The Canadian C-Spine Rule for Radiography in Alert and Stable Trauma Patients

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Context High levels of variation and inefficiency exist in current clinical practice regarding use of cervical spine (C-spine) radiography in alert and stable trauma patients.

Objective To derive a clinical decision rule that is highly sensitive for detecting acute C-spine injury and will allow emergency department (ED) physicians to be more selective in use of radiography in alert and stable trauma patients.

Design Prospective cohort study conducted from October 1996 to April 1999, in which physicians evaluated patients for 20 standardized clinical findings prior to radiography. In some cases, a second physician performed independent interobserver assessments.

Setting Ten EDs in large Canadian community and university hospitals.

Patients Convenience sample of 8924 adults (mean age, 37 years) who presented to the ED with blunt trauma to the head/neck, stable vital signs, and a Glasgow Coma Scale score of 15.

Main Outcome Measure Clinically important C-spine injury, evaluated by plain radiography, computed tomography, and a structured follow-up telephone interview. The clinical decision rule was derived using the κ coefficient, logistic regression analysis, and χ^2 recursive partitioning techniques.

Results Among the study sample, 151 (1.7%) had important C-spine injury. The resultant model and final Canadian C-Spine Rule comprises 3 main questions: (1) is there any high-risk factor present that mandates radiography (ie, age ≥65 years, dangerous mechanism, or paresthesias in extremities)? (2) is there any low-risk factor present that allows safe assessment of range of motion (ie, simple rear-end motor vehicle collision, sitting position in ED, ambulatory at any time since injury, delayed onset of neck pain, or absence of midline C-spine tenderness)? and (3) is the patient able to actively rotate neck 45° to the left and right? By cross-validation, this rule had 100% sensitivity (95% confidence interval [CI], 98%-100%) and 42.5% specificity (95% CI, 40%-44%) for identifying 151 clinically important C-spine injuries. The potential radiography ordering rate would be 58.2%.

Conclusion We have derived the Canadian C-Spine Rule, a highly sensitive decision rule for use of C-spine radiography in alert and stable trauma patients. If prospectively validated in other cohorts, this rule has the potential to significantly reduce practice variation and inefficiency in ED use of C-spine radiography.

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More than 1 million patients with blunt trauma and potential cervical spine (C-spine) injury are treated each year in US emergency departments (EDs).[1,2] Among those patients presenting with intact neurological status (arriving either walking or by ambulance), the incidence of acute fracture or spinal injury is less than 1%.[3-5] Due to concerns about potentially disabling spinal injuries, most clinicians make liberal use of C-spine radiography.[6-9] Nevertheless, such practice is inefficient—more than 98% of C-spine radiographs are negative for fracture.[10-16]

See also p 1893 and Patient Page.

Furthermore, there is considerable practice variation among well-trained emergency physicians, with radiography rates ranging as much as 6-fold.[17] Cervical spine radiography is an example of a "little ticket" item, a low-cost procedure that significantly adds to health care costs due to its high volumes of use.[18,19]

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There are no widely accepted guidelines that have been shown to be both safe and efficient in guiding the use of C-spine radiography. Recently, clinical decision rules have been developed to guide physicians in making diagnostic or therapeutic decisions—for example, the use of radiography for patients with ankle or knee injuries.[20-23] A clinical decision rule may be defined as a decision-making tool that is derived from original research and that incorporates 3 or more variables from the history, physical examination, or simple tests.[24,25] The National Emergency X-Radiography Utilization Study (NEXUS) low-risk criteria for C-spine radiography were recently evaluated in a large study of EDs that found the criteria to be 99.6% sensitive for clinically important injuries.[26] However, the specificity was only 12.9%, leading to concerns that use of the NEXUS criteria would actually increase the use of radiography in some US jurisdictions and in most countries outside of the United States.

We believe that the current inefficiency and variability of clinical practice can be remedied with the development of an accurate, reliable, and clinically sensible decision rule. Hence, the objective of this study was to derive a clinical decision rule that would be highly sensitive for detecting acute C-spine injury among patients sustaining blunt trauma who are alert and stable but at risk for neck injury. This will ultimately allow physicians to be more selective in their use of radiography without jeopardizing patient care.

