Over the last several decades, cranial radiography has been used in patients with blunt head trauma to detect a skull fracture, which is an independent risk factor for a relevant intracranial lesion. However, the usefulness of cranial radiography as a routine method to detect a skull fracture is questionable in patients with minor head injury, a Glasgow Coma Scale (GCS) score of 13–15, witnessed loss of consciousness, definite amnesia, or witnessed disorientation. Radiation exposure and radiological expenses could be reduced by avoiding unnecessary plain head radiographs. Similarly, the extensive use of CT scanning increases radiation-related risk from unnecessary CT scans.

In the past 5 years there has been a shift in the recognition, characterization, and management of patients with traumatic brain injury (TBI). New developments regarding the search for valid risk factors for early diagnosis have occurred. A population-based study conducted in New Zealand found a substantially higher incidence of TBI than in previous studies (790 per 100,000 person-years; 95% CI 749–832). Therefore, sensitive decision rules are essential for the use of cranial CT as a reliable imaging modality for diagnosis of intracranial traumatic lesions.

Risk factors indicating the need for cranial CT scans in elderly patients with head trauma: an Austrian trial and comparison with the Canadian CT Head Rule

Clinical article

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**Object.** This study presents newly defined risk factors for detecting clinically important brain injury requiring neurosurgical intervention and intensive care, and compares it with the Canadian CT Head Rule (CCHR).

**Methods.** This prospective cohort study was conducted in a single Austrian Level-I trauma center and enrolled a consecutive sample of mildly head-injured adults who presented to the emergency department with witnessed loss of consciousness, disorientation, or amnesia, and a Glasgow Coma Scale (GCS) score of 13–15. The studied population consisted of a large number of elderly patients living in Vienna. The aim of the study was to investigate risk factors that help to predict the need for immediate cranial CT in patients with mild head trauma.

**Results.** Among the 12,786 enrolled patients, 1,307 received a cranial CT scan. Four hundred eighty-nine patients (37.4%) with a mean age of 63.9 ± 22.8 years had evidence of an acute traumatic intracranial lesion on CT. Three patients (< 0.1%) were admitted to the intensive care unit for neurological observation and received oropharyngeal intubation. Seventeen patients (0.1%) underwent neurosurgical intervention. In 818 patients (62.6%), no evidence of an acute trauma-related lesion was found on CT. Data analysis showed that the presence of at least 1 of the following factors can predict the necessity of cranial CT: amnesia, GCS score, age > 65 years, loss of consciousness, nausea or vomiting, hypocoagulation, dementia or a history of ischemic stroke, anisocoria, skull fracture, and development of a focal neurological deficit. Patients requiring neurosurgical intervention were detected with a sensitivity of 90% and a specificity of 67% by using the authors’ analysis. In contrast, the use of the CCHR in these patients detected the need for neurosurgical intervention with a sensitivity of only 80% and a specificity of 72%.

**Conclusions.** The use of the suggested parameters proved to be superior in the detection of high-risk patients who sustained a mild head trauma compared with the CCHR rules. Further validation of these results in a multicenter setting is needed. Clinical trial registration no.: NCT00451789 (ClinicalTrials.gov.)

**Key Words**  
head rule  
cranial CT  
minor head injury  
skull radiography  
traumatic brain injury

**Abbreviations used in this paper:** AUC = area under the curve; CCHR = Canadian CT Head Rule; GCS = Glasgow Coma Scale; ICU = intensive care unit; LASSO = least absolute shrinkage and selection operator; TBI = traumatic brain injury.
The widely used Canadian CT Head Rule (CCHR) consists of 5 high-risk factors: failure to reach a GCS score of 15 within 2 hours, suspected open or depressed skull fracture, any sign of basal skull fracture, vomiting ≥ 2 episodes, or age ≥ 65 years. The authors of the CCHR report a sensitivity of 100% for predicting neurosurgical intervention. Similar sensitivity and specificity are given for the New Orleans Criteria, National Emergency X-Ray Utilization Study-II, and Miller Criteria. More recent studies compared the specific CT head rules with the aim of finding the best rule to reduce the number of ordered CT scans. Stiell et al. reevaluated their 2001 study prospectively and found that the use of the CCHR in patients with head trauma resulted in a CT rate of 52.1%. Another study comparing the clinical performance of the CCHR and New Orleans Criteria to detect a traumatic intracranial injury found the highest specificity using the CCHR. Nevertheless, studies conducted outside the US had other results when they applied both of the CT head rules to their patients. The aim of this study was to investigate risk factors that help to predict the need for immediate cranial CT in patients with mild head trauma.

