Should a Head-Injured Child Receive a Head CT Scan? A Systematic Review of Clinical Prediction Rules

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KEY WORDS

systematic review, craniocerebral trauma [MeSH], brain injuries [MeSH], decision-support techniques [MeSH], decision trees [MeSH], clinical prediction rules, clinical decision rules, predictive value of tests [MeSH], human [MeSH], tomography, x-ray computed [MeSH], infant, child, preschool, adolescent

ABBREVIATIONS

CT—computed tomography
ICI—intracranial injury
MeSH—medical subject heading
NPV—negative predictive value
PPV—positive predictive value
GCS—Glasgow coma scale
CI—confidence interval

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abstract

CONTEXT: Given radiation- and sedation-associated risks, there is uncertainty about which children with head trauma should receive cranial computed tomography (CT) scanning. A high-quality and high-performing clinical prediction rule may reduce this uncertainty.

OBJECTIVE: To systematically review the quality and performance of published clinical prediction rules for intracranial injury in children with head injury.

METHODS: Medline and Embase were searched in December 2008. Studies were selected if they included clinical prediction rules involving children aged 0 to 18 years with a history of head injury. Prediction-rule quality was assessed by using 14 previously published items. Prediction-rule performance was evaluated by rule sensitivity and the predicted frequency of CT scanning if the rule was used.

RESULTS: A total of 3357 titles and abstracts were assessed, and 8 clinical prediction rules were identified. For all studies, the rule derivations were reported; no study validated a rule in a separate population or assessed its impact in actual practice. The rules differed considerably in population, predictors, outcomes, methodologic quality, and performance. Five of the rules were applicable to children of all ages and severities of trauma. Two of these were high quality ($\geq$11 of 14 quality items) and had high performance (lower confidence limits for sensitivity $>$0.95 and required $\leq$56% to undergo CT). Four of the 8 rules were applicable to children with minor head injury (Glasgow coma score $\geq$13). One of these had high quality (11 of 14 quality items) and high performance (lower confidence limit for sensitivity = 0.94 and required 13% to undergo CT). Four of the 8 rules were applicable to young children, but none exhibited adequate quality or performance.

CONCLUSIONS: Eight clinical prediction-rule derivation studies were identified. They varied considerably in population, methodologic quality, and performance. Future efforts should be directed toward validating rules with high quality and performance in other populations and deriving a high-quality, high-performance rule for young children. *Pediatrics* 2009;124:e145–e154

Head injuries in children are a common cause for emergency department visits around the world. In North America, head injuries in children occur at an annual rate of 60 to 100 per 100 000 children.[1] Cranial computed tomography (CT) scanning is the diagnostic standard for identifying the presence of intracranial injury (ICI) in children with head injury.[2] It is estimated that 270 000 head CT scans were performed in this population in the United States in 1992, with rates doubling between 1990 and 1999.[3,4] Depending on the setting, 15% to 70% of children who have presented to an emergency department in the United States or Canada with head injury received a CT scan.[5,6] However, results of 70% to 98% of the head CT scans were normal.[5,7–10] Furthermore, there is little consensus about which children with head injury should receive a CT scan, particularly in the setting of minor head injury and for very young children.[6,11–13] Given the potential harm of cranial CT, including the possible need for sedation in young children and lifetime estimated risk of cancer mortality of 1 per 1400 head CT scans, predicting which children can be safely managed without CT scanning is vitally important.[14–16]

Clinical prediction rules are potentially powerful evidence-based tools for reducing uncertainty and improving accuracy in medical decision-making by standardizing the collection and interpretation of clinical data.[17] Their aim is also to minimize the use of potentially harmful diagnostic tests. They have been defined as clinical decision-making tools that quantify the relative importance of 3 or more variables from history, physical examination, or simple tests to provide the probability of an outcome or suggest a single diagnostic or therapeutic course of action for an individual patient.[17–19] They differ from decision analysis, which quantifies the value of specified outcomes and uses data from the literature to formulate health care policy; decision-support tools that are designed to prevent errors when implementing decisions that have already been made; and practice guidelines, which reflect a consensus of expert opinion to address several patient care issues within a particular syndrome.[20]

To meet their objectives and to be routinely incorporated into patient care, clinical prediction rules must be rigorously developed, validated, and implemented. Methodologic standards for the development of clinical prediction rules have been described.[18–22] They include 3 main steps in rule development: creating the rule (derivation); testing the rule (validation); and assessing the impact of the rule on physician behavior and clinical outcomes (impact analysis). Several clinical prediction rules have been rigorously developed and widely validated in the adult literature.[23–25] The incorporation of clinical prediction rules into pediatric patient care is less well established.

