The Canadian C-spine rule performs better than unstructured physician judgment


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For the Canadian C-Spine and CT Head Study Group

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Study objectives: We compare the predictive accuracy of emergency physicians' unstructured clinical judgment to the Canadian C-Spine rule.

Methods: This prospective multicenter cohort study was conducted at 10 Canadian urban academic emergency departments. Included in the study were alert, stable, adult patients with a Glasgow Coma Scale score of 15 and trauma to the head or neck. This was a substudy of the Canadian C-Spine and CT Head Study. Eligible patients were prospectively evaluated before radiography. Physicians estimated the probability of unstable cervical spine injury from 0% to 100% according to clinical judgment alone and filled out a data form. Interobserver assessments were done when feasible. Patients underwent cervical spine radiography or follow-up to determine clinically important cervical spine injuries. Analyses included comparison of areas under the receiver operating characteristic (ROC) curve with 95% confidence intervals (CIs) and the κ coefficient.

Results: During 18 months, 6,265 patients were enrolled. The mean age was 36.6 years (range 16 to 97 years), and 50.1% were men. Sixty-four (1%) patients had a clinically important injury. The physicians' κ for a 0% predicted probability of injury was 0.46 (95% CI 0.28 to 0.65). The respective areas under the ROC curve for predicting cervical spine injury were 0.85 (95% CI 0.80 to 0.89) for physician judgment and 0.91 (95% CI 0.89 to 0.92) for the Canadian C-Spine rule (P<.05).

With a threshold of 0% predicted probability of injury, the respective indices of accuracy for physicians and the Canadian C-Spine rule were sensitivity 92.2% versus 100% (P<.001) and specificity 53.9% versus 44.0% (P<.001).

Conclusion: Interobserver agreement of unstructured clinical judgment for predicting clinically important cervical spine injury is only fair, and the sensitivity is unacceptably low. The Canadian C-Spine rule was better at detecting clinically important injuries with a sensitivity of 100%. Prospective validation has recently been completed and should permit widespread use of the Canadian C-Spine rule.


See related article, p. 403.

Introduction

More than 13 million patients with potential neck injuries are evaluated in US emergency departments (EDs) annually, of whom approximately 30,000 have cervical spine injuries and 10,000 have spinal cord injuries. The results from 1 Canadian study would suggest that 185,000 alert, stable adults with potential cervical spine injuries are treated in Canadian EDs annually, 0.9% of whom have cervical spine fractures or dislocations. Previous reports have suggested that clinical judgment is inadequate for predicting cervical spine injuries. The American College of Surgeons Advanced Trauma Life Support course therefore recommends that “… a c-spine film … be obtained on every patient sustaining an injury above the clavicle, and especially a head injury.” Previous reports have supported universal screening for cervical spine injuries, and approximately 97% of US trauma centers have at one time routinely ordered cervical spine radiography for all trauma patients. A recent Canadian study revealed institutional imaging rates ranging from 37% to 72% for alert, stable trauma patients at risk for cervical spine injuries. Universal cervical spine radiography has yielded a positive test rate of less than 3% in most trauma series. We estimate that 110,000 cervical spine radiography assessments are done each year in Canada on alert, stable, adult trauma patients, of which 98% are normal. The cost of inexpensive, high-volume tests may contribute more to rising health care costs than more expensive “high technology” procedures. We estimate that more than CDN$30 million is spent annually in Canada on outpatient cervical spine radiography. Comprehensive radiography to clear the cervical spine requires a large time commitment on the part of medical and hospital staff, distracting them from other responsibilities. A recent survey found that 98% of 300 Canadian emergency physicians would consider using a sensitive, reliable decision rule for the use of cervical spine radiography, suggesting insight into the fallibility of current clinical judgment. Such a rule would have the potential to significantly reduce health care costs, improve efficiency, and improve patient care.
The Canadian C-Spine and CT Head (CCC) Study is a prospective multiphase multicenter study. Phase I of the CCC study involved derivation of a decision rule for cervical spine radiography by using 8,924 patients from 10 Canadian urban teaching and community EDs. Variables were assessed for their interobserver agreement and for their univariate association with clinically important cervical spine injury. The final Canadian C-Spine rule, derived by multivariate recursive partitioning of the strongest variables, was found to be 100% sensitive for detecting the 151 clinically important injuries (Figure 1).

Fig. 1. The Canadian C-Spine rule. MVC, motor vehicle crash.

To justify the time and effort involved in validating and disseminating a clinical decision rule, it is important to know whether the rule improves on diagnostic accuracy of unstructured physician judgment alone. We sought to determine whether the Canadian C-Spine rule would have performed better than physician judgment during Phase I of the CCC Study.