Methods

Study Setting and Population

This was a prospective observational study to compare the clinical performance of 2 different clinical decision rules for patients with minor head injury. The study population consisted of a cohort of 12,786 trauma patients admitted to a university-based Level-I trauma center (Vienna General Hospital) within a period of 16 months between January 2005 and April 2006. Four hundred fifty-six patients were excluded according to the exclusion criteria: 72 with polytrauma, 10 with penetrating head injury, 47 with severe traumatic head injury who were already intubated at admission, and 327 because of incomplete data. This study was registered with the ClinicalTrials.gov database (http://clinicaltrials.gov), and its registration no. was NCT00451789.

Data Collection and Patient Assessment

A standardized assessment protocol was used to record the obtained findings. The inclusion criteria were: blunt head trauma, age > 16 years, GCS score of 13–15, injury within 24 hours prior to admission to the emergency room, a brief neurological examination of the cranial nerves, and strength and sensation in the arms and legs. We recorded pupil reactivity and pupil size. Loss of consciousness (< 5 minutes) was considered if reported by a witness or the patient could not remember the traumatic event (retrograde and/or anterograde amnesia). All participants were asked about nausea. The evaluation included drug or alcohol use, the use of anticoagulants (such as acetylsalicylic acid, clopidogrel, warfarin, and others), a history of epilepsy, cerebral infarction, and dementia. We inquired about vomiting prior to the clinic presentation or in the clinic. The study end point was the detection of: 1) patients with clinically important brain injury who required neurological observation on the intensive care unit (ICU) with or without intracranial pressure monitoring (intracranial pressure probe) and intubation, or neurosurgical intervention; and 2) patients without a brain lesion related to a recent trauma. Exclusion criteria were patients with an obvious penetrating head injury, severe TBI, intubated patients on admission, unstable vital signs, pregnancy, significant extracerebral injury, and polytrauma.

Statistical Methods

All continuous variables were dichotomized as reported by the CCHR. Frequencies and percentages are reported for all risk factors (sex, age, hypocoagulation, dementia, preexisting stroke, hypertension, amnesia, loss of consciousness, epilepsy, pupil size, pupil reactivity, nausea or vomiting, GCS score, focal neurological deficit, alcohol or drug abuse, and fracture line on plain radiograph of the skull). The variables were compared between 2 groups of patients using the chi-square and Fisher exact tests. A multivariate generalized linear model was calculated to determine the influence of the mentioned risk factors on important brain injury. For variable selection the LASSO method (least absolute shrinkage and selection operator) was used. This selection was based on predicted residual sum of squares estimated by 5-fold cross-validation. This method adds and deletes parameters based on a version of ordinary least squares, where the sum of the absolute regression coefficients is constrained. Receiver operating characteristic curves were shown and areas under the curves (AUCs) were calculated. Odds ratios and accompanying 95% CIs were calculated using logistic regression analysis, including all independent variables selected by LASSO. The resulting estimates and 95% CIs did not account for the variable selection procedure. A new CT head rule was defined by the variables selected by LASSO. This head rule predicted an important brain injury if at least 1 of the selected risk factors were present. Furthermore, to assess the predictive power of the CCHR for our data set, its sensitivity and specificity were calculated. All analyses were performed using SAS version 9. The 2-sided significance level was set at 0.05.

Results

In total, 12,786 patients with a mean age of 37.5 ± 28.4 years were enrolled within a period of 16 months between January 2005 and April 2006. Overall, 1307 patients (10.2%) received a cranial CT scan to detect clinically important brain injuries. In 489 patients with a mean age of 63.9 ± 22.8 years, an acute traumatic lesion was found on CT. Three of these patients (< 0.1%) were admitted for neurological observation to the ICU and received oropharyngeal intubation. Seventeen patients (0.1%) underwent neurosurgical intervention. Table 1 lists the frequencies and percentages of the risk factors compared between patients with and without clinically important brain injury. All variables but sex indicated statistically significant differences between the 2 patient groups.

