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# Value of Canadian C-spine rule versus the NEXUS criteria in ruling out clinically important cervical spine injuries: derivation of modified Canadian C-spine rule

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## Abstract

**Purpose** Although, Canadian C-spine rule and the National Emergency X-Radiography Utilization Study (NEXUS) criteria in ruling out clinically important cervical spine injuries have been validated using large prospective studies, no consensus exist as to which rule should be endorsed. Therefore, the aim of the present study was to compare the accuracy of the Canadian C-spine and NEXUS criteria in ruling out clinically important cervical spine injuries in trauma patients. Finally, we introduced the modified Canadian C-spine rule.

**Methods** A prospective diagnostic accuracy study was conducted on trauma patients referred to four emergency departments of Iran in 2018. Emergency physicians evaluated the patients based on the Canadian C-spine rule and NEXUS criteria in two groups of low risk and high risk for clinically important cervical spine injury. Afterward, all patients underwent cervical imaging. In addition, modified Canadian C-spine rule was derived by removing dangerous mechanism and simple rear-end motor vehicle collision from the model.

**Results** Data from 673 patients were included. The area under the curve of the NEXUS criteria, Canadian C-spine, and modified Canadian C-spine rule were 0.76 [95% confidence interval (CI) 0.71–0.81], 0.78 (95% CI 0.74–0.83), and 0.79 (95% CI 0.74–0.83), respectively. The sensitivities of NEXUS criteria, Canadian C-spine, and modified Canadian C-spine rule were 93.4%, 100.0% and 100.0%, respectively.

**Conclusions** The modified Canadian C-spine rule has fewer variables than the original Canadian C-spine rule and is entirely based on physical examination, which seems easier to use in emergency departments.

**Keywords** Cervical spine · Diagnostic imaging · Sensitivity and specificity · Decision supportive technique · Trauma

## Introduction

Traumatic cervical spine injury is one of the most important and challenging issues in the management of patients in emergency departments [1]. These patients comprise a significant portion of long lasting injuries and severe disabilities [2]. Most physicians prefer to conduct various imaging evaluation to rule out cervical spine fracture-dislocations or vertebral instability [3]. However, clinically important cervical injuries are found in less than 3% of patients and the imaging evaluations performed for 97% of these subjects are unnecessary [4]. Moreover, exposure to radiation is another issue. Accordingly, identifying patients with higher risk of

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cervical spine injuries seems to be very important in the management of trauma patients.

Application of the rule out criteria could decrease the assessment time and improve clinical approach to injuries [5–10]. In the past decade, two criteria for ruling out clinically important cervical spine injuries were designed. These two models, presented nearly at the same time, include the Canadian C-spine rule [11] and the National Emergency X-Radiography Utilization Study (NEXUS) criteria [12]. They were designed to decrease the rate of unnecessary imaging in low risk patients for blunt cervical spine injuries. The C-spine scoring criterion was introduced by Stiell et al. in 2001, to identify high-risk patients for traumatic cervical injury. The Canadian C-spine rule is applicable for alert, and stable condition patients and it is a decision rule to perform radiography based on patient's clinical signs and symptoms [11]. The NEXUS criteria for C-Spine imaging were introduced by Hoffman et al. in 2000. The guidelines recommend that if NEXUS criteria for a patient was negative, imaging is not necessary [12].

Currently, they are now being recommended in the guidelines as two reliable diagnostic approaches [13]. Although, NEXUS and Canadian C-spine decision rules have been validated using large prospective studies, no consensus exist as to which rule should be endorsed. Therefore, the present study aimed to compare the accuracy of the Canadian C-spine and NEXUS criteria in ruling out clinically important cervical spine injuries in trauma patients. Finally, we introduced the modified Canadian C-spine rule.

## Materials and methods

### Study design and setting

A prospective diagnostic accuracy study was conducted on trauma patients referred to four emergency departments of Iran between March and November 2018. Cervical radiography was performed for all patients. Based on clinical evaluations and using the Canadian C-Spine and NEXUS criteria, patients were divided into two groups: low risk (no need for imaging) and high risk (need for imaging). The Ethics Committee of the National Institute for Medical Research Development of Iran approved the protocol of the present study. In addition, written informed consent was obtained from all patients.

### Subjects

Patients suspected to have cervical injury were included on the basis of clinical sign and symptoms. Inclusion criteria were presence of clinical signs and symptoms of cervical spine injury and age above 18 years. Exclusion criteria also

include penetrating injury, Glasgow coma scale < 15, acute paralysis, known vertebral diseases, previous C-spine injury and pregnancy. Convenience sampling was implemented for selection of subjects.