Methods

The multicenter, multiphase CCC Study was undertaken with reference to previously described guidelines for developing clinical decision rules. This prospective observational cohort study was undertaken as part of phase I of the CCC Study. It was carried out in 10 Canadian urban teaching and community EDs. Inclusion criteria were all ambulatory or immobilized adult patients who (1) were hemodynamically stable (systolic blood pressure >90 mm Hg and respiratory rate between 10 and 24 breaths/min); (2) were alert (Glasgow Coma Scale [GCS] score of 15); and (3) had either (a) neck pain from any mechanism of
injury or (b) no neck pain but some visible injury above the clavicles, had not been ambulatory, and had experienced a dangerous mechanism of injury. Exclusion criteria were age younger than 16 years, no neck pain or visible injury above the clavicle, GCS score less than 15, unstable vital signs, time of injury more than 48 hours before assessment, penetrating trauma, acute paralysis, known vertebral disease (eg, ankylosing spondylitis, rheumatoid arthritis, spinal stenosis, previous cervical surgery), reassessment of the same injury, and pregnancy.

All attending staff physicians and emergency medicine residents were asked to carry out their normal assessment of each eligible patient. After the clinical interaction, each physician completed a data form with standardized assessments of history and physical findings. The form included the patient’s hospital identification number, contact information, time and details of the injury event, and potential decision rule clinical variables. Physicians were asked to prospectively estimate the probability that the patient would have a clinically important cervical spine injury by circling 1 of the following: 0%, 1%, 2%, 3%, 4%, 5%, 10%, 20%, 30%, 40%, 50%, 75%, or 100%. Physicians were instructed to base this estimate on their judgment after considering the facts obtained in the patient history and physical examination only, without assistance of a structured decision rule and before radiographs, if any, were reviewed. When feasible, a second physician was asked to independently assess the patient and fill out the study form to determine interobserver agreement. In cases in which interobserver data were obtained, each physician was blinded to the findings and impressions of the other, and the forms were filled out prospectively before radiography was undertaken.

Patients underwent plain radiography with or without flexion and extension views and computed tomography (CT) imaging at the discretion of the treating physician after form completion. The decision to order films may not have been based solely on physicians’ stated judgment of likelihood of injury because physicians may adhere to guidelines instructing liberal use of radiography or may agree with reports showing that judgment in these circumstances is poor. Patients who did not undergo radiography participated in a structured telephone interview by a study nurse 14 days after discharge to determine patient outcome and search for undetected injuries. This structured interview was previously validated on a random sample of 389 patients (including 66 with clinically important cervical spine injury) who had all undergone radiography. Clinically unimportant injuries were defined as isolated avulsion fracture of an osteophyte, isolated fracture of a transverse process not involving body or facet joint, isolated fracture of a spinous process not involving the lamina, and isolated compression fracture less than 25% of the vertebral body height. These definitions are based on a consensus opinion and strongly endorsed by a formal survey of 129 Canadian academic emergency physicians, spinal surgeons, and neurosurgeons at 8 centers.

Performance of unstructured physician judgment and the Canadian C-Spine rule were compared by using the areas under the respective receiver operating characteristic (ROC) curves with 95% confidence intervals (CIs). Sensitivity and specificity of unstructured physician judgment (for ≥0% probability) were also evaluated with 2 × 2 classification performance tables and compared with those of the Canadian C-Spine rule (sensitivity 100% [95% CI 98% to 100%] and specificity 42.5% [95% CI 42% to 44%]). The κ coefficient was calculated to measure the interobserver agreement on the subset of patients evaluated by 2 physicians. A reliable estimate was considered to have a κ higher than 0.6. Patients who could not be contacted or for whom incomplete data were available were not included in the final analyses. Analyses were conducted with SAS (SAS Institute, Inc., Cary, NC) statistical software. The research ethics committees of the study hospitals approved the protocol without the need for informed consent. Patients followed up had an opportunity to give verbal consent during the telephone interview by a study nurse.

Results

This component of the CCC Study took place from October 1996 to April 1999. There were 6,265 patients enrolled by more than 200 physicians. Patient characteristics are summarized in Table 1.