The objective of this study was to systematically identify and rigorously evaluate the methodologic quality and performance of existing clinical prediction rules for children with head injury.

METHODS

Inclusion Criteria

Only prospective or retrospective studies that derived, validated, or assessed the impact of a clinical prediction rule were included. A clinical prediction rule was defined as a clinical decision-making tool that:

- includes 3 or more variables obtained from the history, physical examination, or simple diagnostic tests;
- provides the probability of an outcome or suggests a diagnostic or therapeutic course of action for an individual patient; and
- is not a decision analysis, decision-support tool, or practice guideline.

Only studies that involved children (aged 0–18 years) with a history of head injury were included. Studies that involved both adults and children were included if a separate data analysis was performed for the children. Studies that assessed predictors without the obvious intent of creating a clinical decision-making tool were not included.

Search Strategy

We searched Medline, Embase, and the EBM Review up to February 2009. Because there is no medical subject heading (MeSH) that specifies clinical prediction rules, a sophisticated electronic search strategy was developed (see Appendix 1). In addition, the references of identified clinical prediction rules were searched manually. There was no restriction on language.

Selection of Studies

Two reviewers (Drs Maguire and Parkin) independently assessed the inclusion of potentially relevant articles by using a 2-step process. First, the title and abstract from each article identified by the electronic search were assessed for inclusion. Second, publications identified as potentially relevant by title and abstract, or when uncertainty existed, were reviewed manually. When there was discrepancy between the 2 reviewers, studies were discussed and included by consensus. Blinding of journal, institution, and author was not performed. Population characteristics of included studies are shown in Table 1; predictors and outcomes of the studies are outlined in Table 2.

TABLE 1 Population Characteristics of Included Studies

Study	Setting	*n*	Age, y	Age <2 y, %	Type of Injury	GCS: %	CT Performed as Inclusion	Baseline CT Frequency, %	Abnormal CT Results, %	Neurosurgical Intervention, %
Atabaki et al[27] (2008)	4 level 1 pediatric trauma EDs in US	1000	0–21	18.8	Minor head injury	15: 85.2 14: 11.7 13: 3.1	Yes	100	6.5	0.6
Da Dalt et al[28] (2006)	5 level 3 pediatric EDs in northern Italy	3806	0–16	37	Blunt head trauma of any severity	≥14: 98.7 11–13: 0.5 <11: 0.3	No	2	0.6	0.2
Dunning et al[29] (2006)	3 children's EDs, 3 adult teaching EDs, 4 general hospital EDs in England	22 772	0–16	27.3	All head injury	15: 96.6 14: 1.0 13: 0.3 <13: 0.9	No	3	1.2	0.6
Greenes and Schutzman[30] (2001)	1 tertiary care children's ED in US	422	0–2	100	Asymptomatic head injury	NA	No	18	17	0.2
Haydel and Shembekar[31] (2003)	1 level 1 trauma center ED in US	175	5–17	0	Nontrivial minor head injury	15: 100	Yes	100	8	0.6
Oman et al[32] (2006)	21 EDs in US	1666	0–18	12.5	All head injury	15: 6.9	Yes	100	8.3	NA
Palchak et al[33] (2003)	1 pediatric ED in level 1 trauma center in US	2043	0–18	16.5	Nontrivial head injury	≥14: 91	No	62	4.8	1.4
Sun et al[34] (2007)	21 EDs in US	1666	0–18	12.5	All head injury	15: 6.9	Yes	100	8.3	NA

ED indicates emergency department; NA, not applicable.