METHODS

Study Setting and Population

This prospective cohort study was conducted in 10 large Canadian community and university hospitals and included consecutive adult patients presenting to the ED after sustaining acute blunt trauma to the head or neck. We did not include the many patients presenting with trivial injuries, such as simple lacerations to the face.The treating physician's decision of whether to order radiography had no bearing on the enrollment of patients into the study. Patients were eligible for enrollment if they were at some risk for C-spine injury either because they had neck pain from any mechanism of injury, or because they had no neck pain but had all of the following: some visible injury above the clavicles, had not been ambulatory, and had sustained a dangerous mechanism of injury. In addition, patients had to be *alert*, which was defined as a Glasgow Coma Scale (GCS) score of 15 (scale range, 3-15), and *stable*, defined as normal vital signs (systolic blood pressure >90 mm Hg and respiratory rate between 10 and 24/min).

Patients were excluded if they: (1) were younger than 16 years; (2) had minor injuries, such as simple lacerations, and did not fulfill the first 2 inclusion criteria above; (3) had a GCS score lower than 15; (4) had grossly abnormal vital signs; (5) were injured more than 48 hours previously; (6) had penetrating trauma; (7) presented with acute paralysis; (8) had known vertebral disease (ankylosing spondylitis, rheumatoid arthritis, spinal stenosis, or previous cervical surgery), as determined by the examining physician; (9) had returned for reassessment of the same injury; or (10) were pregnant. Eligible patients transferred from other hospitals with suspected C-spine injury were enrolled at the study sites with the proviso that physicians complete the data form prior to reviewing radiographic films. Many of these patients proved not to have C-spine injury. 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 conducted by a study nurse.

Standardized Patient Assessment

All patient assessments were made by staff physicians certified in emergency medicine or by supervised residents in emergency medicine training programs. The physician assessors were trained with a 1-hour session to evaluate patients for 20 standardized clinical findings from the history, general examination, and assessment of neurological status. These potential predictor variables were selected by a team of investigators at a planning consensus conference based on a review of the existing literature and on results of a pilot study. Findings were recorded on a data collection sheet prior to radiography. A subset of patients, where feasible, were independently assessed by a second emergency physician to judge interobserver agreement. An additional 5 demographic variables were obtained from hospital records by study nurses.

Outcome Measures and Assessment

The primary outcome measure was *clinically important cervical spine injury*, defined as any fracture, dislocation, or ligamentous instability demonstrated by diagnostic imaging. *Clinically unimportant cervical spine injuries* generally do not require stabilizing treatment or specialized follow-up and the definition for this has been standardized based on the results of a formal survey of 129 neurosurgeons, spinal surgeons, and emergency physicians at 8 tertiary care hospitals.[27] All C-spine injuries were considered clinically important unless the patient was neurologically intact and had 1 of 4 injuries: (1) isolated avulsion fracture of an osteophyte (2) isolated fracture of a transverse process not involving a facet joint (3) isolated fracture of a spinous process not involving the lamina or (4) simple compression fracture involving less than 25% of the vertebral body height.

After the clinical examination, patients underwent plain radiography of the C-spine according to the judgment of the treating physician, not according to any preset guidelines. Radiographs were interpreted by qualified staff radiologists who were blinded to the contents of the data collection sheet. The reliability of the radiography interpretations was assessed by having all abnormal radiographs and 1% (randomly selected) of normal radiographs reviewed by a second radiologist who was blinded to the first interpretation. Radiography consisted of a minimum of 3 views. Patients also underwent flexion-extension views and computed tomography of the C-spine at the discretion of the treating physician.