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Representation in Study Population</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean age, y (SD)</td>
<td>36.6 (16)</td>
</tr>
<tr>
<td>Range, y</td>
<td>16–97</td>
</tr>
<tr>
<td>Male sex, No. (%)</td>
<td>3,177 (50.6)</td>
</tr>
<tr>
<td>Mean time injury to assessment, h (SD)</td>
<td>3.5 (8.6)</td>
</tr>
<tr>
<td>Arrived by ambulance, No. (%)</td>
<td>3,282 (52.4)</td>
</tr>
<tr>
<td>Transfer from another institution, No. (%)</td>
<td>180 (2.9)</td>
</tr>
<tr>
<td>Ambulatory at any time, No. (%)</td>
<td>4,303 (68.7)</td>
</tr>
<tr>
<td>Upright position during examination, No. (%)</td>
<td>2,355 (37.6)</td>
</tr>
</tbody>
</table>

Neck pain, No. (%) 5,744 (91.7)
Mechanism of injury, No. (%)

<table>
<thead>
<tr>
<th>Mechanism of Injury</th>
<th>No. (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Motor vehicle crash</td>
<td>4,235 (67.6)</td>
</tr>
<tr>
<td>Fall</td>
<td>870 (13.9)</td>
</tr>
<tr>
<td>Pedestrian struck</td>
<td>194 (3.1)</td>
</tr>
<tr>
<td>Assault</td>
<td>213 (3.4)</td>
</tr>
<tr>
<td>Head struck by object</td>
<td>209 (3.3)</td>
</tr>
<tr>
<td>Sports</td>
<td>182 (2.9)</td>
</tr>
<tr>
<td>Bicycle</td>
<td>160 (2.6)</td>
</tr>
<tr>
<td>Axial load</td>
<td>119 (1.9)</td>
</tr>
<tr>
<td>Motorcycle</td>
<td>48 (0.8)</td>
</tr>
<tr>
<td>Motorized recreational vehicle</td>
<td>29 (0.5)</td>
</tr>
<tr>
<td>Other</td>
<td>6 (0.1)</td>
</tr>
</tbody>
</table>

Cervical spine radiography performed, No. (%) 4,344 (69.3)
CT scan performed, No. (%) 236 (3.8)
Cases followed up by telephone, No. (%) 1,956 (31.2)
Clinically important cervical spine injury, No. (%) 64 (1.0)
Clinically unimportant cervical spine injury, No. (%) 16 (0.3)
Fracture, No. (%) 76 (1.2)
Dislocation, No. (%) 6 (0.1)
Ligamentous instability, No. (%) 5 (0.1)
Developed neurologic deficit, No. (%) 5 (0.1)
Stabilizing treatments, No. (%) 69 (1.1)
Internal fixation 14 (0.2)
Halo 23 (0.4)
Brace 5 (0.1)
Rigid collar 27 (0.4)
Admitted to hospital, No. (%) 437 (7.0)

Assessments for 564 (9%) of the patients were carried out by resident physicians. Patients had been transferred from another institution in 180 (3%) cases. The mean patient age was 36.5 years (range 16 to 97 years), and 50.6% were men. Sixty-four patients (1.0%) had at least 1 clinically important cervical spine injury and 16 (0.3%) had clinically unimportant injuries. Fractures occurred in 76 (1%) patients, dislocations in 6 (0.1%), and ligamentous injuries in 5 (0.1%). The most common mechanism of injury was motor vehicle crash, followed by fall. Four hundred thirty-seven (7%) of all study patients were admitted to the hospital, and 69 had stabilizing treatment (internal fixation, halo, rigid collar, or brace).
The distribution of physician probabilities is given in Table 2.

**Table 2. Distribution of physicians' predictions of injury and actual cervical spine injury.**

<table>
<thead>
<tr>
<th>Predicted Probability of Injury.</th>
<th>No, No. (%) (N=6,213)</th>
<th>Yes, No. (%) (N=64)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>3,346 (53.8)</td>
<td>5 (7.8)</td>
</tr>
<tr>
<td>1</td>
<td>1,822 (29.3)</td>
<td>10 (15.6)</td>
</tr>
<tr>
<td>2</td>
<td>481 (7.7)</td>
<td>13 (20.3)</td>
</tr>
<tr>
<td>3</td>
<td>182 (2.9)</td>
<td>6 (9.4)</td>
</tr>
<tr>
<td>4</td>
<td>33 (0.5)</td>
<td>1 (1.6)</td>
</tr>
<tr>
<td>5</td>
<td>225 (3.6)</td>
<td>10 (15.6)</td>
</tr>
<tr>
<td>10</td>
<td>67 (1.1)</td>
<td>7 (10.9)</td>
</tr>
<tr>
<td>20</td>
<td>27 (0.4)</td>
<td>7 (10.9)</td>
</tr>
<tr>
<td>30</td>
<td>14 (0.2)</td>
<td>0</td>
</tr>
<tr>
<td>40</td>
<td>3 (&lt;0.1)</td>
<td>0</td>
</tr>
<tr>
<td>50</td>
<td>13 (0.2)</td>
<td>4 (6.3)</td>
</tr>
<tr>
<td>75</td>
<td>0</td>
<td>1 (1.6)</td>
</tr>
<tr>
<td>100</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

The respective areas under the ROC curve for predicting cervical spine injury were physician judgment 0.85 (95% CI 0.80 to 0.89) and Canadian C-Spine rule 0.91 (95% CI 0.89 to 0.92; \( P < .05 \); Figure 2.)
Fig. 2. ROC curve for predicting cervical spine injury.

