The Rational Clinical Examination

Will Neuroimaging Reveal a Severe Intracranial Injury in This Adult With Minor Head Trauma?
The Rational Clinical Examination Systematic Review

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IMPORTANCE Adults with apparently minor head trauma (Glasgow Coma Scale [GCS] scores ≥13 who appear well on examination) may have severe intracranial injuries requiring prompt intervention. Findings from clinical examination can aid in determining which adults with minor trauma have severe intracranial injuries visible on computed tomography (CT).

OBJECTIVE To assess systematically the accuracy of symptoms and signs in adults with minor head trauma in order to identify those with severe intracranial injuries.

DATA SOURCES We performed a systematic search of MEDLINE (1966-2015) and the Cochrane Library to identify studies assessing the diagnosis of intracranial injuries.

STUDY SELECTION Studies were included that measured the performance of findings for identifying intracranial injury with a reference standard of neuroimaging or follow-up evaluation. Fourteen studies (range, 431-7955 patients) met inclusion criteria with patients having GCS scores between 13 and 15 and 50% or more older than 18 years.

DATA EXTRACTION AND SYNTHESIS Three authors independently performed critical appraisal and data extraction.

RESULTS The prevalence of severe intracranial injury (requiring prompt intervention) among the 23 079 patients with minor head trauma was 7.1% (95% CI, 6.8%-7.4%) and the prevalence of injuries leading to death or requiring neurosurgical intervention was 0.9% (95% CI, 0.78%-1.0%). The presence of physical examination findings suggestive of skull fracture (likelihood ratio [LR], 16; 95% CI, 3.1-59; specificity, 99%), GCS score of 13 (LR, 4.9; 95% CI, 2.8-8.5; specificity, 97%), 2 or more vomiting episodes (LR, 3.6; 95% CI, 3.1-4.1; specificity, 92%), any decline in GCS score (LR range, 3.4-16; specificity range, 91%-99%;), and pedestrians struck by motor vehicles (LR range, 3.0-4.3; specificity range, 96%-97%) were associated with severe intracranial injury on CT. Among patients with apparent minor head trauma, the absence of any of the features of the Canadian CT Head Rule (≥65 years; ≥2 vomiting episodes, amnesia >30 minutes, pedestrian struck, ejected from vehicle, fall >1 m, suspected skull fracture, or GCS score <15 at 2 hours) had an LR of 0.04 (95% CI, 0-0.65), lowering the probability of severe injury to 0.31% (95% CI, 0%-4.7%). The absence of all the New Orleans Criteria findings (>60 years, intoxication, headache, vomiting, amnesia, seizure, or trauma above the clavicle) had an LR of 0.08 (95% CI, 0.01-0.84), lowering the probability of severe intracranial injury to 0.61% (95% CI, 0.08%-6.0%).

CONCLUSIONS AND RELEVANCE Combinations of history and physical examination features in clinical decision rules can identify patients with minor head trauma at low risk of severe intracranial injuries. Certain findings, including signs of skull fracture, GCS score of 13, 2 or more vomiting episodes, decrease in GCS score, and pedestrians struck by motor vehicles, may help identify patients at increased risk of severe intracranial injuries.

JAMA. 2015;314(24):2672-2681. doi:10.1001/jama.2015.16316

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Clinical Scenarios

Case 1

A 67-year-old woman slipped on ice and struck her head. She experienced no loss of consciousness and recalls the entire incident. She vomited once immediately after the fall. Three hours after the fall, she presents to the emergency department and vomits again. There is a 0.5-cm forehead abrasion, and she has a Glasgow Coma Scale (GCS) score of 15 with no abnormal neurologic findings. How likely is it that an emergency computed tomographic (CT) scan of her head would reveal a severe intracranial injury?

Case 2

A 20-year-old man was playing basketball when another player knocked him to the ground. He experienced loss of consciousness for 5 seconds and then returned to the game. On presentation to the emergency department 4 hours after the injury, he has a moderate left-sided headache and a moderate-sized left parietal scalp hematoma but no other abnormal findings. How likely is it that emergency head CT scan for this patient would reveal a severe intracranial injury?

Why Is This Question Important?

Traumatic brain injury is the leading cause of death and disability from injury in the United States, and one-third of all traumatic deaths occur after head trauma.[1] Each year approximately 2.5 million people in the United States present for medical attention after sustaining head trauma.[2] With heightened awareness among the public of the potential adverse consequences of even minor head trauma, the number of medical visits after head trauma has increased over the last decade, costing nearly $76 billion annually in direct and indirect costs.[3-6]

Traumatic brain injury is a heterogeneous disorder representing a spectrum of injuries ranging from concussions to devastating intracranial hemorrhages. Computed tomography is the gold standard for rapidly identifying intracranial injuries that require prompt intervention. Patients with a moderate (GCS score, 9-12) or severe head trauma (GCS score, ≤8; **Box 1**), should undergo emergency head CT to detect intracranial injuries because early interventions reduce morbidity and mortality.[7]

Patients who appear well with GCS scores of 13 or higher and have minimal or no alterations in their mental status have minor head trauma.[8,9] The role of head CT for these patients is less clear than it is for moderately or severely injured patients. Between 5% and 15% of patients with minor trauma have intracranial injuries, although only a small minority of these require an acute neurosurgical intervention.[10] Because minor trauma (89% of all head trauma) is far more common than moderate or severe trauma (11% of all trauma), the absolute number of patients requiring prompt intervention is higher among patients with minor trauma.[11] Although most patients with minor head trauma will not have a serious intracranial injury, CTs identify the injuries, so many patients and their physicians ignore cost and radiation exposure in favor of testing with CT.[12] We conducted a systematic review to determine whether any individual or combinations of findings have high enough diagnostic accuracy to distinguish patients with minor trauma who are at high risk of severe intracranial injury from those with extremely low likelihood of severe intracranial injury.

