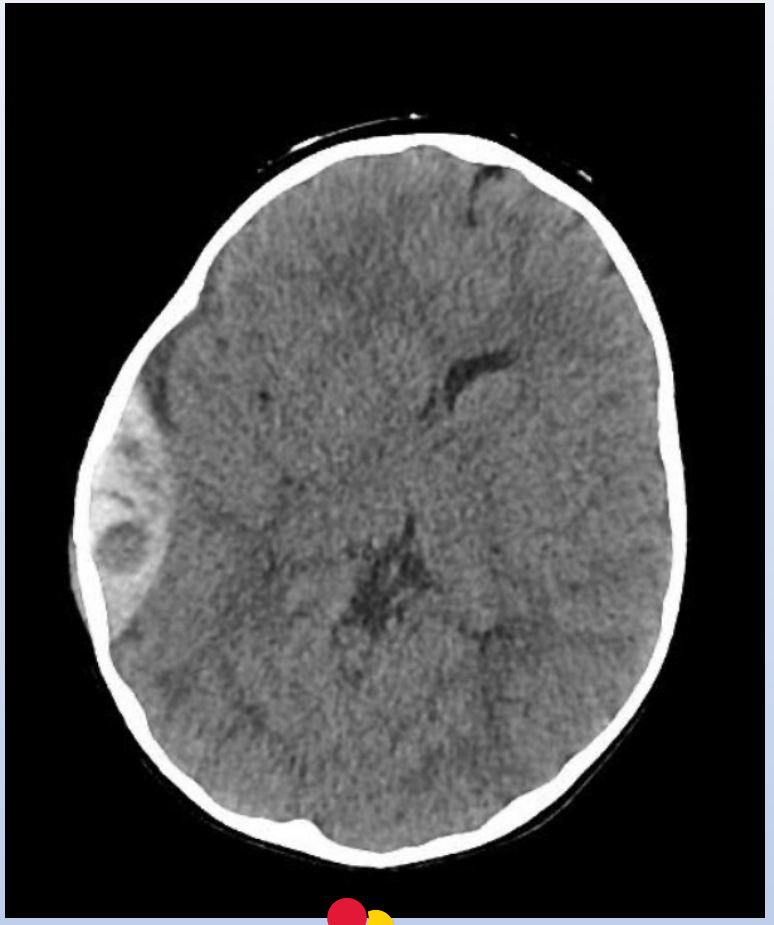
Indications for NS intervention

- Mass effect
  - Midline shift, gyral effacement, ventricle compression
  - Cerebral edema, herniation
  - Hydrocephalus (posterior fossa EDH)
- Swirl sign
  - Active bleeding, rapidly expanding
- Temporal lobe location
  - Higher incidence of brainstem compression
- Large size
  - Thickness > 10mm, volume > 15 mL
  - Though may observe if asymptomatic



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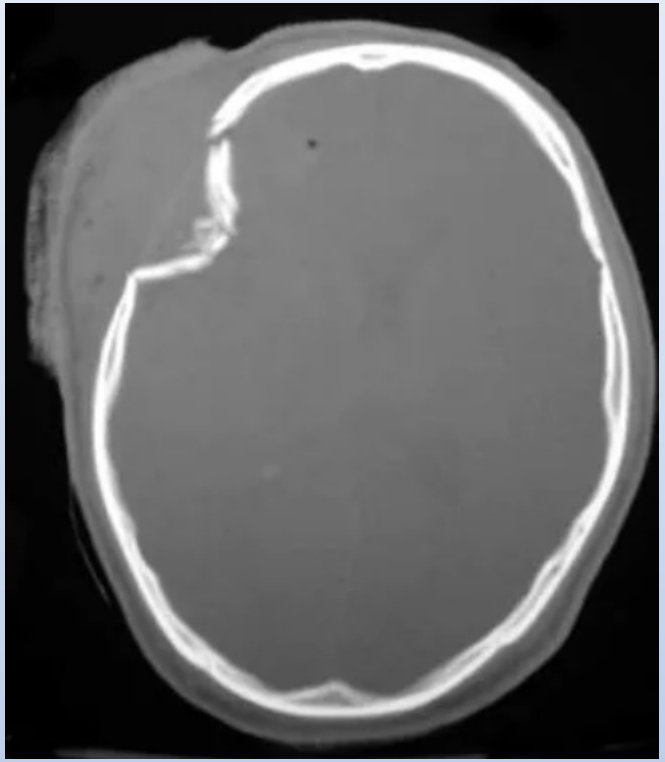
Skull Fractures

- Linear
  - 15-30% are associated with TBI on CT
- Comminuted
- Depressed
  - 30% associated with TBI
- Basilar
  - Significant adverse outcomes
  - Exam:
    - Hemotympanum
    - Raccoon eyes, Battle sign
    - CSF otorrhea, CSF rhinorrhea
    - CN defects



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Possible Indications for NS Intervention

- Linear fracture with > 3mm separation
- Basilar
  - Neurologic deficits
  - CSF leak
  - Symptomatic pneumocephalus
- Depressed
  - Nonoperative when no associated hematoma and when minimally displaced
  - Younger have great ability to heal non-operatively

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Take Home Points

- Understand ciTBI vs TBI
- PECARN screens very well for low-risk ciTBI
- Implement observation
  - Significant reduction in the use of ionizing radiation
- Most minor pediatric head injury does not need imaging
  - ciTBI is rare
  - NS intervention is very rare

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