Because not all patients with blunt trauma routinely undergo C-spine radiography at the Canadian study sites, we could not ethically mandate universal radiography for all eligible patients. Consequently, all enrolled patients who did not have radiography underwent the structured 14-day proxy outcome measure administered by telephone by a registered nurse. Patient telephone numbers were verified by the treating emergency physician. According to this tool, patients were classified as having no clinically important C-spine injury if they met all of the following 4 explicit criteria for 14 days: (1) neck pain rated as none or mild, (2) restriction of neck movement rated as none or mild, (3) use of a cervical collar not required, and (4) neck injury has not prevented return to usual occupational activities. The assessment of these criteria was made by registered nurses who were unaware of the patient's status for the individual predictor clinical variables. Patients who did not fulfill the criteria were recalled for clinical assessment and radiography. Patients who could not be reached were excluded from the final study analysis. These criteria have been previously shown to identify all C-spine injuries in a substudy that applied the telephone follow-up questionnaire to a sample of 389 study patients (including 66 with clinically important C-spine injury) who had all undergone radiography.[28]

Data Analysis

The interobserver agreement for each variable was measured by calculating the κ coefficient, the proportion of potential agreement beyond chance, along with 95% confidence intervals (CIs).[29,30] κ Values were not calculated for variables collected from medical records (eg, age or mechanisms of injury). Univariate analyses were used to determine the strength of association between each variable and the primary outcome to aid selection of the best variables for the multivariable analyses. The appropriate univariate techniques were chosen according to the type of data. For nominal data, the χ^2 test with continuity correction was used; for ordinal variables, the Mann-Whitney U test; and for continuous variables, the unpaired 2-tailed *t* test, using pooled or separate variance estimates as appropriate.

Those variables found to be both reliable ($\kappa > 0.6$) and strongly associated with the outcome measure ($P < .05$) were combined using either recursive partitioning or logistic regression. The objective was to find the best combinations of predictor variables, ie, those highly sensitive for detecting the outcome measure while achieving the maximum possible specificity. Building of the regression model proceeded with forward stepwise selection until no variables met the criteria for entry ($P < .05$) or removal ($P > .10$) for the significance levels of the likelihood-ratio test. Recursive partitioning was performed as an alternative technique using KnowledgeSEEKER, version 3.1 (Angoss Software International, Toronto, Ontario).[31,32] Our experience suggested recursive partitioning may be more suitable than logistic regression when the objective is to correctly classify one outcome group at the expense of the other (ie, where high sensitivity is more important than overall accuracy).

The derived decision rule was cross-validated by comparing the classification of all patients to their actual status for the primary outcomes allowing estimates, with 95% CIs, of the sensitivity and specificity of the rule. In addition, we conducted a statistical validation using a jackknife nonparametric estimate of bias for the sensitivity, specificity, and overall accuracy of the rule.[33,34] The a priori sample size was estimated to be 8000 patients and 120 injury cases, based on the desired precision of 100% sensitivity for clinically important C-spine injury with 95% confidence limits of 97% to 100%.

Table 1. Characteristics of Patients Presenting With Potential Cervical Spine Injury (N = 8924)*

Age, mean (SD), y	36.7 (16)
Range, y	16–98
Men	4600 (51.5)
Time from injury to assessment, mean (SD), h	4.5 (7.4)
Arrived by ambulance	4790 (53.7)
Transfer from another institution	368 (4.1)
Ambulatory at any time	6022 (67.5)
Upright position during examination	3330 (37.3)
Neck pain	8169 (91.5)
Mechanism of injury	
Motor vehicle collision	5975 (67.0)
Fall	1277 (14.3)
Struck as pedestrian	298 (3.3)
Assault	293 (3.3)
Head struck or hit by object	291 (3.3)
Sports	256 (2.9)
Bicycle	221 (2.5)
Axial load	192 (2.2)
Motorcycle	66 (0.7)
Motorized recreational vehicle	47 (0.5)
Other	8 (0.1)
Cervical spine radiography performed	6145 (68.9)
Computed tomography performed	436 (4.9)
Cases followed up by telephone	2779 (31.1)
Clinically important cervical spine injury†	151 (1.7)
Fracture	143 (1.6)
Dislocation	23 (0.3)
Ligamentous instability	9 (0.1)
Clinically unimportant cervical spine injury	28 (0.3)
Avulsion, osteophyte	8 (0.1)
Avulsion, transverse process	5 (0.1)
Avulsion, spinous process	12 (0.1)
Vertebral compression, <25% of body height	3 (0.03)
Developed neurological deficit	11 (0.1)
Stabilizing treatments	161 (1.8)
Internal fixation	25 (0.3)
Halo	55 (0.6)
Brace	19 (0.2)
Rigid collar	62 (0.7)
Admitted to hospital	726 (8.1)

*All values are number (%) unless otherwise noted.
†Some patients had more than 1 injury.