Box 1. Calculation of the Glasgow Coma Scale

Eye Opening (1-4 points)
Spontaneous, 4
Responds to speech, 3
Responds to pain, 2
None, 1

Verbal Response (1-5 points)
Oriented, 5
Confused, 4
Inappropriate words, 3
Incomprehensible sounds, 2
None, 1

Motor Response (1-6 points)
Obey commands, 6
Localize to pain, 5
Withdraw to pain, 4
Abnormal flexion to pain, 3
Extension to pain, 2
None, 1

Total Score
Sum the best eye, verbal, and motor scores for a total of 3-15 points

Methods

Literature Search Strategy

The MEDLINE database (1966-August, 2015) and the Cochrane Library were searched to identify English-language studies that evaluated the identification of traumatic brain injuries using history and physical examination. The search strategy previously developed for The Rational Clinical Examination series that combines 10 exploded MeSH headings (*physical examination*, *medical history taking*, *professional competence*, *sensitivity and specificity*, *reproducibility of results*, *observer variation*, *diagnostic tests*, *routine-decision support techniques*, *Bayes theorem*, *mass screening*) and 2-text word categories (*physical exam$* and *sensitivity* and *specificity*) was used. The intersection of this set with both *traumatic brain injury* (MeSH term exploded), articles in the authors' files, references cited by these articles, and references in textbooks were reviewed. Studies on traumatic intracranial injury using a prespecified selection strategy that focused on patients in which 50% or more of the participants were adults (≥18 years) with head trauma, who presented with GCS scores ranging from 13 through 15 were included (see eAppendix 1 in the Supplement for a more complete description of selection strategy). Studies of patients with GCS scores less than 13 were not included because there is little controversy that lower scores reflect more severe head trauma and higher likelihood of intracranial injury. Studies undergoing full-text review were assigned a Rational Clinical Examination Quality score and Quality Assessment tool for Diagnostic Accuracy Studies (QUADAS) score (see eAppendix 2 and 3 in the Supplement).[13] Not all intracranial injuries visible on CT require further intervention. It was decided a priori to focus on severe intracranial injuries, ie, injuries requiring prompt intervention (eAppendix 1 in the Supplement). These are the injuries relevant to clinicians, as they typically lead to observation in the hospital, neurosurgical evaluation, or operative intervention and include subdural, epidural, ventricular or parenchymal hematoma, subarachnoid hemorrhage, herniation, or depressed skull fracture. Although there is ongoing controversy about the significance of small intracranial hemorrhages, they were included in the outcome both to ensure the most broad but clinically useful outcome measure, and because current practice for most nonneurosurgeons is to refer these patients to a specialist. On the other hand, because closed, nondisplaced skull fractures do not require prompt intervention, they were not included as severe injuries.

Statistical Analyses

Likelihood ratios (LRs), sensitivity, and specificity of findings, along with odds ratios for risk factors, were calculated with 95% confidence intervals (CIs). If any of the values in the sampled 2 × 2 contingency table were 0, then 0.5 was added to all cells to calculate LRs.[14] When calculating the sensitivities of the clinical decision rules, we assumed the presence of 1 of the variables of the rule would lead to detection of the outcome. This is not always true when the rules are designed to identify low-risk patients; presence of 1 of the features of the rule does not mandate CT acquisition. The summary prevalence (pretest probability) was calculated with random-effects measures.

When there were 4 or more studies of quality level I through III for individual findings or similar combinations of findings, we used bivariate summary measures. When there were only 3 studies or when the hierarchical summary receiver operating characteristics model did not converge on a reliable solution, univariate random-effects estimates were used (Comprehensive Meta-Analysis, version 2.2046, Biostat).[15-17] Level IV studies were not included in the summary measures. SAS version 9.2 (PROC NLMixed or PROC GLIMMIX; SAS Institute Inc) was used for all analyses. We summarized findings evaluated in only 2 studies with the range, and we used point estimates with 95% CIs for findings evaluated in only 1 study. For summary measures that included 3 or more studies, heterogeneity was assessed with the I^2 parameter, with values greater than 50% suggesting real heterogeneity between studies rather than spurious heterogeneity (Comprehensive Meta-Analysis).[18]

Results

Study Characteristics

A total of 2760 studies were identified through our literature review (eFigure in the Supplement), of which 14 met criteria for inclusion (eTable 1 in the Supplement).[19-32] These studies came from 8 different countries, creating an international sample. Six articles used overlapping data sets, and only unique data from each article were incorporated into our results. Sample sizes for included studies ranged from 431 to 7955 patients.