In 818 patients no evidence of an intracranial traumatic lesion was found on CT; the mean age of these patients was 36.4 ± 28.1 years. Table 2 shows the parameter...
Comparison of rules for CT scans in the elderly with head trauma

TABLE 1: Frequencies and percentages of the risk factors compared between patients with and without clinically important brain injury*

<table>
<thead>
<tr>
<th>Variable</th>
<th>Total</th>
<th>Clinically Important Brain Injury</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Low Risk (%) (n = 12297)</td>
<td>High Risk (%) (n = 489)</td>
</tr>
<tr>
<td>female sex</td>
<td>5373</td>
<td>5164 (42.0)</td>
</tr>
<tr>
<td>age (≥65 yrs)</td>
<td>2784</td>
<td>2506 (20.4)</td>
</tr>
<tr>
<td>hypocoagulation</td>
<td>922</td>
<td>783 (6.4)</td>
</tr>
<tr>
<td>history of dementia or cerebrovascular infarction</td>
<td>302</td>
<td>234 (1.9)</td>
</tr>
<tr>
<td>hypertension</td>
<td>422</td>
<td>371 (3.0)</td>
</tr>
<tr>
<td>amnesia</td>
<td>845</td>
<td>660 (5.4)</td>
</tr>
<tr>
<td>unconsciousness</td>
<td>736</td>
<td>583 (4.7)</td>
</tr>
<tr>
<td>seizures</td>
<td>278</td>
<td>240 (2.0)</td>
</tr>
<tr>
<td>anisocoria</td>
<td>141</td>
<td>105 (0.9)</td>
</tr>
<tr>
<td>nausea/vomiting</td>
<td>519</td>
<td>465 (3.8)</td>
</tr>
<tr>
<td>GCS score (&lt;15)</td>
<td>419</td>
<td>299 (2.4)</td>
</tr>
<tr>
<td>focal neurological deficit</td>
<td>42</td>
<td>25 (0.2)</td>
</tr>
<tr>
<td>alcohol or drug abuse</td>
<td>1486</td>
<td>1385 (11.3)</td>
</tr>
<tr>
<td>skull fracture</td>
<td>67</td>
<td>44 (0.4)</td>
</tr>
<tr>
<td>pupil reactivity</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 (sluggish)</td>
<td>251</td>
<td>211 (1.7)</td>
</tr>
<tr>
<td>2 (fixed)</td>
<td>14</td>
<td>7 (0.1)</td>
</tr>
<tr>
<td>3 (impaired)</td>
<td>22</td>
<td>143 (1.2)</td>
</tr>
<tr>
<td>pupil shape</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 (irregular)</td>
<td>9</td>
<td>4 (0.1)</td>
</tr>
<tr>
<td>2 (preexisting pathology)</td>
<td>32</td>
<td>28 (0.2)</td>
</tr>
<tr>
<td>pupil size</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 (narrow)</td>
<td>48</td>
<td>37 (0.3)</td>
</tr>
<tr>
<td>2 (dilated)</td>
<td>13</td>
<td>11 (0.1)</td>
</tr>
</tbody>
</table>

* The p values for all variables were significant (<0.0001) except for female sex (p = 0.74).

estimates and p values of the multivariate generalized linear model obtained by LASSO regression and ORs with 95% CIs obtained by logistic regression. The variables of amnesia, GCS score, age, loss of consciousness, hypocoagulation, dementia, preexisting stroke, pupil size/anisocoria, fracture line on conventional radiograph of the skull, nausea/vomiting, and focal neurological deficit were used to discriminate cases at high risk for brain injury. The receiver operating characteristic curve is shown in Fig. 1 upper, and achieves an AUC of 0.87.

The potential classification performance of the new head rule to predict brain injury showed a sensitivity of 90% and a specificity of 69%. A need for neurological intervention had a sensitivity of 90% and a specificity of 67%. Applying the proposed head rule to the studied cohort of patients resulted in a detection rate of 90.4% (442 patients), with the outcome measure “clinically important” not detected in 47 patients (9.6%). Using our model for the outcome measure “need for neurological intervention,” 18 patients (90%) were detected and 2 patients (10%) would not have been detected.

