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


Summary
Background CT imaging of head-injured children has risks of radiation-induced malignancy. Our aim was to identify children at very low risk of clinically-important traumatic brain injuries (ciTBI) for whom CT might be unnecessary.

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

Findings We enrolled and analysed 42 412 children (derivation and validation populations: 8502 and 2216 younger than 2 years, and 25 283 and 6411 aged 2 years and older). We obtained CT scans on 14 969 (35·3%); ciTBIs occurred in 376 (0·9%), and 60 (0·1%) underwent neurosurgery. In the validation population, the prediction rule for children younger than 2 years (normal mental status, no scalp haematoma except frontal, no loss of consciousness or loss of consciousness for less than 5 s, non-severe injury mechanism, no palpable skull fracture, and acting normally according to the parents) had a negative predictive value for ciTBI of 1176/1176 (100·0%, 95% CI 99·7–100·0) and 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. The prediction rule for children aged 2 years and older (normal mental status, no loss of consciousness or loss of consciousness for less than 5 s, non-severe injury mechanism, no signs of basilar skull fracture, and no severe headache) had a negative predictive value of 3798/3800 (99·95%, 99·81–99·99) and 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. Neither rule missed neurosurgery in validation populations.

Interpretation These validated prediction rules identified children at very low risk of ciTBIs for whom CT can routinely be obviated.

Introduction Traumatic brain injury is a leading cause of death and disability in children worldwide. In the USA, head trauma in individuals aged 18 years and younger results in about 7400 deaths, over 60 000 hospital admissions, and over 600 000 emergency department visits every year.11 Children with clinically-important traumatic brain injury (ciTBI) needing acute intervention, especially neurosurgery, should be identified rapidly. CT is the reference standard for emergently diagnosing traumatic brain injuries, although some brain injuries are not seen on CT.12 About 50% of children assessed in North American emergency departments for head trauma undergo CT.13,14 (Paul M, Centers for Disease Control and Prevention, personal communication). Between 1995 and 2005, CT use more than doubled.15 Furthermore, many traumatic brain injuries identified on CT do not need acute intervention, and some are false positives or non-traumatic findings. Clinical studies using abnormal CT findings as the outcome measure for identifying children with traumatic brain injuries might promote excessive CT use. Children with apparently minor head trauma (Glasgow Coma Scale [GCS] scores of 14–15) are the group most frequently assessed. These children commonly undergo neuroimaging and account for 40–60% of those with traumatic brain injuries seen on CT.16,17 Less than 10% of CT scans in children with minor head trauma, however, show traumatic brain injuries. Furthermore, injuries needing neurosurgery are very uncommon in children with GCS scores of 14–15.18,19 Reduction of CT use is important because ionising radiation from CT scans can cause lethal malignancies.20,21 The estimated rate of lethal malignancies from CT is between 1 in 1000 and 1 in 5000 paediatric cranial CT
CTs in those younger than 2 years and 20% of CTs in those aged 2 years and older.

Data to guide clinical decision making for children with head trauma are urgently needed because head trauma is common and CT use is increasing.42–44 Children sustaining minor head trauma infrequently have traumatic brain injuries and rarely need neurosurgery. The small risk of ciTBI after minor head trauma should be balanced against the risks of ionising radiation of CT.45–47 Improved methods to assess head-injured children and evidence-based use of CT are research priorities.48–50 CT scans are the source of two-thirds of the collective radiation from diagnostic imaging,51 and an estimated one million children every year in the USA are unnecessarily imaged with CT.52

Many of the predictors identified in our rules have been studied previously with conflicting results, and variables identified as predictors of traumatic brain injuries in some studies were not predictive in others.53–56,37–40 These conflicting results are partly attributable to insufficiently large sample sizes to produce precise risk estimates. Additionally, the lack of validation studies compromises the generalisability of previous rules. The current study is very large, allowing sufficient statistical power to generate robust and generalisable rules. Their accuracy was confirmed by validation populations. Furthermore, as recommended by the investigators of a recent systematic review of paediatric head CT prediction rules,37 we validated the rules in a diverse population, and derived and validated a separate rule for preverbal children (<2 years of age).

Another important feature of our analysis is that we excluded children with GCS scores of less than 14, in whom the risk of traumatic brain injury on CT is more than 20%.53–56,37–40 “This substantial risk outweighs the radiation risk from CT, and therefore CT use in this group is not controversial. Inclusion of these patients with low GCS scores artificially increases rule performance. Similarly, our study also excluded asymptomatic children with very-low-risk injury mechanisms, to avoid overinflating the negative predictive value.

CT is the reference standard for rapid detection of traumatic brain injuries, but might also identify minor or unrelated findings irrelevant for acute management. Definitions of ciTBIs in children have not been agreed upon, although some previous prediction studies have excluded minor CT findings.8,19 Conversely, CT imaging might miss some injuries identifiable by other modalities.14 and children might need hospital admission for traumatic brain injury despite normal CT scans.19 In our study, we used a patient-oriented composite outcome measure, which included both CT results and clinical outcomes. The use of a patient-oriented outcome overrides the imperfect sensitivity and specificity of CT for identifying traumatic brain injuries, and allows minor and incidental CT findings to be ignored.

Children younger than 2 years are the most sensitive to radiation, increasing the importance of CT reduction. Clinicians’ confidence in assessing very young patients is also usually lower than for older patients, especially outside of children’s hospitals. Furthermore, centres participating in this study were mainly paediatric hospitals with rates of CT use substantially lower than those in non-children’s hospitals.37 The potential reduction in CT use by application of these prediction rules could therefore be greater in general hospitals, where most children seeking emergency care in the USA are assessed.38

We identified a large group of children in whom CT can be avoided. Although the overall rate of CT use in this study was lower than that of the US national average,39 application of the prediction rules might nonetheless result in substantial reduction of CT use in centres similar to those participating in our study. The extent of this reduction is unclear, however, as not all children outside
10 of kids @ low risk of brain injuries

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Lanet

minor head injury → CT? So what's the problem? $ sedate $ false positives

lethal causes: 1 in 1000-5000

42,442 kids < 2y

NPV = 100%
Sens = 100%

≥ 2y

NPV = 99%
Sens = 96.8%

Excluded:

trivial injuries
severe injuries
comorbid conditions

End Points:

death in ED
nhs hosp 22 days

GCS≤14 or other signs of altered mental status, or palpable skull fracture

CT recommended

<2y

Not frontal hematomas

Observation vs. CT on the basis of other clinical factors including:

- Physician experience
- Multiple versus isolated findings
- Worsening symptoms or signs after ED observation
- Age < 3 months
- Parental preference

3.3% of population 4-5% risk of CTB

1 in 23

CT not recommended

GCS≤14 or other signs of altered mental status, or palpable skull fracture

Observation vs. CT on the basis of other clinical factors including:

- Physician experience
- Multiple versus isolated findings
- Worsening symptoms or signs after ED observation
- Age < 3 months
- Parental preference

16.6% of population 4-5% risk of CTB

1 in 24

CT recommended

>2y

History of LOC, or history of vomiting, or severe mechanism of injury, or severe headache

CT not recommended

58.3% of population 6-7% risk of CTB

1 in 2000

CT not recommended

severe

moderate

mechanisms