Prevalence of Intracranial Injury in Patients With Minor Head Trauma

The prevalence of severe intracranial injury in the 23 079 patients with minor trauma was 7.1% (95% CI, 6.8%-7.4%; I^2 = 90%), and the prevalence of injuries leading to death or requiring neurosurgical intervention was 0.9% (95% CI, 0.78%-1.0%; I^2 = 77%).[19-32]

Accuracy of Findings From the Clinical History and Physical Examination

Risk Factors

Several risk factors were associated with severe intracranial injury (**Table 1**). When examining these factors separately, pedestrians struck by automobiles were at highest risk of intracranial injuries (LR range, 3.0-4.3).[24,27] At a baseline prevalence of 7.1%, this confers a predictive value of 19% to 25% for an intracranial injury for pedestrians struck by automobiles. Age 65 years or older (LR, 2.3; 95% CI, 1.8-3.1) and age older than 60 years (LR, 2.2; 95% CI, 1.6-3.2) were also associated with intracranial injuries in multiple studies.[22-25,27-31] Absence of seat belts and falls from 1 m or higher were associated with intracranial injuries, but these findings were only reported in 1 study (eTable 3 in the Supplement).[27,29] Other risk factors such as chronic alcohol use, bicycle collisions, or absence of bike helmets had LR CIs that included 1.0 (eTable 3 in the Supplement).[23,24,27,28]

Symptoms

The presence of vomiting after head trauma, especially repetitive vomiting of at least 2 episodes (LR, 3.6; 95% CI, 3.1-4.1) or posttraumatic seizures (LR, 2.5; 95% CI, 1.3-4.3) were important findings that increased the likelihood of an intracranial injury (Table 1).[21-23,25,27-29] At a baseline prevalence of 7.1%, the presence of repetitive vomiting after head trauma confers a predictive value of 19% to 24% for an intracranial injury. Although loss of consciousness (LR, 1.6; 95% CI, 1.1-2.1) or the presence of headache (LR, 1.2; 95% CI, 1.0-1.5) may alarm patients and their physicians, as isolated findings they were less important than other symptoms.[20,23,24,27,28] Patients who remained conscious were less likely to have an intracranial injury, but the LR was only 0.60 (95% CI, 0.39-0.81). At a baseline prevalence of 7.1%, remaining conscious confers a predictive value of 3% to 6% for an intracranial injury. Other symptoms were less diagnostically accurate or only assessed in 1 level I to III study (eTable 3 in the Supplement).

Signs

The presence of physical examination features suspicious for skull fractures in patients with only minimal alterations in their mental status, substantially increased the likelihood of intracranial injury (LR, 16; 95% CI, 3.1-59) (Table 1).[20,24,29] These signs included an open fracture of the skull that was visible on physical examination, a depressed fracture that was palpated, or a basilar skull fracture manifested as postauricular ecchymosis (the Battle sign), hemotympanum, cerebrospinal fluid otorrhea, or raccoon eyes (**Figure 1**). At a baseline prevalence of 7.1%, the presence of features suspicious for skull fractures confers a predictive value of 19% to 82% for an intracranial injury. Patients without signs of skull

Table 1. Summary Data (Quality Level I-III) for Findings to Identify Severe Intracranial Injuries[a]

Characteristics	No. of Studies	% (95% CI)[b] Sensitivity	Specificity	Positive LR (95% CI)[b]	I^2, %	Negative LR (95% CI)[b]	I^2, %	Probability of Severe Intracranial Injury, (95% CI), % Finding Present[c]	Finding Absent[c]
Risk Factors									
Mechanism of injury									
Dangerous[27-29,d]	3	39 (27-53)	82 (77-85)	2.1 (1.5-2.9)	86	0.75 (0.61-0.92)	93	14 (10-18)	5.4 (4.5-6.6)
Pedestrian struck[24,27]	2	10-17	96-97	3.0-4.3		0.87-0.93		19-25	6.2-6.6
Age ≥65 y[23,27-29]	4	35 (27-43)	85 (77-91)	2.3 (1.8-3.1)	82	0.77 (0.72-0.82)	0	15 (12-19)	5.6 (5.2-5.9)
Age >60[22,24,28,29]	4	34 (24-46)	84 (73-92)	2.2 (1.6-3.2)	74	0.78 (0.70-0.85)	6.7	14 (11-20)	5.6 (5.1-6.1)
Coagulopathy[20,22-24]	4	4.9 (1-27)	98 (92-99)	2.2 (1.0-4.2)	0	0.97 (0.79-1.0)	77	14 (7.1-24)	6.9 (5.7-7.1)
Male[24,27]	2	74-76	32-43	1.1-1.3		0.56-0.80		7.8-9.0	4.1-5.8
Symptoms									
Vomiting									
≥2 episodes[27-29]	3	27 (14-47)	92 (87-95)	3.6 (3.1-4.1)	0	0.76 (0.61-0.95)	95	22 (19-24)	5.5 (4.5-6.8)
Any episodes[20,22,23,25,28,29]	6	18 (14-22)	92 (91-94)	2.3 (1.8-2.8)	0	0.89 (0.85-0.93)	32	15 (12-18)	6.4 (6.1-6.6)
Nausea[23,25]	2	19-29	85-86	1.4-1.9		0.84-0.94		9.7-13	6.0-6.7
Posttraumatic seizure[21-23,28,29]	5	3.1 (1.4-6.8)	99 (98-99)	2.5 (1.3-4.3)	0	0.98 (0.95-0.99)	0	16 (9.0-25)	7.0 (6.8-7.0)
Anterograde amnesia[22,27,28]	3	27 (7.4-63)	73 (62-82)	2.2 (1.6-3.1)	82	0.75 (0.64-0.88)	79	14 (11-19)	5.4 (4.7-6.3)
Loss of consciousness[21,23,24,27,28]	5	65 (55-74)	59 (48-70)	1.6 (1.1-2.1)	96	0.60 (0.39-0.81)	88	11 (7.8-14)	4.4 (2.9-5.8)
Any amnesia[23,27,29]	3	50 (7-93)	75 (46-91)	1.5 (0.81-2.8)	93	0.55 (0.31-0.97)	98	10 (5.8-18)	4.0 (2.3-6.9)
Headache[20-25,27-29]	9	50 (39-60)	60 (47-73)	1.2 (1.0-1.5)	77	0.84 (0.73-0.94)	57	8.4 (7.1-10)	6.0 (5.3-6.7)
Signs									
Skull fracture[e]									
Any[21,24,29]	3	16 (3-52)	99 (98.7-99.2)	16 (3.1-59)	90	0.85 (0.48-0.98)	98	55 (19-82)	6.1 (3.5-7.0)
Basal[23,25,27-29]	5	18 (10-27)	97 (96-98)	6.0 (3.9-8.0)	60	0.84 (0.76-0.92)	91	31 (23-38)	6.0 (5.5-6.6)
Open[27,28]	2	12-13	97-97	4.6-5.0		0.90-0.91		26-28	6.4-6.5
GCS score									
Any decline[27,28]	2	21-31	91-99	3.4-16		0.76-0.80		21-55	5.5-5.8
<15 at 2 h[27-29]	3	45 (20-74)	87 (57-97)	3.5 (1.6-7.6)	98	0.63 (0.45-0.89)	98	21 (11-37)	4.6 (3.3-6.4)
Initial score									
13[19,27,28]	3	15 (12-18)	97 (96-98)	4.9 (2.8-8.5)	86	0.88 (0.84-0.93)	66	27 (18-39)	6.3 (6.0-6.6)
14[19,23,24,27]	4	34 (25-43)	92 (86-97)	4.2 (0.85-7.6)	99	0.71 (0.60-0.83)	94	24 (6.1-37)	5.1 (4.4-6.0)
Focal neurologic deficit[21,23]	2	4.8-17	91-99	1.9-7.0		0.91-0.96		13-35	6.5-6.8
Trauma above the clavicle[22,28,29]	3	22 (5.5-58)	74 (49-90)	1.3 (1.1-1.5)	55	0.80 (0.62-1.0)	58	9.0 (7.8-10)	5.8 (4.5-7.1)

