Predicting intracranial computed tomography findings in patients with minor head injury by using logistic regression

Clinical article

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Object. The aim of this study was to develop a decision rule for physicians in developing countries to identify patients with minor head injury who will benefit from emergency brain CT scanning.

Methods. Three hundred eighteen patients with a history of blunt head trauma and a Glasgow Coma Scale (GCS) score ≥ 13 who had presented within 12 hours of trauma underwent nonenhanced brain CT and were included in this prospective study. Computed tomography findings that necessitated neurosurgical care (either observation or intervention) were considered as positive findings. Logistic regression was used to develop the decision rule.

Results. Computed tomography scans were always normal in patients < 65 years old who did not have an obvious head wound, a raccoon sign, vomiting, memory deficit, or a decrease in their GCS score. Patients with 1 major criterion (GCS score < 14, raccoon sign, failure to remember the impact, age > 65 years, or vomiting) or 2 minor criteria (wound at the scalp or GCS score < 15) had an abnormal CT scan in 13% of the cases.

Conclusions. The decision rule developed by the authors appears to be 100% sensitive and 46% specific for positive findings on brain CT and will, in developing countries, help clarify the decision to obtain scans.

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KEY WORDS • minor head injury • decision rule • computed tomography scan • logistic regression

Minor head injury is defined as a history of LOC, amnesia, or disorientation in a conscious and talking patient, that is, one with a GCS score of 13–15. Patients with minimal head injury may not experience an LOC or other neurological alteration. There is some variation in the definition of minor head injury. In this paper, patients with a history of blunt head trauma presenting with a GCS score of 13–15 on the initial emergency department evaluation were considered to have minor head injuries.

Minor head injuries constitute ~ 70–90% of all treated brain injuries. Different studies have estimated the prevalence of significant intracranial lesions on CT from 0.7% to as high as 20%. Because most of these patients have insignificant injuries requiring no specific therapy, some authorities are reluctant to advocate CT studies in all such patients. In contrast, other authorities, concerned with the potentially dramatic consequences of a missed finding, tend to encourage the liberal use of brain CT in such patients.

Patients with moderate to severe head injury usually show obvious clinical signs, simplifying the decision to perform a head CT scan; however, this decision becomes less evident when evaluating those with minor head injury. The estimated number of patients with head trauma in the US ranges from 800,000 to 2 million cases annually. Of these cases, > 80% are classified as minor head injuries.

The incidence of hospital-treated patients with mild traumatic brain injury is ~ 100–300 cases per 100,000 population. Note, however, that such mild traumatic brain injury is not treated at hospitals, and the true population-based rate is probably > 600 cases per 100,000 population.

Annually in the US, 1 million patients with blunt head trauma undergo head CT scanning.
Decision rules that help physicians identify patients with clinically significant lesions on CT would reduce the number of scans performed and save millions of dollars in unnecessary scans. A 10% reduction in the number of scans ordered for minor head injury could result in a $20 million reduction in healthcare expenditures in the US. Of course, CT scanning is an expensive modality in developing countries as well. Additional benefits would include saving time, reducing overcrowding in the emergency and radiology departments, and preventing unnecessary transfers from facilities without access to CT.$20 million reduction in healthcare expenditures in the emergency and radiology departments, and preventing unnecessary transfers from facilities without access to CT.

In another study, we developed a decision rule for rural physicians to identify which patients with minor head injury could be safely monitored without the need to refer them for CT scanning. The Deputy of Health in the Iranian Ministry of Health and Medical Education supported the current study to verify our previous findings. In the present study, we used logistic regression to differentiate the subset of patients with minor head injury who may demonstrate intracranial lesions if they underwent brain CT scanning. Our goal was to develop a guideline for rural physicians in developing countries to determine which patients with minor head injury would need CT scanning.