The continuous CCHR score for important brain injury consisting of the high-risk factors (for neurological intervention) and medium-risk factors (for brain injury on CT) and the model developed by stepwise logistic regression analysis to predict clinically important brain injury, achieved an AUC of 0.79 in our data set (Fig. 1 lower). The CCHR showed a sensitivity of 78% and a specificity of 74% for clinically important brain injury when applied to our patient sample. The need for neurological intervention had a sensitivity of 80% and specificity of 72%. Applying the CCHR to the studied cohort of Viennese patients, a detection rate of 77.5% (379 patients) was found, with 110 patients (22.5%) not detected for the outcome measure “clinically important.” For the outcome measure “need for neurological intervention,” 16 patients (80%) were detected and 4 patients (20%) were missed.

Discussion

We developed a set of criteria derived from our clinical experience, influenced by the internationally used New Orleans Criteria, National Emergency X-Ray Utilization Study-II, and CCHR head rules to detect clinical important head injury. The CCHR is one of the most frequently used clinical decision rules for patients with blunt head trauma. Our study differs from the CCHR regarding the age of the studied patients. The patients in our study represent typical demographics of a European capital city.
Table 3 shows sensitivities, specificities, and outcome measures of the main head rules.

**Outcome Measures**

We focused our study on 2 internationally recognized outcome measures. The first was “need for neurological intervention,” which requires neurological observation on the ICU or neurosurgical intervention. The second was “clinically important” brain lesion, which is an acute brain finding revealed on CT and which normally requires admission to the hospital and neurological follow-up. The definition of high-risk criteria helps to effectively detect patients with these injuries.19,24,25 Patients without an acute intracranial finding on CT (such as those with chronic subdural hematoma or hygroma, posttraumatic lacunar lesions, and questionable traumatic lesions that cannot be differentiated by using an emergency CT scan) and negative CT scans were classified as low risk. In this group of patients, MRI of the head is indicated, instead of an emergency CT scan.29 Additionally, if available, the discrimination between clinically acute and nonacute lesions can be supported by the use of modern biomarkers such as S100-β, neuron-specific enolase, glial fibrillary acid protein, and ubiquitin carboxy-terminal hydrolase L1.1,3,10,14,18,28 In these patients there is enough time to wait until the results of the biomarker essays are available.

**Development of a Model of High-Risk Factors**

The first step of our analysis aimed to detect patients with low and high risk for the mentioned outcome measures. We found 16 risk factors that were statistically significant for helping physicians differentiate between high-risk and low-risk patients with TBI. The second step of our analysis used a multivariate regression model, which yielded 10 high-risk factors. Elderly patients with any 1 of 10 high-risk factors are at substantial risk for neurological intervention or clinically important brain injury, and in our opinion an emergency CT scan is mandatory in these cases. Therefore, based on our study results, the strongest risk factors appear to be amnesia, GCS score < 15, age > 65 years, loss of consciousness, hypocoagulation, dementia or a history of ischemic stroke, anisocoria, skull fracture, development of focal neurological deficit, and nausea/vomiting.

**Role of Risk Factors**

The evaluation of the predictive accuracy of GCS verbal, motor, and eye components, and pupil size and...
Comparison of rules for CT scans in the elderly with head trauma

TABLE 3: Comparison of the performance of published head rules*

<table>
<thead>
<tr>
<th>Study</th>
<th>Sensitivity (95% CI)</th>
<th>Specificity (95% CI)</th>
<th>No. of Included Patients</th>
<th>CT Rate†</th>
<th>Outcome Measures</th>
</tr>
</thead>
<tbody>
<tr>
<td>CCHR25</td>
<td>100% (92%-100%)</td>
<td>68.7% (67%-70%)</td>
<td>3121</td>
<td>only 32.2% would need CT</td>
<td>neurological intervention</td>
</tr>
<tr>
<td>NOC24</td>
<td>100%</td>
<td>25%</td>
<td>909</td>
<td>22% reduction</td>
<td>detection of intracranial injury</td>
</tr>
<tr>
<td>Miller18</td>
<td>100%/65%‡</td>
<td>63%</td>
<td>2143</td>
<td>65% reduction</td>
<td>neurosurgical intervention/abnormal CT scan</td>
</tr>
<tr>
<td>NEXUS-II6</td>
<td>98.3% (97.2%-99%)</td>
<td>13.7%</td>
<td>13,728</td>
<td>not applicable</td>
<td>detection of intracranial injury</td>
</tr>
</tbody>
</table>