Abbreviations: GCS, Glasgow Coma scale; LR, likelihood ratio.

[a] See eTable 2 in the Supplement for results from individual studies.

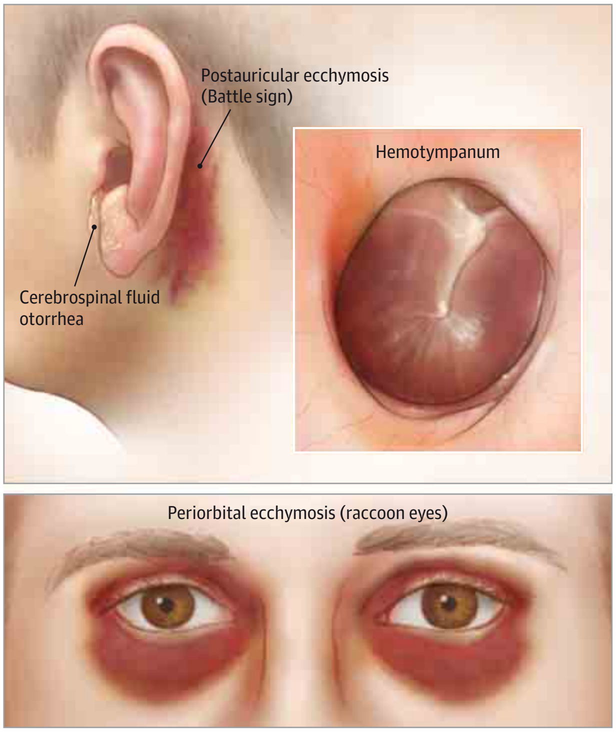
[b] For findings evaluated in only 1 study, point estimate and 95% CIs are shown, findings evaluated in 2 studies are shown as range, findings evaluated in 3 or more studies are shown as summary measure with 95% CIs or I^2.

[c] Values derived from a baseline prevalence of injury of 7.1%. The probability of intracranial injury for the presence of the finding is the positive predictive value. The probability of intracranial injury for the absence of the finding is 1, the negative predictive value.

[d] Dangerous mechanism is a pedestrian struck by a vehicle, an occupant ejected from a motor vehicle, or a fall from an elevation of more than 1 m or 5 stairs.

[e] Skull fracture is considered when signs of a fracture are identified on the physical examination, including an open fracture of the skull that was visible on physical examination, a depressed fracture that was palpated, or a basilar skull fracture manifested as postauricular ecchymosis (the Battle sign), hemotympanum, cerebrospinal fluid otorrhea, or raccoon eyes (Figure 1).

Figure 1. Signs of Basilar Skull Fracture



Box 2. Clinical Decision Rules to Rule Out Intracranial Injuries

New Orleans Criteria[22]

Older than 60 years

Intoxication

Headache

Any vomiting

Seizure

Amnesia

Visible trauma above the clavicle

Canadian CT Head Rule[27]

65 years or older

Dangerous mechanism (pedestrian struck by vehicle, occupant ejected from vehicle, fall >1 m or 5 stairs)

Vomiting more than 1 episode

Amnesia longer than 30 minutes

GCS score less than 15 at 2 hours

Suspected open, depressed, or basilar skull fracture

Interpretation of the Rules

Patients without any features of the rule are at low risk of severe intracranial injury.

The decision to discharge, observe, or CT the patient with 1 or more features of a rule depends on the setting, clinician's judgment about the likelihood of injury, patient preference, number of features present, and the particular features present.

Abbreviations: CT, computed tomography; GCS, Glasgow Coma Scale.

fracture may still have intracranial injuries, as the LR approaches 1.0 (LR, 0.85; 95% CI, 0.48-0.98).