**Methods**

In this prospective study we evaluated patients 15–70 years old with a history of blunt head trauma who had presented within 12 hours after trauma and had a GCS score ≥ 13. The following patients were excluded from analysis: 1) opium-addicted patients, 2) those with concurrent major wounds or fractures that necessitated specialized care in a hospital, 3) patients whose condition was unstable and who could not be safely transferred to the radiology department, 4) patients suspected of malingering, and 5) those who refused to participate in the study. After the interview and physical examination, all patients underwent nonenhanced brain CT scanning. Skull radiographs were not routinely obtained. In each hospital, patients were examined by 1 of 4 physicians dedicated solely to the evaluation of participants in this study. The physicians were not allowed to take part in any other activities at the hospital, and they remained on standby from 1 patient to the next. Physicians were blinded to the results of the brain CT scans at the time of clinical evaluation.

A protocol was developed to obtain the patient history and perform the physical examination. To ensure protocol standards, a wireless video camera was used to monitor the first 10 physical examinations performed by every physician. For the remainder of the data-gathering period, a digital voice recorder was used to record the voices of the patients and physicians during both physical examinations and interviews. A quality-control team listened to all recordings; in the event of any protocol deviation while gathering data, prompt feedback was given to the physician. All physicians blindly examined 6 medical students who had been trained to mimic a patient with a specific minor head injury. The physicians then received relevant feedback according to their evaluation from this standardized group.

To minimize any mistakes in data gathering, we compared all paper records with the voice records and thoroughly evaluated any discrepancies. To minimize the risk of data entry error, paper records were double entered into Epi Info 2000 by different operators and were automatically compared to reveal any discrepancies.

A single radiologist, who was blinded to the patients' clinical states, interpreted all CT scans at the end of the study. A single neurosurgeon reviewed reports indicating any abnormal findings. Results necessitating neurosurgical care, either supervision or intervention, were regarded as positive findings. The following findings were considered positive: skull fracture (including depressed, linear, mastoid, comminuted, basilar, and sphenoid fracture), intracranial hemorrhage (including epidural, subdural, subarachnoid, intraparenchymal, and petechial hemorrhage), brain contusion, pneumocephalus, midline shift, and the presence of an air fluid level.

In a tabular analysis, the statistical relationship between the positive finding and signs and symptoms was evaluated using a chi-square test. The Student t-test was used to compare the mean of continuous variables among the patients. The Type I error level was set at 0.05 for all statistical tests.

To develop a predictive model, a logistic regression analysis was performed using STATA, version 8 (Stata Corp.); the “robust” option was used to estimate the coefficients. The variables in the model were dichotomous except for “amount of GCS decline,” which could take values 0, 1, or 2. Because of collinearity, we had to keep either “failure to remember the impact” or “retrograde amnesia.” We preferred the former given the simplicity of examination at the clinic and a lack of missing values.

Predictive variables were entered into the model and removed automatically in a backward elimination process. In the case of collinearity among variables, only 1 of them was entered into the model. To evaluate the usefulness of the model, logit π was calculated for all patients and plotted in an ROC curve; the area under the curve was calculated as well.

No medical service was deferred because of this study. Informed consent was obtained from all patients. The medical ethics committee approved the study protocol.

**Results**

Four hundred ten patients 15–70 years of age with a history of blunt head trauma and a GCS score ≥ 13 who had presented within 12 hours of trauma at 2 university hospitals in Tehran were screened for this study. Ninety-two patients were excluded according to our exclusion criteria (Table 1). Three hundred eighteen patients remained in the study; 76% of patients were male and 24% were female. The mean age of the male patients was 31 ± 14 years, and of the females, 39 ± 16 years; the difference was statistically significant (p < 0.001).

A traffic accident was the most prevalent cause of injury among patients of both sexes, followed by falls (Table 2).

The GCS score was 15 in 89.5% of the patients, 14 in
The purpose of this study was to develop a decision rule for rural physicians to identify which patients with minor head injury need to undergo brain CT scanning. In the treatment of patients with head injury, it is important to detect all significant intracranial findings, and thus the decision rule should provide as high as possible sensitivity.

For our decision rule to be 100% sensitive, it is necessary to refer all patients with logit $\pi \geq -4.08$ for CT scanning (Table 3). The presence of some signs and symptoms in the model that are considered to be major criteria could result in a logit $\pi > -4.08$. The presence of other sets of signs and symptoms (that is, minor criteria) is not enough to raise logit $\pi > -4.08$. The coefficients of variables differentiate the major and minor criteria. A coefficient $>1.109$ indicates a major criterion given that its presence is enough to raise logit $\pi$ to $-4.08$ regardless of the presence of other signs and symptoms.