Physicians' stated judgment had a sensitivity of 92% (95% CI 82% to 96%) for predicting a probability of clinically important fracture of greater than 0% and would have missed 5 cases (). For 89 cases, the interobserver $\kappa$ for predicting a 0% probability of important cervical spine injury according to physician judgment was only 0.46 (95% CI 0.28 to 0.65). For comparison purposes, the Canadian C-Spine rule had a sensitivity of 100% (95% CI 94% to 100%) in 6,265 patients (Table 3).

**Table 3. Classification of performance of physician judgment to predict at least 0% probability of clinically important cervical spine injury.***

<table>
<thead>
<tr>
<th>Physician Judgment</th>
<th>Cervical Spine Injury</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td>Yes</td>
<td>59</td>
</tr>
<tr>
<td>No</td>
<td>Yes</td>
<td>5</td>
</tr>
</tbody>
</table>

* Sensitivity 92.2% (82%–96%); specificity 53.8% (53%–55%); $\kappa$ 0.46 (0.28–0.65).

The specificities of physician judgment and the Canadian C-Spine rule for clinically important injury are 53.9% (95% CI 53% to 55%) and 44.0% (95% CI 43% to 45%), respectively (Tables 3 and 4).

**Table 4. Classification of performance of the Canadian C-Spine rule for clinically important cervical spine injury.***
The suboptimal sensitivity of physician judgment alone for detecting important cervical spine injuries, combined with the potential for profound adverse outcomes when cervical spine injuries are missed, means that many patients with a low perceived likelihood of injury will still undergo radiographic investigation. This study would support this practice because physicians estimated the probability of having an important injury at 0% for 5 patients who were eventually found to have such an injury. Most Canadian and US emergency physicians disagree, however, with universal cervical spine imaging advocated by some guidelines. The high patient volume, brief patient-physician contact, uncertain follow-up, and medicolegal risk associated with emergency medicine practice coupled with the lack of validated decision rules in this area have historically left little alternative to the reluctant universal application of radiography. Our study suggests that physicians actually order more cervical spine radiographs than they would if they relied on their clinical judgment alone, suggesting that physicians do not rely solely on their judgment. Physicians' current practice is sensitive at the expense of specificity because of this overuse. We chose to compare the Canadian C-Spine rule to physicians' “likelihood of injury” estimate rather than to their current ordering practice for precisely this reason. We believed it important to compare the Canadian C-Spine rule with what physician judgment would offer if judgment alone were relied on to limit use.

In the derivation phase, the Canadian C-Spine rule for cervical spine radiography was 100% sensitive for detecting 151 clinically important injuries. The current study has shown that the Canadian C-Spine rule is more accurate than physician judgment. The derivation phase of the Canadian C-Spine rule would suggest that cervical spine radiography use rates by using the rule would be approximately 60%. According to this result, physicians using the Canadian C-Spine rule may confidently reduce their cervical spine radiography rate significantly while avoiding appreciable risk of missing important cervical spine injuries. Physicians did not order radiographs on 1,981 patients in this study, whereas the Canadian C-Spine rule would have correctly predicted that an additional 745 patients would not have required imaging, a reduction of 17.5%. Avoiding radiography on some patients with blunt neck trauma probably will shorten the time to “clearing” the cervical spine, which would in turn reduce length of stay, lessen the burden of care for health care staff, facilitate mobilization of the patients for investigation and treatment, and help ease the increasing congestion in many large EDs. The rule has recently undergone prospective validation. The US-based National Emergency X-Radiography Utilization Study (NEXUS) criteria were recently found to have a sensitivity of 99.0% and specificity of 12.9% in a large validation study. The relatively low specificity means that adherence to this rule may fail to decrease ordering rates among physicians outside of the United States and in some cases may actually increase use. A retrospective application of the NEXUS criteria to a CCC Study population revealed a sensitivity of only 93%. One of the reasons for this outcome may be the low interobserver reliability associated with certain criteria in the US study. Our CCC Study data would suggest, for example, that such aspects as intoxication and distracting injury are poorly defined and hard to assess, with interobserver reliabilities of 0.22 and 0.41, respectively. Wide application of the NEXUS rule should be preceded by further investigation of its sensitivity and interobserver reliability in a broad population.