Patients with GCS scores of 13 or higher are frequently considered to have minor trauma. A depressed GCS score, including a GCS score of 13 (LR, 4.9; 95% CI, 2.8-8.5), GCS score of less than 15 two hours after the injury (LR range, 1.6-7.6), or any decline in GCS score (LR range, 3.4-16), increased the likelihood of intracranial injury.[21,27-29] At a baseline prevalence of 7.1%, a GCS score of 13 has a predictive value of between 18% and 39% for an intracranial injury, whereas any decline in GCS score has a predictive value of between 21% and 55%. A focal neurologic deficit had an LR range (1.9-7.0) that is of value for identifying the patient at higher likelihood of intracranial injury.[21,23] These deficits can include any new abnormalities on the neurologic examination that can be localized to particular anatomic location in the brain, such as anisocoria, visual change, aphasia, focal motor or sensory deficit, ataxia, or other gait abnormalities. Other findings evaluated in the retrieved articles, such as intoxication and prolonged amnesia, were less diagnostically useful (eTable 3 in the Supplement).[21-24,27-29]

Clinical Decision Rules

Although individual signs and symptoms do not have sufficient diagnostic accuracy to rule out the presence of intracranial injury, combinations of historical and physical examination features in clinical decision rules may be more useful (**Box 2** and eTable 4 in the Supplement). For these rules, the absence of any findings of the rule suggests that the patient is at low risk of intracranial injury and typically does not require head CT or observation. **Table 2** describes the performance of these rules in cohorts of patients with or without loss of consciousness, amnesia, or disorientation. The positive LR for these rules was lower than the positive LR from the results of nearly all of the individual historical and physical examination findings shown in Table 1. Only the Canadian CT Head Rule and New Orleans Criteria were derived in large cohorts of patients with minor head trauma, validated, and subsequently compared in multiple studies.[19,22,23,26-29] The accuracy of the Canadian CT Head Rule for identifying patients with intracranial injury exceeded the New Orleans Criteria in all but one study (eTable 5 in the Supplement).[19,22,23,26-29]

For each rule, a negative result (no feature present) suggests that head CT or observation typically is not required. In contradistinction to the lack of relative effectiveness of positive results from the rules, the absence of all clinical findings composing a rule had a much better sensitivity and therefore a lower negative LR than the results for individual historical and physical examination findings in Table 1. When the Canadian CT Head Rule was applied to patients with GCS scores of 13 to 15 and loss of consciousness, amnesia, or disorientation, the rule identified patients presenting with minor head trauma at low risk of severe intracranial injury (LR, 0.04; 95% CI, 0-0.65).[19,26-29] Using the summary prevalence of 7.1%, the absence of all the features on the Canadian Head CT lowers the probability of a severe intracranial injury to 0.31% (95% CI, 0%-4.7%). The New Orleans Criteria also accurately identified patients at lower risk of intracranial injury (LR, 0.08; 95% CI, 0.01-0.84).[19,22,26,28,29] Using the summary prevalence of 7.1%, the absence of any of the New Orleans Criteria lowers the probability of a severe intracranial injury to 0.61% (95% CI, 0.08%-6.0%).

When applied to patients with or without loss of consciousness, amnesia, or disorientation, the rules continued to identify patients at lower risk of intracranial injury, albeit not as well as in the cohorts with these characteristics. For these patients, the rules identified patients at low risk of intracranial injury with an LR of 0.29-0.33 for the Canadian Head CT rule and 0.26 for the New Orleans Criteria.[19,23]

When limited to patients with GCS scores of 15 and loss of consciousness, amnesia, or disorientation, the rules also identified patients at lower risk of intracranial injury (eTable 6 in the Supplement). In this cohort, the CIs surrounding the point estimate of the negative LR for the rules was narrower for the New Orleans Criteria (LR, 0.08; 95% CI, 0.01-0.84) compared with the Canadian CT Head Rule (LR, 0.09; 95% CI, 0.01-1.4).[19,22,26,28,29] The results for the New Orleans Criteria were homogenous across the 5 studies (I^2 = 15%).

The Canadian CT Head Rule (LR, 0.05; 95% CI, 0.01-0.21) and New Orleans Criteria (LR, 0.70; 95% CI, 0.14-3.4) identified patients at low risk of injuries requiring neurosurgical intervention (eTable 7 in the Supplement). The Canadian CT Head Rule (LR, 0.08; 95% CI, 0.01-0.84) and New Orleans Criteria (LR, 0.21; 95% CI, 0.09-0.47) also identified patients at low risk of any injury on CT, including nondisplaced, linear skull fractures (eTable 8 in the Supplement).

Limitations

Our study focused on the evaluation of adults and adolescents with minor trauma. Children present with unique signs and symptoms of intracranial injury; therefore, studies focusing only on this age group were not included (eAppendix 1 in the Supplement). Separate clinical decision rules exist to guide the management of children with minor head trauma.[33-35]

The clinical decision rules were derived in cohorts with different inclusion criteria rendering it difficult to compare their performance directly. The original Canadian CT Head Rule included patients with GCS scores of 13 to 15 and witnessed loss of consciousness, amnesia, or disorientation (Box 2).[27] The original New Orleans Criteria included patients with GCS scores of 15 only and loss of consciousness or amnesia (Box 2).[22] When the rules are compared in these original derivation cohorts, they perform similarly (eTable 5 in the Supplement). Subsequent validation studies have compared the performance of the rules in common cohorts, including patients with GCS scores of 13 to 15 regardless of the presence of loss of consciousness, amnesia, or disorientation as well as cohorts with only patients with GCS scores of 15 and loss of consciousness, amnesia, or disorientation. Similarly, different types of physicians performed the studies. Most were emergency physicians but neurologists and neurosurgeons also participated. Notably, the diagnostic performance of the physical examination was similar among different types of physicians.