Data from 673 patients were included. The mean age of these patients was  $34.3 \pm 19.4$  years. Sixty-three (9.4%) patients were 65 years of age or older and 466 (69.2%) were male. The mechanism of injury was high speed motor vehicle collision (MVC)/rollover/ejection in 259 (38.7%) patients. Twenty-nine (4.3%) patients had transient altered level of consciousness after injury (Table 1). All patients underwent cervical spine radiography. (Sixty-seven patients were evaluated by CT scan or MRI.) Imaging showed 61 (9.1%) cases of clinically important cervical spine injuries.

### Index test

Data were gathered prospectively from the patients. An emergency medicine specialist was assigned to collect the information in each emergency department. On admission, patients' demographic variable, medical history, and physical examination were recorded in the pre-designed

**Table 1** baseline characteristics of included patients

Variable	Value
Age (mean $\pm$ SD; year)	34.3 $\pm$ 19.4
Sex (n, %)	
Male	466 (62.2)
Female	207 (30.8)
Mechanism of injury (n, %)	
high speed MVC/rollover/ejection	259 (38.7)
Pedestrian to car	114 (22.1)
Fall from $\geq$ 3 ft (0.9 m)/5 stairs	78 (11.7)
bicycle collision	32 (4.8)
Simple rearend motor vehicle collision	186 (27.8)
Heart rate (mean $\pm$ SD; beat/min)	89.5 $\pm$ 14.6
Systolic blood pressure (mean $\pm$ SD; mmHg)	114.2 $\pm$ 22.9
Diastolic blood pressure (mean $\pm$ SD; mmHg)	79.0 $\pm$ 20.6
Respiratory rate (mean $\pm$ SD; per min)	18.1 $\pm$ 3.3
SPO2 (mean $\pm$ SD; %)	95.8 $\pm$ 2.1
Paresthesia (n, %)	38 (5.7)
Sitting position in the ED (n, %)	402 (59.7)
Ambulatory at any time (n, %)	331 (49.2)
Delayed neck pain (n, %)	601 (89.3)
Midline tenderness (n, %)	431 (64.0)
Able to actively rotate neck 45° left and right (n, %)	490 (27.8)
Focal neurologic deficit (n, %)	61 (9.1)
Altered level of consciousness (n, %)	29 (4.3)
Intoxication (n, %)	26 (3.9)
Distracting injury (n, %)	154 (22.9)

checklists. The factors involved in the Canadian C-spine and NEXUS models were included in the checklists.

Emergency physicians evaluated the patients based on the Canadian C-spine rule and NEXUS criteria in two groups of low risk and high risk for clinically important cervical spine injury. Afterward, all patients underwent cervical imaging. Evaluation of patients by Canadian C-spine rule and NEXUS criteria was performed before cervical radiography.

## Reference index

Cervical radiography was performed on three views of cross-table lateral, anteroposterior, and open-mouth of the odontoid. The outcome was defined as presence of clinically important cervical spine injury. These injuries include any type of fracture-dislocation and vertebral instability. Although computed tomography (CT) scan and magnetic resonance imaging (MRI) are considered as the standard modalities for the diagnosis of these conditions, their application in all patients is not clinically practical and cannot be justified. Therefore, in patients who are candidates for CT or MRI imaging, the final diagnoses were made based on these imaging methods while the rest only underwent radiography of the cervical spine. All patients with an abnormal radiography underwent CT scanning. In addition, 16 patients underwent MRI imaging. The imaging results were interpreted by a musculoskeletal radiologist (having at least 4 years' experience) who was blinded to the patients' clinical condition.

## Statistical analyses

According to Hajian-Tilaki study [15], by considering a sensitivity of 95% for NEXUS criteria or Canadian C-spine rule, prevalence of 10% for abnormal cervical spine radiography, and a marginal error of 0.05, a minimum sample size of 365 patients was required.

The modified Canadian C-spine rule was derived by including the seven variables of original Canadian C-spine rule, having removed dangerous mechanism and simple rear-end MVC from the model.

Patients were categorized as positive or negative for clinically important cervical spine injuries according to their imaging. Based on the NEXUS criteria, Canadian C-spine rule and modified Canadian C-spine rule, the patients were also classified as "need for imaging" and "no need for imaging".

Discriminatory power of the Canadian C-spine rule and the NEXUS criteria for cervical spine imaging were assessed by estimating the area under the receiver operating curve (AUC), sensitivity, specificity, positive predictive value, negative predictive value, positive likelihood ratio and

negative likelihood ratio (with a 95% confidence interval). Analysis was performed using STATA 14.0 program.