Major criteria included a GCS score $<14$, presence of the raccoon sign, failure to remember the impact, an age $>65$ years, and vomiting after impact; minor criteria included a GCS score $<15$, an age $>5$ and $15$ minutes, an age $>55$ years, and retrograde amnesia $>5$ and $30$ minutes had probability values between $0.05$ and $0.20$.

The logistic regression model (logit $\pi$) is as follows: $-5.189 + [1.001(amount\ of\ GCS\ score\ decline)] + [0.715(presence\ of\ wound\ at\ scalp)] + [1.614(occurrence\ of\ vomiting)] + [2.134(presence\ of\ raccoon\ sign)] + [2.335(age > 65 years)] + [1.109(failure\ to\ remember\ impact)].$ The area under the ROC curve plotted for the model (Fig. 1) was 89.6% (95% CI 84–95%).

By increasing logit $\pi$, the sensitivity of the model to detect every positive finding began to decrease, and at the same time the specificity of the model increased (Table 3). None of the patients with positive findings had a logit $\pi < -4.08$.

Discussion

The purpose of this study was to develop a decision rule for rural physicians to identify which patients with minor head injury need to undergo brain CT scanning. In the treatment of patients with head injury, it is important to detect all significant intracranial findings, and thus the decision rule should provide as high as possible sensitivity.

For our decision rule to be 100% sensitive, it is necessary to refer all patients with logit $\pi \geq -4.08$ for CT scanning (Table 3). The presence of some signs and symptoms in the model that are considered to be major criteria could result in a logit $\pi > -4.08$. The presence of other sets of signs and symptoms (that is, minor criteria) is not enough to raise logit $\pi$ to $-4.08$. The coefficients of variables differentiate the major and minor criteria. A coefficient $>1.109$ indicates a major criterion given that its presence is enough to raise logit $\pi$ to $-4.08$ regardless of the presence of other signs and symptoms.

Major criteria included a GCS score $<14$, presence of the raccoon sign, failure to remember the impact, an age $>65$ years, and vomiting after impact; minor criteria included a scalp wound and a GCS score $<15$.

According to the current model, if CT scanning is ordered for patients with 1 major criterion or 1 minor plus another minor or a major criterion, a sensitivity of 100% against a specificity of 46% would be achieved. Because logit $\pi$ for 43% of the patients was $< -4.08$ (Table 3), in using the above decision rule, only 57% of our patients would be referred for brain imaging.

On the basis of our data, none of the patients who, according to our criteria, should not be referred for imaging would have intracranial findings, whereas 13% of those referred for imaging would have findings on CT.

A normal GCS score after a minor head injury does not guarantee the absence of significant neurological injury, as 0.6% of such patients require neurosurgical intervention. According to our data, the presence of some signs and symptoms should be considered as an indication for CT scanning even in patients with a normal GCS score.

### TABLE 1: Criteria for the exclusion of patients with mild head trauma

<table>
<thead>
<tr>
<th>Reason for Exclusion</th>
<th>No. of Patients</th>
</tr>
</thead>
<tbody>
<tr>
<td>patient refusal to participate in study</td>
<td>42</td>
</tr>
<tr>
<td>concomitant injury necessitating urgent medical intervention (other than neurosurgical)</td>
<td>21</td>
</tr>
<tr>
<td>incomplete medical data</td>
<td>11</td>
</tr>
<tr>
<td>suspected malingering due to legal conflicts</td>
<td>9</td>
</tr>
<tr>
<td>CT units out of service</td>
<td>5</td>
</tr>
<tr>
<td>patient addicted to opium</td>
<td>4</td>
</tr>
<tr>
<td>total</td>
<td>92</td>
</tr>
</tbody>
</table>