There is also debate about which injuries visible on CT are clinically important, and studies often classify injuries differently. Because current practice for clinicians who initially evaluate patients is to observe or to refer to a specialist all patients with intracranial injuries visible on CT (except isolated, linear, nondepressed skull fractures), we included these injuries.

The rules do not demonstrate perfect sensitivity for intracranial injury and may not detect subtle injuries, such as arterial dissection, venous sinus thrombosis, or diffuse axonal injury. Moreover, patients with no injuries visible on initial noncontrast head CT

Table 2. Accuracy of Clinical Decision Rules for Identifying Patients at Low Risk of Severe Intracranial Injury After Minor Head Trauma in Cohorts With Different Presenting Characteristics[a]

Rule	No. of Studies	% (95% CI)[b] Sensitivity	Specificity	Positive LR (95% CI)[b]	I^2, %	Negative LR (95% CI)[b]	I^2, %	Probability of Severe Intracranial Injury, (95% CI), % ≥1 Finding Present[c]	No Findings Present[c]
Patients With Loss of Consciousness, Amnesia, or Disorientation									
Canadian CT head rule[19,26-29]	5	99 (78-100)	40 (34-46)	1.6 (1.5-1.8)	97	0.04 (0-0.65)	95	11 (10-12)	0.31 (0-4.7)
NEXUS-II[29]	1	84 (75-90)	35 (31-40)	1.3 (1.2-1.4)		0.47 (0.30-0.73)		9.0 (8.4-9.7)	3.5 (2.2-5.3)
New Orleans criteria[19,22,26,28,29]	5	99 (90-100)	13 (8.1-22)	1.1 (1.1-1.2)	95	0.08 (0.01-0.84)	41	7.8 (7.8-9.0)	0.61 (0.08-6.0)
Patients With or Without Loss of Consciousness, Amnesia, or Disorientation									
Canadian CT head rule[19,23]	2	86-87	39-50	1.4-1.7		0.29-0.33		9.7-12	2.2-2.5
NICE[20]	1	86 (80-90)	46 (44-48)	1.6 (1.5-1.7)		0.31 (0.23-0.43)		11 (10-12)	2.3 (1.7-3.2)
New Orleans criteria[19,23]	2	95-99	3.1-19	1.0-1.2		0.26-0.26		7.1-8.4	1.9-1.9
NCWFNS[19,23]	2	97-98	2.9-14	1.0-1.2		0.17-0.58		7.1-8.4	1.3-4.2

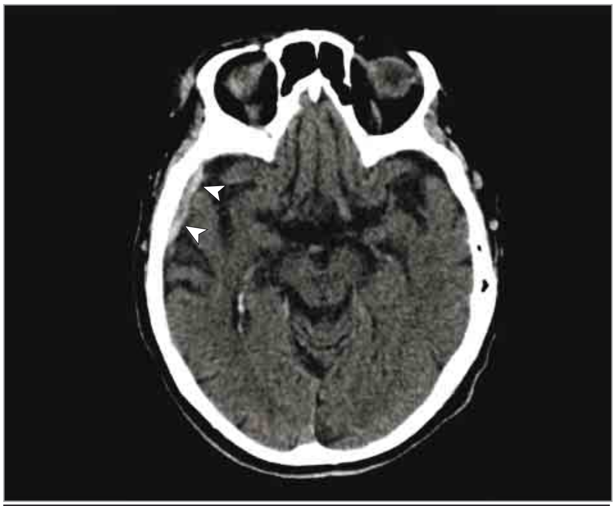
Abbreviations: CT, computerized tomography; LR, likelihood ratio; NCWFNS, Neurotraumatology Committee of the World Federation of Neurosurgical Societies; NEXUS, National Emergency X-ray Utilization Study; NICE, National Institute for Clinical Excellence.

[a] See eTable 5 in the Supplement for results from individual studies.

[b] For findings evaluated in only 1 study point estimate and 95% CI shown, findings evaluated in 2 studies are shown as range, and findings evaluated in 3 or more studies are shown as summary measure with 95% CI and I^2.

[c] Values based on a baseline prevalence of injury of 7.1%.

Figure 2. Subdural Hemorrhage on Head–Computed Tomographic Scan



Single slice of noncontrast computed axial tomographic scan of the head showing a small acute hematoma (arrows) without any mass effect in the middle cranial foss on the patient's right side.

may later develop symptoms of these conditions or postconcussive syndrome. We did not assess the ability of the clinical assessment to identify these injuries, which often only lead to signs or symptoms hours to days after the initial injury, or which are only visible with magnetic resonance imaging or contrast-enhanced CT. On discharge all patients should be instructed to follow-up with a physician, if they develop new or worsening symptoms.

No included studies directly compared the performance of clinical decision rules to physician judgment. This is a crucial step in the development of a decision rule because there is little value in a rule that misses injuries and increases the frequency of CT acquisition compared with physician judgment. Studies report mixed results of the effect of the rules on the frequency of CT acquisition.[19,28,36,37] In North America, where CTs are obtained frequently for patients with minor head trauma, application of the rules could result in a potential reduction in CT acquisition.[28] In terms of actual implementation of the rules into practice, the only randomized study showed no difference in CT acquisition in Canada before and after implementation of the Canadian CT Head rule.[38] However, there was a low baseline frequency of CT acquisition in this study that showed a secular trend of increased CT acquisition in both implementation and control emergency departments. Potential barriers to implementation that may limit the effect of the rules include patient expectations, physician concern that the rule does not work as well as clinical judgment, CT being perceived as the local standard of care, medicolegal concerns, or perception that CT results in a more efficient disposition of patients.[37,39,40]

The effect of the rules on clinical practice is also unclear. Overall, decision analyses suggest the rules can be cost-effective compared with imaging all patients with minor head injury or not imaging any patients. However, analyses have not compared the performance of the rules to current practice or physician judgment.[10,41-43] Moreover, the conclusions of decision analyses are heavily affected by assumptions about the management of patients who are not low risk based on the rules (observation, CT, or discharge), as well as the costs resulting from CT radiation and missed injuries.