RESULTS

Between October 1996 and April 1999, 12782 eligible patients were examined at the study sites. Of these, 8924 patients were enrolled and assessed for the primary outcome measure, clinically important C-spine injury, and thus made up the final study group (**TABLE 1**). Not included in this study group were 3281 eligible patients examined but not enrolled by the treating physicians. All characteristics of these nonenrolled patients were very similar to those of the patients enrolled except for slightly higher rates of arrival by ambulance (61% vs 54%), transfer from another hospital (10% vs 4%), and incidence of C-spine injury (3.2% vs 2.0%). Finally, 577 eligible patients were also not included in the final study group because they did not undergo C-spine radiography and could not be reached for the proxy outcome measure. This latter group were much less severely injured: only 32% arrived by ambulance, 0.2% were transfers from other hospitals, and only 0.9% were admitted to hospital. Of the patients in the final study group, 6185 (68.9%) underwent C-spine radiography and the remaining 31.1% underwent the structured 14-day telephone proxy outcome measure administered by a registered nurse. Of all study patients, 151 (1.7%) were determined to have a clinically important C-spine injury. The radiologists showed 100% agreement in diagnosing C-spine injury. An additional 28 (0.3%) patients were judged to have a clinically unimportant C-spine injury, primarily avulsion fractures. No patient contacted for the proxy outcome measure was later determined to have a C-spine injury.

TABLE 2 and TABLE 3 show the association between the predictor variables and clinically important C-spine injury as determined by univariate analyses. Overall, we evaluated 25 primary predictor variables (20 from the physician's form and 5 from the chart) as well as another 8 created by combination or cutpoints. Table 2 also shows the interobserver agreement for the primary clinical variables from those patients (n=150) examined by 2 physicians.

Table 2. Univariate Correlation and κ Values for Variables From History and Examination for Clinically Important Cervical Spine Injury*

	C-Spine Injury (n = 151)	No C-Spine Injury† (n = 8773)	χ^2‡	κ (n = 150)
Questions From History				
Age, mean, y	45.0	36.6	. . .	. . .
Age ≥65 y	22.5	7.0	53.4	. . .
Men	66.9	51.3	14.5	. . .
Arrived by ambulance	86.8	53.1	67.6	. . .
Ambulatory at any time after injury	44.4	68.0	37.8	0.87
Midline posterior neck pain	89.7	60.1	49.0	0.69
Posterolateral neck pain	26.5	61.2	67.6	0.45
Time to neck pain, mean, min	16	38	. . .	. . .
Immediate neck pain	79.0	52.9	35.7	. . .
Numbness or tingling in extremities	24.0	9.4	35.9	0.77
Weakness in extremities	8.0	3.0	12.5	0.54
Questions From Physical Examination				
Sitting position during examination	6.0	37.9	70.5	0.74
Distracting painful injuries	15.2	7.7	11.8	0.41
Facial injury	43.1	18.8	56.1	0.75
External head injury	48.3	20.3	71.1	0.76
Unreliable findings due to drugs or ethanol	8.0	4.1	5.4	0.22
Sensory deficit in extremities	6.0	1.9	12.2	0.60
Motor deficit in extremities	4.6	1.2	14.6	0.93
Neck tenderness midline	86.1	57.3	50.6	0.78
Neck tenderness posterolateral	51.3	65.8	13.6	0.32
Tenderness maximal at midline (n = 5078)	87.3	51.4	27.8	0.72
Neck deformity, stepoff or crepitus (n = 6422)	3.9	1.2	5.8	. . .
Able to actively rotate neck 45° left and right	4.0	56.4	170.1	0.67
Able to actively flex neck	1.3	53.8	180.0	0.63

*All values are percentages unless otherwise indicated. C-spine indicates cervical spine; ellipses, not applicable.
†Includes patients with no injury and those with clinically unimportant injury.
‡Higher χ^2 values indicate a stronger statistical association. For all χ^2 values greater than 4.9, $P<.05$.