8.6%, and 13 in 2%. Twenty patients (6.3%) had positive intracranial findings on CT. The different lesions demonstrated on the brain scans were as follows: depressed fracture (6 cases), comminuted fracture (1 case), basal skull fracture (4 cases), frontal or ethmoid sinus fracture (4 cases), lamina papyracea fracture (1 case), hemorrhage into the sphenoid sinus (2 cases), epidural hematoma (2 cases), subdural hematoma (3 cases), intraparenchymal hematoma (4 cases), intraventricular hemorrhage (1 case), subarachnoid hemorrhage (2 cases), petechial hemorrhage (3 cases), brain contusion (2 cases), pneumocephalus (3 cases), brain edema or swelling (11 cases), midline shift (1 case), and compression of subarachnoid cisterns (3 cases). (The total number of lesions exceeds 20 because most patients had $>1$.) None of the patients had an air fluid level on CT. Ten patients needed craniotomy according to the attending neurosurgeon; other patients received conservative care. All patients were discharged from the hospital alive except a 70-year-old patient who had an intraparenchymal hematoma, basal skull fracture, and hemorrhage into the sphenoid sinus and died after surgery.

On univariate tabular analysis, the following variables were significantly related to positive findings on a patient’s brain CT scan: age $>65$ years, a GCS score $<15$, the presence of other signs and symptoms, and retrograde amnesia $>15$ minutes.

The following variables were not significantly related to positive findings on brain CT: wound at the scalp, posttraumatic amnesia, anesthesia after trauma, otorrhea, otorrhagia, a battle sign, patient sex, abnormal behavior on admission, nausea, dizziness, generalized headache, pupil size, impaired direct or indirect pupil reflex, nystagmus, blurred vision, use of anticoagulants, mechanism of trauma, position in the traffic accident, and systolic and diastolic blood pressure. Of the variables not related to positive CT findings, anesthesia $>5$ and $15$ minutes, an age $>55$ years, and retrograde amnesia $>5$ and $30$ minutes had probability values between $0.05$ and $0.20$.

The logistic regression model (logit $\pi$) is as follows: $-5.189 + [1.001(amount\ of\ GCS\ score\ decline)] + [0.715(presence\ of\ wound\ at\ scalp)] + [1.614(occurrence\ of\ vomiting)] + [2.134(presence\ of\ raccoon\ sign)] + [2.335(age > 65 years)] + [1.109(failure\ to\ remember\ impact)]$. The area under the ROC curve plotted for the model (Fig. 1) was 89.6% (95% CI 84–95%).

### TABLE 2: Mechanisms of injury, according to patient sex

<table>
<thead>
<tr>
<th>Injury Mechanism</th>
<th>M (%)</th>
<th>F (%)</th>
<th>Overall (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>fall</td>
<td>17.4</td>
<td>28.4</td>
<td>19.9</td>
</tr>
<tr>
<td>traffic accident</td>
<td>63.6</td>
<td>62.2</td>
<td>63.3</td>
</tr>
<tr>
<td>hit by blunt object</td>
<td>12.4</td>
<td>8.1</td>
<td>11.4</td>
</tr>
<tr>
<td>other</td>
<td>6.6</td>
<td>1.4</td>
<td>5.4</td>
</tr>
<tr>
<td>total</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
</tbody>
</table>

By increasing logit $\pi$, the sensitivity of the model to detect every positive finding began to decrease, and at the same time the specificity of the model increased (Table 3). None of the patients with positive findings had a logit $\pi < -4.08$. 

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Miller et al.\textsuperscript{11} have studied awake patients (GCS Score 15) referred to the emergency department after an acute head injury associated with an LOC (Table 4). These authors proposed the use of 4 clinical criteria (severe headache, nausea, vomiting, and depressed skull fracture on physical examination) to define minor head injury, which allowed a 61% reduction in the number of head CTs performed and still identified all patients who required neurosurgical intervention and most of those with an abnormal scan.

Miller and colleagues\textsuperscript{31} criteria were developed for patients with no decline in GCS scores, whereas our study included patients with GCS score decreases of up to 2 points. A comparison of their analysis with our current study is represented in Table 4. In our model, the depressed fracture proposed by Miller et al. is substituted with a scalp wound, which is easier for rural physicians to detect.