Scenario Resolution

Case 1

Despite the absence of loss of consciousness, this patient's presentation is concerning for an intracranial injury. She does not have any of the signs of moderate or severe head trauma that would mandate immediate CT, such as altered mental status or depressed GCS score. However, her repeated vomiting is a concerning feature that should prompt referral and head CT. Assuming a pretest probability of 6.8% (the lower bound of 95% CI for the prevalence of intracranial injury), the posttest probability with 2 episodes of vomiting is 21% for intracranial injury. Her vomiting and age are features of the Canadian Head CT Rule and New Orleans Criteria.

The patient underwent a head CT upon referral to the emergency department, revealing a subdural hemorrhage (**Figure 2**). The patient was admitted to the hospital and observed for 48 hours. Her symptoms improved, results from her neurologic examination remained normal, and she was discharged from the hospital after 48 hours of observation with outpatient neurosurgical follow-up in 2 weeks and detailed follow-up instructions.

Case 2

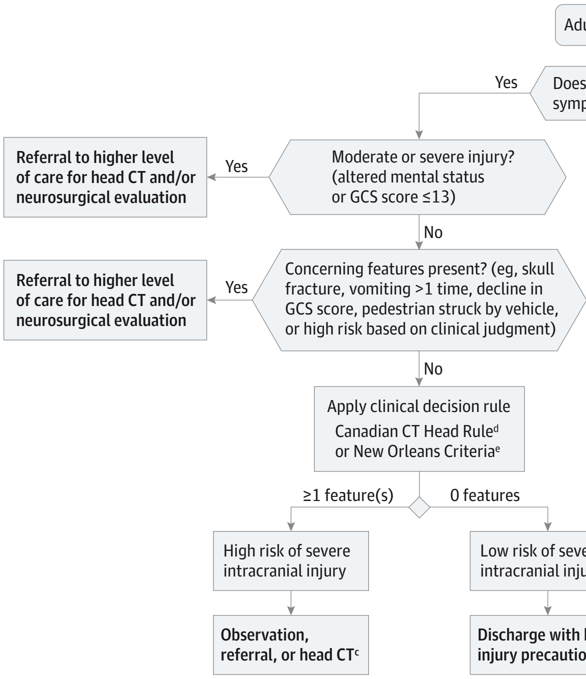
This patient does not have moderate or severe head trauma or any of the concerning features that would mandate emergency CT acquisition. Therefore, a clinical decision rule can be applied to assess if the patient is at low risk of intracranial injury and can be discharged safely. This patient does not meet any of the criteria for CT by the Canadian CT Head Rule. Assuming a pretest probability of 7.4%—the upper bound of the 95% CI for the prevalence of intracranial injury—the posttest probability of intracranial injury with none of the features of the Canadian Head CT rule is 0.32%. Notably, the patient did have a headache, 1 of the features of the New Orleans Criteria. However, the presence of 1 of the variables of the rule does not mandate CT acquisition.

Despite loss of consciousness and a headache, this patient did not undergo CT. Based on clinical judgment augmented by the Canadian CT Head Rule, he was discharged with an accompanying adult. He was given strict precautions to return if he developed severe or worsening headache, multiple episodes of vomiting, seizure, or worsening mental status. On follow-up 1 week later, he was symptom free and cleared to return to his normal activities.

Discussion

No individual historical or physical examination features can completely rule out intracranial injury following minor trauma. Prior studies of minor head trauma have limited their cohorts to patients with loss of consciousness or amnesia implying that patients without these features are not at significant risk of injury. However, the summary LRs associated with the absence of these signs are inadequate to rule out injury (loss of consciousness LR, 0.60; 95% CI, 0.39-0.81; amnesia LR, 0.55; 95% CI, 0.31-0.97).[21,23,24,27-29] Patients without these features remain at risk of intracranial injury and require evaluation (**Figure 3**). On initial evaluation, patients without objective evidence of trauma to the head or symptoms of head trauma 2 hours

Figure 3. Evaluation of Patients With Potential Head Trauma[a]



[a] These recommendations are intended to provide general support for decision making and should not replace clinical judgment. CT indicates computed tomography; GCS, Glasgow Coma Scale.

[b] Dangerous mechanisms is a pedestrian struck by a vehicle, an occupant ejected for a motor vehicle, or a fall from elevation of more than 1 m or 5 stairs.

[c] The decision to discharge, observe or order a CT scan depends on the setting, clinician's judgement about the likelihood of injury, patient preference, number of features present, and the particular features present.

[d] The Canadian CT Head Rule includes age 65 years or older, dangerous mechanism, vomiting more than once, amnesia for more than 30 minutes, GCS score of less than 15 at 2 hours, or a skull fracture.

[e] The New Orleans Criteria includes older than 60 years, intoxication, headache, any vomiting, seizure, amnesia, visible trauma above the clavicle.

after their injury can typically be discharged in the company of an adult, with precautions to return for further evaluation if they develop (1) multiple episodes of emesis; (2) severe or worsening headache; (3) seizure; or (4) deteriorating mental status. Although most patients with intracranial injuries will display signs or symptoms of intracranial injury on initial evaluation, patients older than 60 years, with a coagulopathy, or dangerous mechanism can still have intracranial injuries despite the absence of signs or symptoms. These patients may require observation or head CT.