TABLE 2 Predictors and Outcomes of Included Studies

Study	Predictors	Outcome
Atabaki et al[27] (2008)	GCS <15; mental status change; sensory deficit; dizziness; bicycle injury; age <2 y; skull defect on examination; evidence of skull fracture	ICI on CT scan
Da Dalt et al[28] (2006)	GCS <15; focal neurologic signs; clinical signs of basal skull fracture; palpable scalp depression or scalp hematoma in temporoparietal or occipital areas; LOC >20–30 s; persistent headache; persistent drowsiness; amnesia	ICI on CT scan or Death
Dunning et al[29] (2006)	LOC >5 min; amnesia >5 min; drowsiness; vomiting ≥3 times; suspicion of NAI; seizure after injury; GCS <14 or GCS <15 if <1 y; penetrating or depressed skull injury; suspected or tense fontanel; signs of basal skull fracture; positive focal neurology; bruise, swelling or laceration >5 cm if <1 y; road traffic crash at >40 m/h; fall of >3 m; high-speed injury from a projectile	Death or neurosurgical intervention or clinically significant ICI on CT scan
Greenes and Schutzman[30] (2001)	Composite score ≥3; age; hematoma size; hematoma location	Skull fracture or ICI on CT scan or radiograph
Haydel and Shembekar[31] (2003)	Headache; emesis; intoxication; memory deficit; seizure; trauma above clavicles	Depressed skull fracture or ICI on CT scan
Oman et al[32] (2006)	Significant skull fracture; altered LOC; neurologic deficit; persistent vomiting; scalp hematoma; abnormal behavior; coagulopathy	Clinically important ICI on CT scan
Palchak et al[33] (2003)	Abnormal mental status; signs of skull fracture; scalp hematoma if ≤2 y; history of vomiting	Traumatic brain injury requiring acute intervention (neurosurgical procedure, antiepileptic pharmacotherapy for >7 d, neurologic deficit persisting until hospital discharge, ≥2 nights of hospitalization)
Sun et al[34] (2007)	Abnormal mental status; signs of skull fracture; scalp hematoma if ≤2 y; high-risk vomiting; severe headache	Clinically important ICI on CT scan

LOC indicates loss of consciousness; NAI, Non-accidental injury; GCS, Glasgow Coma Scale.

TABLE 3 Quality Assessment Score for Clinical Prediction-Rule Derivation

Criteria	Score
Data collected prospectively	1 = yes
Study site(s) well described	1 = yes
Study population well described	1 = age, injury severity, and injury types reported
Predictors well defined	1 = predictors were unambiguous
Blinding of predictor assessors	1 = predictor assessors were blind to CT results
Outcome well defined	1 = outcome was unambiguous
Blinding of outcome assessors	1 = radiologists were blind to predictors
Predictors reproducible	1 = reproducibility in children reported and $\kappa > 0.5$
Adequate follow-up of outcomes	1 = outcomes assessed after hospital discharge
Rule applied to all patients at risk	1 = rule applied to all head-injured patients (not only those who had head CT performed)
Adequate model power	1 = No. of outcomes to potential predictors at 10 or more
Adequate reporting of results	1 = sensitivity, specificity, PPV, and NPV reported
Clinical sensibility	1 = predictors and outcome were clinically meaningful
Ease of bedside use	1 = reviewers could easily apply rule at the bedside
Total	14

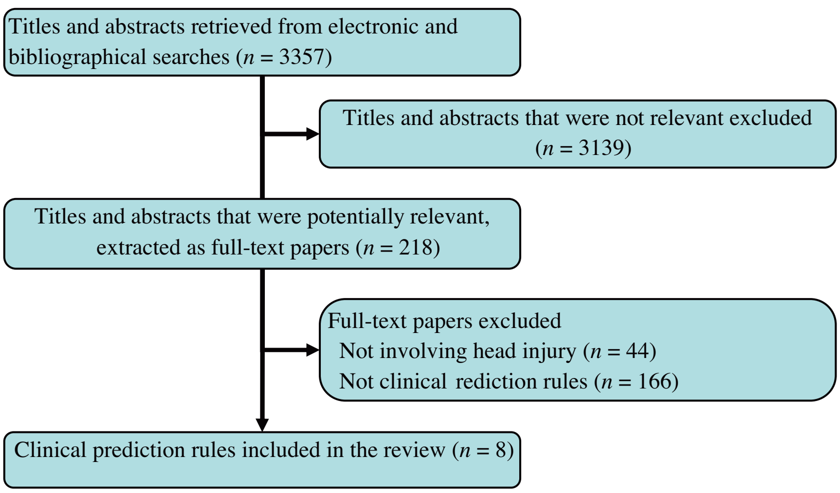

FIGURE 1
Selection process for clinical prediction rules on ICI in head injury.