Logistic regression analysis (TABLE 4) provided a model with good overall accuracy for discriminating cases with clinically important C-spine injury (area under the receiver operating characteristic curve, 0.91; $P=.94$ for the Hosmer-Lemeshow goodness-of-fit test). We also conducted recursive-partitioning analysis, which ultimately resulted in a more clinically acceptable model. The predictor variables in this latter statistical model were then combined into a simple algorithm, the "Canadian C-Spine Rule" (FIGURE). This clinical decision rule asks 3 basic questions and establishes the safety of evaluating active range of motion by identifying high-risk and low-risk factors.

The potential classification performance of the Canadian C-Spine Rule for identifying 151 cases with clinically important C-spine injury reveals a sensitivity (95% CI) of 100% (98%-100%) and a specificity of 42.5% (40%-44%) (TABLE 5). From the jackknife statistical analysis, we calculated the bias-corrected estimates for sensitivity to be 100% and those for specificity to be 42.63%; the bias for overall accuracy was estimated to be 2.12%. We estimate a potential C-spine radiography rate of 58.2% in this cohort, a relative reduction of 15.5% from 68.9%. The rule also would have identified 27 out of 28 patients with clinically unimportant C-spine injury. One 63-year-old patient not identified had a small C3 osteophyte avulsion fracture and was discharged from the ED with a cervical collar.

COMMENT

This represents the largest derivation study yet conducted of patients having potential C-spine injury, evaluating the accuracy and reliability of 25 clinical variables and enrolling 8 times more patients than any previous derivation study. We developed a highly sensitive clinical decision rule that, if prospectively validated, will allow physicians to rationally order C-spine radiography for alert and stable trauma patients who are at risk for neck injury. This will lead to more timely and efficient use of resources without jeopardizing patient care. This new Canadian C-Spine Rule identifies those trauma patients who require C-spine radiography based on 3 simple clinical questions. First, patients judged to be at high risk due to age, dangerous mechanism of injury, or paresthesias must undergo radiography. Second, patients with any 1 of 5 low-risk characteristics may safely undergo assessment of active range of motion. Third, patients who are able to actively rotate their neck 45° to the left and to the right, regardless of pain, do not require C-spine radiography. The Canadian C-Spine Rule was derived according to strict methodological standards and provides a very tight CI around the estimated sensitivity of 100% for detecting injury. Future studies will further evaluate the rule for accuracy and reliability, acceptability to clinicians, and actual impact on patient care.

We believe that current use of C-spine radiography for alert and stable trauma patients is very inefficient and highly variable.[12,15,16] Most patients in the United States undergo radiography regardless of their clinical presentation. While Canadian practice is more selective, we have shown that there is very large variation among hospitals and physicians in their use of C-spine radiography.[17] This 2-fold variation among hospitals and 6-fold variation among certified attending emergency physicians persisted even after using multivariable analysis to control for differences in severity of trauma. There is considerable controversy among emergency physicians, neurosurgeons, and trauma surgeons regarding indications for C-spine radiography. Some firmly maintain that all trauma patients should undergo radiography.[3,7,35-37] For example, in its Advanced Trauma Life Support Course, the American College of Surgeons recommends that " . . . C-spine films should be attained on every patient sustaining an injury above the clavicle and especially a head injury."[38] Other trauma clinicians agree that a selective approach is ideal but do not give clear recommendations.[39-41] Most authors suggest that radiography may not be required in alert patients with no pain or tenderness of the neck.[42-46] Such an approach is still very conservative, but only a few authors are willing to suggest that radiography may be withheld in alert patients with neck pain if there is no midline bone tenderness of the neck.[47,48] According to Neifeld and colleagues,[13] "the real difficulty exists in patients who are awake, alert, have normal physical examination findings and have minimal or no symptoms." This latter group represents the largest group of blunt trauma patients and the greatest potential for improved efficiency of radiography. Our own surveys have shown that most Canadian physicians and those in the United States disagree with guidelines for universal C-spine radiography and support evidence-based guidelines if they are shown to be accurate and reliable.[49]