Haydel et al.\textsuperscript{7} have developed criteria for CT scanning in patients with minor head injury by using a recursive-partitioning analysis of 1429 such patients referred to a single institute with a GCS score of 15. Their criteria, known as the New Orleans Criteria, consist of headache, vomiting, age > 60 years, drug or alcohol intoxication, deficits in short-term memory, physical evidence of trauma above the clavicles, and seizure (Table 4). The presence of any of these factors in a patient with minor head injury was considered to be an indication for CT scanning. These criteria led to a sensitivity of 100% and a specificity of 25%, although authors of later studies have reported lower specificity, that is, 12.1–12.7\textsuperscript{20} or even 3–5.6%.\textsuperscript{28} Among the criteria proposed by Haydel and associates,\textsuperscript{7} the probability values for headache (0.16), vomiting (0.65), and coagulopathy (0.78) were not significant on univariate analysis. Their study did not include patients without LOC or amnesia, because at their center CT scans are not routinely ordered for such patients. Furthermore, the New Orleans Criteria were defined based on patients with no decrease in the GCS score on admission.

TABLE 3: Sensitivity and specificity of model at different levels of logit π and probability

<table>
<thead>
<tr>
<th>Logit π</th>
<th>Probability of Positive Finding on CT (%)</th>
<th>Cumulative % of Patients</th>
<th>Sensitivity (%)</th>
<th>Specificity (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>-5.19</td>
<td>0.6</td>
<td>23.3</td>
<td>100</td>
<td>0</td>
</tr>
<tr>
<td>-4.47</td>
<td>1.1</td>
<td>41.7</td>
<td>100</td>
<td>25</td>
</tr>
<tr>
<td>-4.19</td>
<td>1.5</td>
<td>43.0</td>
<td>100</td>
<td>44.6</td>
</tr>
<tr>
<td>-4.08</td>
<td>1.7</td>
<td>51.3</td>
<td>100</td>
<td>46.1</td>
</tr>
<tr>
<td>-3.57</td>
<td>2.7</td>
<td>58.7</td>
<td>95</td>
<td>54.6</td>
</tr>
<tr>
<td>-3.47</td>
<td>3.0</td>
<td>60.3</td>
<td>95</td>
<td>62.5</td>
</tr>
<tr>
<td>3.00</td>
<td>95.3</td>
<td>100</td>
<td>0</td>
<td>100</td>
</tr>
</tbody>
</table>

* According to our rule.

In contrast to the New Orleans Criteria, our decision rule is applicable for all patients with a history of blunt head trauma regardless of their GCS score; it appears to be 100% sensitive and 46% specific for positive findings. The relatively large sample in the study by Haydel and colleagues compared with ours (1429 vs 318 patients) makes the estimates of the sensitivity and specificity of their criteria more stable than our estimates. Therefore, our criteria should not necessarily be considered more specific than the New Orleans Criteria. Note, however, that there is no evidence that our decision rule is less specific. Both models contain variables that did not have a statistically significant relationship with positive findings on univariate analysis but did on multivariable analysis.

Stiell et al.\textsuperscript{22} have developed the Canadian CT head rule based on a multicenter study of 3121 patients with minor head injury (Table 4). This rule consists of 5 high-risk criteria that suggest the risk of neurological intervention (sensitivity 100% and specificity 68.7%); some later studies have revealed a lower specificity of 37.2\textsuperscript{18} and 2 medium-risk criteria that suggest the risk of significant brain injury on CT (sensitivity 98.4% and specificity 49.6%); later studies have demonstrated a specificity of 39.4\textsuperscript{18}. The presence of any of the 7 criteria indicates the need for a brain CT scan to detect a clinically significant injury. Using the Canadian CT head rule, 46% of patients would not need to undergo CT scanning. In developing this head rule, patients with minimal head injury were not included because patients without LOC, amnesia, or disorientation were excluded from the study, and not all patients underwent CT scanning based on the judgment of their treating physician.\textsuperscript{22} Note, however, that we included all patients with a history of blunt head trauma.