Assessment of Methodologic Quality

The quality of the included studies was assessed by using 14 items from published guidelines for use in the derivation of clinical prediction rules.[17–20,26] Each item was recorded as present (1) or absent (0), with a maximum total of 14 (Table 3). Three reviewers (Drs Maguire, Boutis, and Parkin) independently extracted data from the studies by using the data abstraction form shown in Appendix 2. Discrepancies between the 3 reviewers were discussed and resolved by consensus. Ease of bedside use was evaluated as present if all 3 reviewers felt they could easily apply the rule at the bedside.

Assessment of Rule Performance

For each rule, the following variables were abstracted: sensitivity, specificity, negative predictive value (NPV) and positive predictive value (PPV) for ICI, and the predicted frequency of CT scanning that would result if the rule were applied to every patient (rule-predicted CT frequency). Given that physicians would not feel comfortable using a rule that missed more than a very small number of children with acute brain injury and that such a rule should reduce cranial CT use, rule performance was assessed by the sensitivity of the rule and the rule-predicted CT frequency.[18,21,24,25]

Because rule performance is likely affected by age and injury severity, we separately examined rule performance in 3 populations: (1) children of all ages and injury severities; (2) children with minor head injury (defined as a Glasgow coma score [GCS] of ≥13 at presentation[25]); and (3) young children (<3 years of age). Some rules were examined in more than 1 of the above-listed populations.

RESULTS

We screened 3357 titles and abstracts identified by the search strategy as being potentially relevant (see Fig 1). Two hundred eighteen studies were extracted as full-text articles and assessed for inclusion. Eight studies fulfilled all inclusion criteria.[27–34]

Description of Studies

Table 1 displays the population characteristics of the 8 included studies. All studies described derivations of a rule. None validated a rule in a separate population from that in which it was derived or assessed the rule's clinical impact. Five studies were multicenter,[27–29,32,34] and 3 were single center.[30,31,33] The median number of children enrolled was 1666, ranging from 422 to 22 772. In no study was CT scanning performed on every child from an unselected population. Four studies included only children for whom imaging was performed at the discretion of the attending physician,[27,31,32,34] and 4 studies included children regardless of whether imaging was performed.[28–30,33] The studies varied considerably in the characteristics of the population's age, injury severity, baseline CT frequency, ICI identified on CT scan, and need for neurosurgical intervention. For 2 studies, rules derived from the same population but us-

TABLE 4 Methodologic Quality of Included Studies

Study	Prospective	Study Sites Well Described	Patients Well Described	Predictors Well Defined	Predictor Assessor Blinding	Outcome Well Defined	Outcome Assessor Blinding	Predictors Reproducible	Adequate Follow-up	Applied to All Patients at Risk	Adequate Model Power	Adequate Reporting of Results	Clinically Sensible	Ease of Use	Total (of 14)
Atabaki et al[27] (2008)	Yes	Yes	Yes	No	Yes	Yes	No	No	No	No	No	Yes	Yes	Yes	8
Da Dalt et al[28] (2006)	Yes	Yes	Yes	No	No	No	No	No	Yes	Yes	No	Yes	Yes	Yes	8
Dunning et al[29] (2006)	Yes	Yes	Yes	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	No	11
Greenes and Schutzman[30] (2001)	Yes	Yes	Yes	No	Yes	Yes	No	No	Yes	Yes	No	No	Yes	No	8
Haydel and Shembekar[31] (2003)	Yes	Yes	Yes	Yes	Yes	Yes	No	No	No	No	No	Yes	Yes	Yes	9
Oman et al[32] (2006)	Yes	Yes	No	Yes	Yes	Yes	No	No	No	No	Yes	Yes	Yes	Yes	9
Palchak et al[33] (2003)	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	13
Sun et al[34] (2007)	No	Yes	No	Yes	Yes	Yes	No	Yes	No	No	Yes	Yes	Yes	Yes	9
	7	8	6	5	6	7	0	3	4	4	4	7	8	6	

ing different predictors were described.[32,34] Two studies derived several rules from children of different ages and injury severities.[29,33] In total, there were 5 rules derived from children of all ages and injury severities,[28,29,32–34] 4 derived from children with minor head injury (GCS ≥13),[27,29,31,33] and 4 derived from young children (<3 years of age).[30,32–34]

Predictors included in the rules and outcomes predicted by the rules also varied considerably (Table 2). Predictors of ICI common to 6 or more rules included a GCS of <15, mental status changes, evidence of skull fracture, and scalp hematoma.