Table 3. Univariate Correlation of Variables From Mechanism of Injury for Clinically Important Cervical Spine Injury*

Mechanism Questions	C-Spine Injury (n = 151)	No C-Spine Injury (n = 8773)	χ^2_1
Mechanism of injury			212.3
Motor vehicle collision	49.7	67.3	
Motorcycle collision	1.3	0.7	
Bicycle collision	2.0	0.4	
Bicycle struck	0.7	1.1	
Other bicycle	0	1.0	
Pedestrian struck	0.7	2.0	
Pedestrian struck and thrown	1.3	1.4	
Fall from an elevation			
<1 m or 5 stairs	9.9	8.3	
≥1-3 m or 5-15 stairs	11.9	4.3	
>3 m or 15 stairs	3.3	1.5	
Assault with fist or feet	0.7	2.7	
Assault with blunt object	0	0.7	
Sports	0	2.9	
Contact sports (axial load)	8.6	1.2	
Heavy object onto head (axial load)	2.0	0.3	
Fall onto head (axial load)	2.0	0.1	
Diving	3.3	0.3	
Head struck by other object	0.7	1.9	
Head struck on object	0	1.4	
Motorized recreational vehicles	2.0	0.5	
Other	0	0.1	
Dangerous mechanism†	58.9	13.4	254.5
No seatbelt (n = 5975)‡	58.7	74.7	. . .
Bicycle helmet used (n = 221)‡	75.0	33.6	3.7
Motor vehicle collision	49.7	67.3	. . .
Ejected	6.7	0.6	44.4
Rollover	38.7	5.0	165.5
Death in same collision	2.7	0.3	17.3
Head-on collision	16.0	4.8	24.2
Simple rear-end collision	1.3	31.9	38.0
Highway speed (60-100 km/h)	54.7	7.9	276.6
High speed (>100 km/h)	13.3	1.6	276.6
Bull's-eye damage to windshield (n = 5975)	0	1.7	118.9

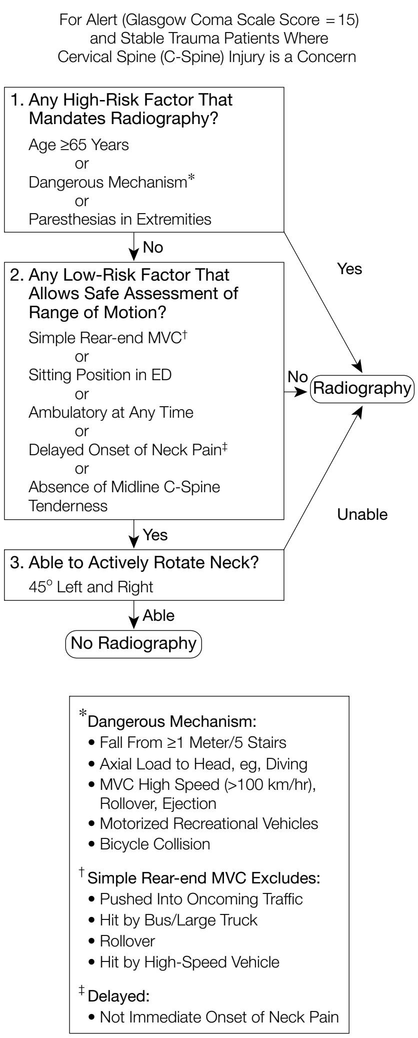
*C-spine indicates cervical spine; ellipses, not applicable.
†Defined as a fall from an elevation ≥1 m or 5 stairs, axial load to the head (eg, diving), high-speed (>100 km/h) motor vehicle collision, rollover, ejection, bicycle collision, motorized vehicle collision.
‡Data applicable to some patients only.