Several historical and physical examination features are highly associated with intracranial injury and should likely prompt referral and observation or CT. Studies of minor head trauma often include patients with GCS scores of 13. Such patients frequently harbor intracranial injuries (LR, 4.9; 95% CI, 2.8-8.5), and therefore from a decision-making perspective, would be more aptly considered to have moderate head trauma.[19,27,28] Like patients with severe head trauma (GCS score ≤8), these patients should be referred for emergency care and undergo observation or CT. In patients with more minor trauma (GCS scores of 14-15 and minimal alterations in mental status), pedestrians struck by a motor vehicle (LR, 3.0-4.3), signs of skull fracture (LR, 16; 95% CI, 3.1-59), decline in GCS score (LR range, 3.4-16), and multiple episodes of vomiting (LR, 3.6; 95% CI, 3.1-4.1) were highly predictive of intracranial injury.[21,24,27-29] These features are relatively uncommon in patients with minor head trauma, but when they are present should raise concern for intracranial injury and typically prompt an emergency CT scan. Ultimately the decision to obtain a CT will depend on the overall clinical scenario, eg, a pedestrian brushed by a motor vehicle at very low speed, who is asymptomatic, does not usually require a head CT.

Other features classically described with head injuries do not substantially increase the likelihood of intracranial injury. Although the absence of loss of consciousness and amnesia do not rule out intracranial injury, the presence of these features does not markedly increase the risk of intracranial injury (loss of consciousness LR, 1.6; 95% CI, 1.1-2.1; amnesia LR, 1.5; 95% CI, 0.81-2.8).[21,23,24,27-29] Other commonly described features of head injury, including headache, nausea, intoxication, dizziness, and signs of trauma above the clavicle had LRs of less than 2 for intracranial injury. For all of these features, the decision to obtain a CT depends on many factors including the setting, provider experience, patient preference, and number of features present.

All patients with minor head trauma do not require neuroimaging. Both the Canadian CT Head Rule and New Orleans Criteria provide a series of historical and physical examination features that can be applied to patients to help determine whether patients are at sufficiently low risk of intracranial injury as to be discharged without observation or neuroimaging. Both rules have been extensively validated and result in an extremely small number of missed injuries. With higher specificity in all but one included study, the Canadian CT Head Rule resulted in fewer negative CTs than the New Orleans

Criteria.[19,22,23,26-29] Although the upper bound of the CIs for these rules in certain cohorts may cause physicians to hesitate in accepting them for their potential to rule out intracranial injury, the Choosing Wisely campaign recently included utilization of these clinical decision rules as 1 of 5 key recommendations aimed at reducing costs and improving patient care.[44]

There are several important considerations when applying the rules to a patient with head injury. It is crucial that the rules are applied accurately with the intended patient population (eg, neither rule was studied extensively in patients with coagulopathy, intoxication, age >75 years, or presenting >24 hours after injury). In addition, while described as "rules," these instruments should augment and not replace clinical judgment. For example, the rules were not intended for application to very low-risk patients with trivial injuries (eg, healthy adult walking into an object at low speed) or high-risk patients (eg, elderly patient, who is supratherapeutic on warfarin, struck in the head by a baseball). Application of the rules indiscriminately to these patients deemed at very low or high risk of injury based on clinical judgment could increase the frequency of CT utilization or missed injuries.

Notably with their high sensitivity and low to intermediate specificity, the rules are also designed to identify patients at low risk of injury who do not require CT. Often they are misinterpreted as the presence of one of the features of the rule mandates CT acquisition. The decision to discharge, observe, or recommend CT to the patient with at least 1 feature of a rule depends on the setting, clinician's judgment about the likelihood of injury, patient preference, number of features present, and the particular features present. If observed, patients should undergo CT if their signs or symptoms worsen.

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Conflict of Interest Disclosures: All authors have completed and submitted the ICMJE Form for Disclosure of Potential Conflicts of Interest. Dr Easter reports that he has received grants from Agency for Healthcare Research and Quality, during the conduct of the study. Dr Meehan reports receiving grants from the National Football League Players Association, the National Hockey League Alumni Association, ABC-CLio Publishing, and Wolters Kluwer. No other disclosures were reported.

Funding/Support: This work was supported in part by grants K12 HS019464-01, Physician Scientist Award (Dr Easter), and K02 HS017526, an Independent Scientist Award (Dr Haukoos), both from the Agency for Healthcare Research and Quality, R01AI106057 from the National Institute of Allergy and Infectious Diseases (Dr Haukoos), the National Football League Players Association (Dr Meehan), and the National Hockey League Alumni Association through the Corey C. Griffin Pro-Am Tournament (Dr Meehan).

Additional Contributions: We thank Ali Raja, MD, MBA, MPH, Brigham and Women's Hospital; Jeffrey Bytomski, DO, Duke University; Cory Adamson, MD, PhD, MHSc, MPH, Emory School of Medicine and Atlanta Veterans Affairs Medical Center; David Simel, MD, Durham Veterans Affairs Medical Center and Duke University; Joshua Broder, MD, Duke University Medical Center for their critical commentary on previous versions of this article; Ryan Friedberg, MD, Beth Israel Deaconess Medical Center for study selection and data extraction; Karen Knight, MSLS, University of Virginia, for assistance with the literature search. None of whom received compensation for their assistance.

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