The 4 studies that included only children in whom imaging was performed used ICI identified on imaging as the sole outcome.[27,31,32,34] Two of the 4 studies that included children with head injury regardless of whether imaging was performed attempted to identify clinically important outcomes such as neurosurgical intervention, death, and/or clinically significant imaging findings.[29,33]

Methodologic Quality

The methodologic quality of the studies is summarized in Table 4. The study sites of all studies were adequately described, and all prediction rules included clinically sensible predictors and outcomes. The most poorly addressed quality items were blinding of radiologists to clinical information (0 of 8), predictor reproducibility (3 of 8), adequate follow-up of outcomes (4 of 8), application of the rule to all patients at risk (4 of 8), and adequacy of model power (4 of 8).

Studies met between 8 and 13 of the 14 quality items. The 2 highest-quality studies (Dunning et al[29] and Palchak et al[33]) assessed outcomes in a diverse population of children (not just those who had imaging performed) and adequately assessed outcomes. The study with the highest quality did not report outcome-assessor blinding.[33] The study with the second highest quality did not report outcome or predictor-assessor blinding and, with 14 predictors in the rule, was felt to be difficult to use at the bedside.[29]

Rule Performance

Rule performance was compared separately for children with any severity of trauma (Table 5), for children with minor head injury (Table 6), and for young children (Table 7). In rules for children with any severity of trauma, the lower limits of the 95% confidence interval (CI) for sensitivity ranged from 0.82 to 0.97. The frequency with which head CT would be ordered if the rule was applied to all patients (rule-predicted CT frequency) varied from 14% to 86%. In the highest-performing rule, the lower limit of the 95% CI for sensitivity was 0.96, and the rule-predicted CT frequency was 14%.[29]

For rules applicable to children with minor head injury (Table 6), the lower limit of the 95% CIs for sensitivity ranged from 0.73 to 0.94. Rule-predicted CT frequency varied between 13% and 77%. The highest-performing rule had a lower limit of the 95% CI for sensitivity of 0.94 and a rule-predicted CT frequency of 13%.

Rules for young children performed less well (Table 7), with the lower limit of the 95% CIs ranging from 0.72 to 0.87 and rule-predicted CT frequencies between 35% and 95%. The highest-performing rule had a lower limit of the 95% CI for sensitivity of 0.87 and a rule-predicted CT frequency of 35%.

DISCUSSION

We performed a systematic review of clinical prediction rules for predicting which head-injured children should receive a cranial CT scan. Eight clinical

TABLE 5 Rule Performance for Children With Any Severity of Trauma

Study	*n*	Rule-Predicted CT frequency, %	Sensitivity (95% CI)	Specificity (95% CI)	NPV (95% CI)	PPV (95% CI)
Da Dalt et al[28] (2006)	3806	28	1.00 (0.82–1.00)	0.73 (0.71–0.74)	1.00 (0.998–1.00)	0.021 (0.01–0.03)
Dunning et al[29] (2006)	22 772	14	0.98 (0.96–1.00)	0.87 (0.87–0.87)	0.999 (0.999–1.00)	0.09 (0.08–0.10)
Oman et al[32] (2006)	1666	86	0.99 (0.95–1.00)	0.15 (0.13–0.17)	0.99 (0.97–1.00)	0.095 (0.08–0.11)
Palchak et al[33] (2003)	2043	56	1.00 (0.97–1.00)	0.46 (0.44–0.49)	1.00 (0.997–1.00)	0.092 (0.08–0.11)
Sun et al[34] (2007)	1666	59	0.90 (0.86–0.95)	0.43 (0.40–0.45)	0.98 (0.97–0.99)	0.13 (0.11–0.15)

TABLE 6 Rule Performance for Children With Minor Head Injury (GCS ≥13)