Agreement of overall clinical impression according to unstructured physician assessment for risk of injury was poor. The \( \kappa \) value measures agreement beyond that which would be expected by chance alone. In this study, the \( \kappa \) for estimation of the patient's overall risk of important injury was only 0.46, which is not the case, however, for agreement on specific individual patient variables. Individual components of the Canadian C-Spine rule were incorporated into the final decision rule only after they were poorly defined and hard to assess, with interobserver reliabilities of 0.22 and 0.41, respectively.
were found to have high interobserver agreement defined a priori as a \( \kappa \) value higher than 0.6.\textsuperscript{33}

There are several potential limitations to this study. Some individuals may be concerned about the interpretation of “clinically unimportant cervical spine injury.” We have, however, demonstrated good acceptance of our definition by Canadian academic neurosurgeons, spine surgeons, and emergency physicians. The priority of diagnostic imaging for these trauma patients should be to identify cervical spine injuries that require treatment and follow-up. “Clinically unimportant cervical spine injuries,” according to the academic surgeons in our survey, require neither stabilizing treatment nor specialized follow-up and are unlikely to be associated with long-term problems. For patients who do not require urgent specific treatment for neck injuries, we are aware of no literature reports suggesting that emergency radiography is likely to predict the rare long-term complication, such as a chronic pain.

Not all physicians in the study may have been aware of the explicit definitions used for clinically unimportant injury, nor were they surveyed for individual understanding of the definitions used. Their predicted probability of clinically important injury may not be based on the study definitions. We believe, however, that this difference would accurately reflect the reality that individual physicians would have their own concept and threshold for unimportant injuries.

Some readers may be concerned that not all study patients underwent cervical spine radiography. We could not ethically insist on universal radiography for all patients, because many Canadian physicians withhold radiography for patients who they have a low risk of injury. Unimaged patients were only classified as having no clinically important injury if they satisfied all criteria on the structured, validated, 14-day, telephone proxy outcome tool administered by a registered nurse.

Physicians were asked to estimate their predicted likelihood of clinically significant injury for each patient at study form completion. This estimate may have knowingly or unknowingly been influenced by the completion of the form. The study required only that physicians document their findings for each element of the rule, much as they would do on a patient medical record, and did not involve application of the rule. The Canadian C-Spine rule is highly sensitive and specific, is based on standard elements obtained during the initial patient interaction, and has high interobserver reliability. For these reasons, we believe that any influence completion of the rule may have had on physicians' estimates would have narrowed the gap between their unassisted judgment and the performance of the rule, meaning that eliminating this measurement bias would make the improvement seen with the rule over unstructured judgment even more pronounced. Similarly, patients transferred for assessment may have had previous cervical spine radiographs. Physicians were asked to complete the study forms before reviewing any radiographs, and no breaches of protocol were reported. Any previous physician knowledge of radiography results in this small percentage of patients (3%) would have falsely improved physician judgment and resulted in a conservative estimate of the superiority of the Canadian C-Spine rule.

We acknowledge that not all eligible patients were enrolled in the study, which is not unusual for a clinical study. The characteristics of patients not enrolled were similar to those of the patients who were enrolled.

The limitations of physicians' unstructured judgments have resulted in widespread universal use of cervical spine radiography in stable, alert, adult trauma patients. In this substudy of the CCC Study, we have shown that the Canadian C-Spine rule for cervical spine radiography is more accurate than physician judgment alone. We believe that use of a prospectively derived and validated, reliable, and practical decision rule for the use of cervical spine radiography in these patients will reduce radiography rates without compromising patient care. Prospective validation of the Canadian C-Spine rule has recently been completed. Further study is needed to determine whether practice patterns can change with its implementation.

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**Author contributions:**

IGS and GAW conceived the study, designed the trial, and obtained research funding. IGS, GAW, and KLV supervised the conduct of the trial and data collection. GHG, RB, GB, DC, JD, MAE, IM, RDM, LM, MR, MS, JW, KLV, and CC undertook recruitment of participating centers and patients and managed the data, including quality control. IGS, GAW, and VDM provided statistical advice on study design and analyzed the data. HL provided clinical consultation. IGS chaired the data oversight committee. GB drafted the manuscript, and all authors contributed substantially to its revision. IGS takes responsibility for the paper as a whole.
References