Our study is different from those described above in terms of “external validity.” The Miller and colleagues’ criteria and the New Orleans Criteria (Haydel et al.)\textsuperscript{7} were developed for minor head injury accompanied by a normal GCS score on admission. The Canadian CT head rule included minor head injury and a GCS score of 13–15; however, in developing the Canadian head rule, only those patients whose treating physician had prescribed brain CT actually underwent the procedure. Moreover, none of the above studies included patients with minimal head injury,

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TABLE 4: Comparison of study criteria to perform CT scanning in patients with minor head trauma

<table>
<thead>
<tr>
<th>Factor</th>
<th>Miller et al., 1997</th>
<th>Haydel et al., 2000*</th>
<th>Stiell et al., 2001†</th>
<th>Smits et al., 2007‡</th>
<th>Present Study§</th>
</tr>
</thead>
<tbody>
<tr>
<td>criteria to perform CT</td>
<td>nausea, severe headache, vomiting, drug or alcohol intoxication, short-term memory deficits, trauma above clavicles, seizure</td>
<td>age &gt;60 yrs, headache, vomiting, drug or alcohol intoxication, sign of basal skull fracture, severe headache, posttrauma amnesia &gt;4 hrs, clinical signs of skull fracture, GCS score &lt;15 at 2 hrs after trauma;</td>
<td>high-risk criteria: age &gt;65 yrs, suspected open or depressed skull fracture, &gt;2 vomiting episodes, sign of basal skull fracture, GCS score &lt;15 at 2 hrs after trauma;</td>
<td>major criteria: pedestrian or cyclist vs vehicle, ejected from vehicle, vomiting, posttrauma amnesia &gt;4 hrs, clinical signs of skull fracture, GCS score &lt;15, GCS deterioration &gt;2 points, use of anticoagulants, posttrauma seizure, age &gt;60 yrs; minor criteria: fall from any elevation, persistent anterograde amnesia, posttrauma amnesia of 2–4 hrs, skull contusion, neurological deficit, LOC, GCS score drop of 1 point, age 40–60 yrs</td>
<td>major criteria: GCS score &lt;14, raccoon sign, failure to remember the impact, age &gt;65, vomiting after impact; minor criteria: a scalp wound, GCS score &lt;15</td>
</tr>
<tr>
<td>patients included in study</td>
<td>GCS Score 15</td>
<td>GCS Score 15 w/ LOC or amnesia</td>
<td>GCS Score 13–15 w/ witnessed LOC, definite amnesia, or witnessed disorientation; CT prepared according to treating physician's judgment</td>
<td>GCS Score 13–14, or GCS Score 15 w at least 1 of following risk factors: history of LOC, short-term memory deficit, amnesia for traumatic event, posttrauma seizure, vomiting, severe headache, clinical evidence of intoxication, use of anticoagulants or history of coagulopathy, external evidence of injury above clavicles, neurological deficit</td>
<td>GCS Score 13–15 including min head injury</td>
</tr>
<tr>
<td>patients excluded from study</td>
<td>no LOC</td>
<td>no LOC or amnesia, declined CT, concurrent injury precluding use of CT</td>
<td>min head injury (no LOC, amnesia, or disorientation), seizure before assessment in hospital</td>
<td>transferred from another hospital, CT contraindicated, or concurrent injuries precluding head CT on presentation</td>
<td>suspected of malingering, concomitant major injury in other organs necessitating in-hospital specialized care, opium addict</td>
</tr>
<tr>
<td>reduction in no. of CTs based on criteria</td>
<td>61% (original study)</td>
<td>22% (original study), 3% (external validation)¶</td>
<td>46% (original study), 37.3% (external validation)¶</td>
<td>23–30% (original study)</td>
<td>43% (original study)</td>
</tr>
</tbody>
</table>

* New Orleans Criteria.
† Canadian CT head rule.
‡ The CHIP study.
§ Current study included a broader category of patients with mild head injury. The model was developed for rural physicians in developing countries; therefore, it used simple signs and symptoms easy for general physicians to measure.
¶ Smits et al., 2005.
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as an LOC, amnesia, and disorientation were essential for patients to enter these studies. However, we included patients with a GCS score of 13–15 on presentation to the emergency department regardless of their history of loss of memory or consciousness or disorientation.