Study	*n*	Rule-Predicted CT Frequency, %	Sensitivity (95% CI)	Specificity (95% CI)	NPV (95% CI)	PPV (95% CI)
Atabaki et al[27] (2008)	1000	54	0.95 (0.86–0.99)	0.49 (0.46–0.52)	0.99 (0.98–0.99)	0.12 (0.09–0.15)
Dunning et al[29] (2006)	22 579	13	0.98 (0.94–0.99)	0.87 (0.87–0.88)	0.999 (0.999–1.00)	0.05 (0.05–0.06)
Haydel and Shembekar[31] (2003)	175	77	1.00 (0.73–1.00)	0.26 (0.19–0.33)	1.00 (0.89–1.00)	0.10 (0.06–0.17)
Palchak et al[33] (2003)[a]	1098	52	0.95 (0.83–0.99)	0.50 (0.46–0.53)	1.00 (0.99–1.00)	0.07 (0.05–0.09)

[a] For predicting traumatic brain injury on CT scan on children who underwent a CT scan.

TABLE 7 Rule Performance for Young Children

Study	*n*	Rule-Predicted CT Frequency, %	Sensitivity (95% CI)	Specificity (95% CI)	NPV (95% CI)	PPV (95% CI)
Greenes and Schutzman[30] (2001)[a]	422	35	0.98 (0.87–1.00)	0.49 (0.40–0.58)	0.98 (0.90–0.99)	0.40 (0.31–0.50)
Oman et al[32] (2006)[b]	309	95	1.00 (0.86–1.00)	0.05 (0.03–0.09)	1.00 (0.78–1.00)	0.085 (0.06–0.12)
Palchak et al[33] (2003)[a,c]	194	69	1.00 (0.82–1.00)	0.34 (0.27–0.41)	1.00 (0.95–1.00)	0.11 (0.06–0.18)
Sun et al[34] (2007)[a]	208	89	1.00 (0.72–1.00)	0.11 (0.06–0.16)	1.00 (0.82–1.00)	0.04 (0.02–0.08)

[a] For children younger than 2 years.
[b] For children younger than 3 years.
[c] For predicting traumatic brain injury on CT scan on children who underwent a CT scan.

prediction-rule derivation studies were identified. They varied considerably in population, predictors, and outcomes, and none were validated in a separate population. The authors of 2 studies attempted to identify clinically meaningful outcomes,[29,33] whereas others sought to identify any trauma-related CT change regardless of whether acute intervention would be required.[27,28,30,31]

To assess the methodologic quality of these prediction rules, we quantified the presence or absence of 14 items considered to be important for high-quality clinical prediction rules.[17–20,26] The quality of the rules varied considerably (Table 4). The most important quality issue that affected the majority of the studies related to including only patients for whom a CT scan was ordered by the attending physician. Because clinical prediction rules are intended to be used for all patients presenting with a head injury, this represents an important limitation. It is recognized that it is not possible or desirable for studies to perform CT scans on all children with head injury. To overcome this, 4 studies followed children who did not undergo CT scanning for clinically important outcomes such as subsequent return to an emergency department, CT scan, neurosurgical intervention, or death.[28–30,33]

For children with any severity of head trauma (Table 5), the top-performing rule had excellent performance (sensitivity: 0.98 [95% CI: 0.96–1.00]; rule-predicted CT frequency: 14%).[29] This rule had the second highest methodologic quality (11 of 14 quality components). The highest-quality rule (13 of 14 quality components) had excellent sensitivity (1.0 [95% CI: 0.97–1.00]) but had a rule-predicted CT frequency of 56%, which may increase cranial CT use in some settings.[33]

Rules derived from children with any severity of injury have limited utility, because in the setting of major head trauma, pediatric emergency physicians are likely to order cranial CT scanning regardless of the recommendations of a clinical prediction rule. Thus, a rule is likely to be most useful for children with minor head injury. The top-performing rule for children with minor head injury (Table 6) had a sensitivity of 0.98 (95% CI: 0.94–0.99) and a rule-predicted CT frequency of 13%.[29] This rule has 14 predictors affecting its ease of use at the bedside. However, predicting ICI accurately in children with minor head injury may require a complex rule. If this is the case, tools that aid with data collection and computation in the emergency department may be needed for this complex rule to be implemented successfully.