Table 4. Odds Ratios of Clinical Variables in the Final Model for Predicting Clinically Important Cervical Spine Injury*

Variable	Coefficient	OR (95% CI)
Intercept	−3.63	
Dangerous mechanism†	1.65	5.2 (3.7-7.3)
Age ≥65 y	1.30	3.7 (2.4-5.6)
Paresthesias in extremities	0.77	2.2 (1.4-3.3)
Ambulatory at any time after injury	0.03	1.0 (0.7-1.5)
Sitting position in ED	−0.57	0.61 (0.3-1.2)
Delayed onset of neck pain	−0.85	0.4 (0.3-0.7)
Absence of midline neck tenderness	−0.69	0.5 (0.3-0.8)
Able to rotate neck 45° left and right	−3.15	0.04 (0.01-0.3)
Simple rear-end MVC‡	−2.56	0.08 (0.03-0.2)

*OR indicates odds ratio; CI, confidence interval; ED, emergency department; and MVC, motor vehicle collision.
†Fall from an elevation ≥1 m or 5 stairs; axial load to the head; high-speed MVC, rollover, or ejection; bicycle collision; and motorized recreational vehicle collision.
‡Excludes vehicles pushed into oncoming traffic, hit by bus or large truck, rolled over, or hit by high-speed vehicle.

Figure. The Canadian C-Spine Rule



MVC indicates motor vehicle collision; ED, emergency department.

A number of studies have been conducted in recent years by emergency physicians, trauma surgeons, and radiologists to identify a group of trauma patients who do not need C-spine radiography. Unfortunately, these studies have great variability in design and none could be considered robust according to methodological standards for the development of clinical decision rules. An exception are the US-based NEXUS criteria, which have recently received prominent attention after the publication of a huge validation study incorporating more than 34000 patients.[26,48,50] These guidelines state that no C-spine radiography is required if patients satisfy all 5 low-risk criteria: absence of midline tenderness, normal level of alertness, no evidence of intoxication, no abnormal neurological findings, and no painful distracting injuries. We have concerns about the sensitivity, specificity, and reliability of these criteria. The authors' own calculated specificity of 12% is very low and may actually lead to an increase in the use of C-spine radiography in most countries outside of the United States. Clinicians in Canada have found 2 of the criteria ("presence of intoxication" and "distracting painful injuries") to be poorly reproducible. We recently attempted a retrospective validation of the NEXUS criteria based upon our database of 8924 patients and found that the criteria failed to predict 10 of 148 clinically important injuries, yielding a sensitivity of only 93%.[51] We believe that the NEXUS criteria should be further evaluated, prospectively and explicitly, for sensitivity, specificity, and interobserver agreement in multiple sites before they can be accepted for widespread clinical use.

One strength of our study was the strict adherence to methodological standards for the derivation of clinical decision rules.[24,25,52-54] The primary outcome measure, clinically important C-spine injury, was clearly defined and was assessed in a blinded fashion. In addition, the clinical findings used as predictors were standardized and collected without knowledge of the outcome measure. The reproducibility of the predictor findings was assessed by having a subset of patients examined by 2 physicians. The study subjects were selected without bias and based on preset criteria rather than on the subjective decision of individual physicians to order C-spine radiography. These patients represented a wide spectrum of clinical characteristics and geographic sites, hence increasing generalizability. The mathematical techniques for deriving the rule were explicit and appropriate. We believe that the format of the rule, a simple list of questions, makes it clinically sensible for the intended audience of busy emergency physicians. Furthermore, the rule appears to be highly sensitive for the clinically important outcome, making its use safe for patient care. In addition, it is relatively specific, making it an efficient tool. The true impact of the Canadian C-Spine Rule, however, can only be determined in a prospective study to evaluate the accuracy, interobserver agreement, clinician acceptability, and potential radiograph ordering rates in a new patient population.