* Miller = Miller criteria; NEXUS-II = National Emergency X-Ray Utilization Study-II; NOC = New Orleans Criteria.
† Rate of CT scans that are necessary or could be reduced when following the proposed guidelines.
‡ Sensitivity was 100% for detecting patients who required surgical intervention and 65% for detecting patients with an abnormal CT scan.

reactivity, for TBI was featured in a new German multicenter study.5 Pupil reactivity together with the GCS motor component score performed best in predicting high risk. The GCS verbal response component followed by pupil reactivity showed the best accuracy for predicting high risk. Our data show a good overall significance (p < 0.0001) for the subgroups of pupil reactivity: 1) sluggish (delayed pupil constriction in reaction to light); 2) fixed (no response to a light stimulus); and 3) impaired reactivity due to preexisting eye pathology (glaucoma or cataract). Pupil shape (irregular, and preexisting eye pathology) as well as pupil size (narrow and dilated sub-categories) showed high significance for predicting TBI. Additionally, anisocoria was also a significant risk factor.

Hypocoagulation was another significant risk factor in our patients. Evidence exists that anticoagulation and the degree of anticoagulant therapy has a key role in the development of intracranial hemorrhage after minor head injury.7,18,28 Based on this study, we recommend admission and neurological observation for at least 24 hours for patients with hypocoagulation to detect delayed progression of hemorrhage.

Our results are consistent with recent studies indicating skull fractures as an independent risk factor for neurosurgically relevant intracranial lesions.11 Due to the higher risk of intracranial bleeding with skull fractures, a German study group recommended early repeated CT for patients with skull fractures.27

In our patients we found 1 or more of the following variables associated with the occurrence of detectable brain lesions: history of hypertension as well as history of cerebral infarction, underlying dementia, focal neurological deficit, and seizure before or after trauma. Most of these variables were excluded in the original CCHR, but are included in newer guidelines.26 However, as our data show, these are important risk factors for TBI in elderly patients. Amnesia before or after the impact, as well as the physical symptoms of nausea and vomiting, are recognized key factors in patients with head trauma.9,13 The true evaluation of the duration of amnesia in our patients, if not witnessed and reported by a bystander, was not possible because of many cofactors. Therefore, we consider amnesia as a valuable risk factor independent of its duration. Our proposed head rule had a detection rate of 90.4% versus 77.5% for the outcome measure “clinically important,” and a detection rate of 90% versus 80% for the outcome measure “need for neurological interven-

Conclusions

To our knowledge, this study is among the first to combine a set of clinical parameters influenced by the CCHR with a focus on the elderly population. The strength of the present study is the large number of patients. Especially for the large group of patients with mild TBI who might require neurosurgical intervention or observation on ICU, these guidelines can help to clarify which patients need urgent CT of the brain. The use of the suggested parameters proved to be superior in the detection of high-risk patients who sustained a mild head trauma compared with the CCHR rules. Further validation of the results of this study in a multicenter setting is needed.

Acknowledgments

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Disclosure

The authors report no conflict of interest concerning the materials or methods used in this study or the findings specified in this paper.

Author contributions to the study and manuscript preparation include the following. Conception and design: Wolf, Machold. Acquisition of data: Wolf, Machold, Kecht, Leitgeb, Widbalm, Hajdu, Sarahrudi. Analysis and interpretation of data: Wolf,
Machold, Frantal, Kecht, Pajenda, Leitgeb, Sarahudi. Drafting the article: Wolf. Critically revising the article: all authors. Reviewed submitted version of manuscript: all authors. Approved the final version of the manuscript on behalf of all authors: Wolf. Statistical analysis: Frantal. Study supervision: Wolf, Hajdu, Sarahudi.

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