The performance of rules for young children was, in general, poorer than rules for the other populations (Table 7). The highest-performing rule had a sensitivity of 0.98 and a wide CI (95% CI: 0.87–1.00), with a rule-predicted CT frequency of 35%. This rule met only 8 of the 14 methodologic quality items, and its ease of use was limited by the need for a summation score for 12 predictor variables.[30]

It is important to acknowledge the limitations of this systematic review. First, the electronic search strategy may not have identified all clinical prediction rules for head injury in children. However, examination of the reference lists of all identified prediction-rule publications failed to reveal any additional studies. Second, the proposed quality metric treated each quality item with equal weight, and it is possible that certain components may be more important than others. Third, although the items used to assess methodologic quality have been well described in the literature,[17–20,26] they have not been rigorously developed or validated. They are, however, very similar to those widely accepted for evaluating the quality of studies of diagnostic tests.[35]

CONCLUSIONS

With this systematic review we have identified 8 clinical prediction rule derivation studies for predicting which children with head injury should receive cranial CT scanning, 2 of which have strong quality and performance.[29,33] However, neither of them have been validated in different populations. Clinical prediction rules for children with minor head injury that have high quality and performance at the derivation stage should be prospectively validated in different populations. A high-quality and high-performing rule has not yet been derived for very young children. Thus, further study is needed before a clinical prediction rule for children with head injury can be recommended for use in routine practice.

APPENDIX 1: CLINICAL PREDICTION RULE FOR HEAD-INJURY SYSTEMATIC REVIEW—ELECTRONIC SEARCH STRATEGY

With the assistance of Elizabeth Uleryk (Director, Hospital for Sick Children Library), a comprehensive literature search was run by using the OVID search platform in Medline, Embase, and the EBM Review–Cochrane Database of Systematic Reviews from the beginning of the database until November, 2008. The following terms were searched by using specific database indexing and text-word equivalents to identify articles for review.

(Craniocerebral trauma/ or models, statistical/ or Monte Carlo method/ or probability/ or regression analysis/ or multivariate analysis/ or predict*.mp.) AND (decision trees/ or predictive value of tests/ or ([decision: or predict:] adj5 [rule: or model: or algorithm: or aid or score:]).ti,ab.) AND (limit to age groups birth to 18 years of age or pediatrics/) AND (cohort studies/ or longitudinal studies/ or follow-up studies/ or prospective studies/ or prognosis/ or disease-free survival/ or treatment outcome/ or treatment failure/ or disease progression/ or morbidity/ or incidence/ or prevalence/ or mortality/ or cause of death/ or fatal outcome/ or hospital mortality/ or infant mortality/ or maternal mortality/ or survival rate/ or survival analysis/ or disease-free survival/ or natural history.tw. or evaluation studies.pt. or evaluation studies as topic/ or validation studies.pt. or validation studies as topic/ "sensitivity and specificity"/ or predictive value of tests/ or ROC curve/ or diagnostic errors/ or false negative reactions/ or false positive reactions/ or observer variation/ or likelihood functions/ or (likelihood or likelihood ratio:).tw. or pediatrics.jn. or journal of pediatrics.jn. or ambulatory pediatrics.jn. or annals of emergency medicine.jn or ("archives of pediatrics" or "*archives of pediatrics and adolescent medicine*"). Jn.

APPENDIX 2: CLINICAL PREDICTION RULE FOR HEAD INJURY SYSTEMATIC REVIEW—METHODOLOGIC QUALITY-ASSESSMENT TOOL

Record Number: ______________________ Reviewer: ___________

Paper Citation: ____

Study Type:	Derivation	Validation	Impact analysis
	Single center	Multicenter	

Rule Evaluation (please circle yes or no):

1. Data collected prospectively	Yes/No
2. Study site(s) well described	Yes/No
3. Population well described (age, gender, injury severity, mechanisms of injury)	Yes/No
4. Predictors:	
Identification and definition	Yes/No
Blind assessment	Yes/No
5. Outcome:	
Definition	Yes/No
Blind assessment	Yes/No
6. Reproducibility of predictors	Yes/No
7. Adequate followup (followup postdischarge)	Yes/No
8. Rule applied to all patients at risk (not just those with CT)	Yes/No
9. Adequate power (outcomes/predictors ≥ 10)	Yes/No
10. Adequate reporting of results (Sn, Sp, PPV, NPV reported)	Yes/No
11. Clinically sensible	Yes/No
12. Easy to use at the bedside	Yes/No
Total Score	**___/14**

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