Conversely, our study has potential limitations that warrant discussion. Some may be concerned about our use of clinically important C-spine injury as the primary outcome. Our definition has, however, been well accepted by Canadian academic neurosurgeons, spine surgeons, and emergency physicians. We believe that this represents a pragmatic and very safe approach to patient care. The priority of diagnostic imaging for these trauma patients should be to identify C-spine injuries that require treatment and follow-up. Clinically unimportant C-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. Furthermore, the Canadian C-Spine Rule has also proven to be very sensitive for the clinically unimportant injuries, missing only 1 small avulsion fracture that required treatment with a cervical collar only.

Another potential limitation is that not all study patients underwent C-spine radiography. The Canadian clinicians in our study often withhold diagnostic imaging for trauma patients whom they consider to be at low risk for injury. Consequently, we could not ethically insist upon universal radiography for all patients. Patients were only classified as having no clinically important injury if they satisfied all criteria on the structured 14-day telephone proxy outcome tool. Patients who could not fulfill all criteria were recalled for radiography and patients who could not be reached were excluded from the final analysis. The proxy outcome tool has been validated and shown to be very accurate in identifying patients with clinically important injuries. In addition, we acknowledge that not all eligible patients were enrolled in the study. However, this is not unusual for a clinical study and we are confident that there was no selection bias—the characteristics of patients not enrolled were very similar to those of the patients who were enrolled.

The Canadian C-Spine Rule encompasses many variables that have previously not been prominently considered in guidelines for the use of C-spine radiography. We found that patients 65 years or older and those experiencing paresthesias were at considerable risk of C-spine injury, and that all such patients should undergo radiography. In addition, our data clearly demonstrate that particular mechanisms of injury are associated with substantially increased risk of important injury and that patients with such injuries should not be further examined prior to radiography. Furthermore, our results demonstrate that 5 factors put the patient at very low risk of injury and allow safe assessment of range of motion: simple rear-end motor vehicle collision, found to be in the sitting position in the ED, ambulatory status at any time after the injury, delayed onset of neck pain, and absence of midline C-spine tenderness. The final common pathway of the Canadian C-Spine Rule requires patients to successfully demonstrate an ability to rotate the neck actively left and right a minimum of 45°, regardless of pain. This assessment mirrors clinical practice in Canada but would appear to be a relatively uncommon approach in US sites that have adopted the NEXUS criteria.

There are 2 potential implications of a decision rule or guideline for the use of C-spine radiography in alert and stable trauma patients. First, patient management would become standardized and more efficient. The great variation of current practice and the extremely low yield of radiography suggest a need for accurate and reliable guidelines. A sensitive and specific decision rule would reduce the unnecessary use of radiography and would allow much more rapid triage and evaluation of patients brought to the ED by ambulance stretcher. Such patients often languish for hours on an uncomfortable backboard before their C-spine is judged free of injury.

Second, an accurate decision rule could lead to significant savings for our health care systems. The current variation in practice and very low yield of C-spine radiography among alert and stable trauma patients would suggest significant potential for reducing the use of this radiography. Our survey of emergency physicians in 5 North American and European countries clearly indicates a willingness to adopt a decision rule for C-spine radiography.[55] Based on our studies that show large reductions in the use of ankle radiography after the implementation of the Ottawa Ankle Rules,[20,21] we estimate that a 25% to 50% relative reduction in the use of C-spine radiography could be safely achieved.

There is currently much controversy in the literature and much variation and inefficiency in clinical practice regarding the use of C-spine radiography for alert and stable trauma patients. Our study has developed the highly sensitive Canadian C-Spine Rule to identify a large group of patients for whom C-spine radiography is unnecessary. If prospectively validated in other cohorts, this rule has the potential to standardize and improve efficiency in the use of C-spine radiography in EDs.

Table 5. Performance of the Canadian C-Spine Rule for Clinically Important Cervical Spine Injury*

Decision Rule	Clinically Important Injury: Yes	Clinically Important Injury: No
Yes	151	5041
No	0	3732
Sensitivity, % (95% CI)	100 (98-100)	
Specificity, % (95% CI)	42.5 (40-44)	
Radiograph ordering rate, %	58.2	

*CI indicates confidence interval.

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