Smits et al.19 have proposed a CHIP prediction rule consisting of 10 major and 8 minor criteria (Table 4) based on a multicenter study of 3181 patients. Their study included a broader population of patients with minor head injury compared with those in the Miller et al.,21 Haydel et al.,7 and Stiell et al.22 studies. However, in the Smits et al. study, patients with a GCS score of 15 were included if they had some concomitant risk factor.19 We studied all patients with minor head injury whose GCS score was 13–15 regardless of any other concomitant risk factors. Therefore, the results of our study could be applied to a broader spectrum of patients with minor head injury.

Our study covers a broader spectrum of patients in terms of outcome measure as well. The New Orleans Criteria considered any acute intracranial injury on CT scan as the primary outcome measure (subdural, epidural, or parenchymal hematoma; subarachnoid hemorrhage; cerebral contusion; or depressed skull fracture7), whereas the Canadian CT head rule used neurosurgical intervention as the primary outcome measure and clinically significant intracranial injuries as the secondary outcome measure. The authors of the Canadian CT head rule study argued that small solitary cerebral contusions, small subarachnoid hemorrhages, small subdural hematomas, and isolated pneumatic phalaxus were not clinically important because these lesions typically do not require neurosurgical intervention.6 The primary outcome measure in the CHIP prediction rule was any traumatic intracranial finding on CT, which included all traumatic neurocranial findings except for isolated linear skull fractures.19 A secondary outcome measure in the CHIP prediction rule was neurosurgical intervention contingent on the initial CT. However, we considered broader intracranial findings on CT as an outcome measure including linear skull fracture as well as depressed, mastoid, comminuted, basilar, and sphenoid fracture; epidural, subdural, subarachnoid, intraparenchymal (including petechial), and intraventricular hemorrhage; brain contusion; pneumatic phalaxus; and midline shift.

Using our decision rule, the number of CT scans in the target population could be reduced up to 43%. The resultant reduction in the number of scans following the application of other criteria is displayed in Table 4, but note that the target populations of the reviewed studies are different. Our study includes a broader population than that in the Canadian CT head rule study (Stiell et al.22). Moreover, the Canadian head rule study includes a larger population than those of the New Orleans and Miller criteria studies. Therefore, the potential of these criteria to safely reduce the number of brain CT scans could not be compared as a means of their cost containment advantage.

The low specificity of the decision rule we developed might lead to a considerable number of false-positive cases. However, this misclassification would not impose a large burden on patients as they would just be referred for a CT scan that would show normal findings. Therefore, we think it is not necessary to place another screening stage—that is, observation—before referring patients for CT scanning.

Our study was subject to limitations. Our failure to detect an association between intracranial lesions and some neurological signs and symptoms may be due to the absence of these signs and symptoms in minor head injury. In other words, an impact strong enough to produce a neurological sign would cause a moderate to severe head injury, and our study was not designed to develop a decision rule for patients with this type of injury. On the other hand, a larger patient sample could increase the possibility of detecting other neurological signs in patients with minor head injury and result in a better predictive power of the model.

The various times of scanning after trauma may be another limitation of our study. Patients underwent scanning after an initial evaluation at the emergency department regardless of the time elapsed since the trauma. If the sensitivity of a single CT scan depended on the time elapsed from the occurrence of trauma, we were unable to include it in the model.

Because of our limited sample size, we were unable to examine the consistency of the results across time strata, for example, 4-hour time periods; this factor should be addressed in future studies.

The aim of our study was to develop a decision rule for physicians in the rural areas of developing countries to determine which patients with minor head injury should be referred to the hospital for CT scanning. Therefore, we excluded patients with minor head injury accompanied by major trauma to other organs that necessitated specialized care in the hospital, as such patients should be referred to the hospital anyway. This factor may limit the external validity of our model to patients with isolated minor head injury without concomitant injury.

The presented decision rule is useful for rural physicians to decide which patients should be referred for CT scanning. The model needs a larger sample size and external validation before being capable of preventing a patient from being referred for CT scanning despite the clinical opinion of the attending physician.

Conclusions

The decision rule we developed is capable of determining which patients with minor head injury will have positive findings on brain CT scans and should be referred to the emergency room after blunt head trauma. The criteria used for this rule are simple and can be easily measured by rural health personnel in developing countries. However, the rule must be tested on a larger sample size.

Disclosure

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