## Results

### Value of NEXUS criteria for cervical spine imaging

According to the NEXUS criteria, 324 patients did not have clinically important cervical spine injuries. From this figure, 320 patients had normal cervical imaging (true negative = 320) while 4 patients had cervical injuries (false negative = 4). NEXUS criteria identified 349 patients who required imaging; 57 patients had clinically important cervical spine injuries (true positive = 57) and 292 had normal imaging (false positive = 292). Accordingly, the AUC of the NEXUS criteria in ruling out cervical injuries was 0.76 (95% CI 0.71–0.81) (Fig. 1). The sensitivity and specificity of NEXUS criteria were 93.4% and 52.3%, respectively (Table 2).

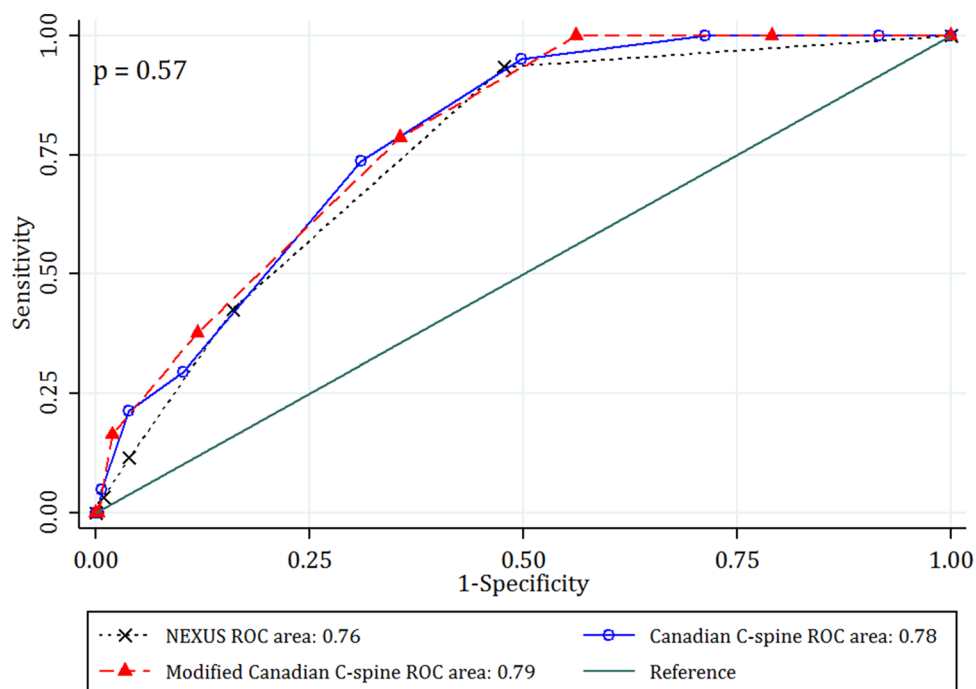
### Value of Canadian C-spine rule for cervical spine imaging

Based on the Canadian C-spine rule, 51 patients did not have clinically important cervical spine injuries. All of these 51 patients had a normal cervical imaging (true negative = 51). Canadian C-spine rule identified 622 patients who required imaging; 61 cases had clinically important cervical spine injuries (true positive = 61) and 561 had normal imaging (false positive = 561). Accordingly, the AUC of the Canadian C-spine in ruling out cervical injuries was 0.78 (95% CI 0.74–0.83) (Fig. 1). The sensitivity and specificity of this rule out criteria were 100.0% and 8.3%, respectively (Table 2).

### Value of modified Canadian C-spine rule for cervical spine imaging

Based on the modified Canadian C-spine rule, 128 patients did not have clinically important cervical spine injuries. These patients had normal cervical imaging (true negative = 128). Modified Canadian C-spine rule identified 545 patients who required imaging; 61 cases had clinically important cervical spine injuries (true positive = 61) and 484 had normal imaging (false positive = 484). Accordingly, the AUC of the modified Canadian C-spine in ruling out cervical injuries was 0.79 (95% CI 0.74–0.83) (Fig. 1). The sensitivity and specificity of this rule out criteria were 100.0% and 20.9%, respectively (Table 2). Figure 2 presents the modified Canadian C-spine rule.

**Fig. 1** Area under the curve of NEXUS criteria, Canadian C-spine rule, and modified Canadian C-spine rule in rule out of imaging in cervical trauma patients



**Table 2** Performance of Canadian C-spine rule and NEXUS criteria for cervical spine imaging

	NEXUS		Canadian C-spine		Modified Canadian C-spine	
	Value	95% CI	Value	95% CI	Value	95% CI
True positive	57	–	61	–	61	–
True negative	320	–	51	–	128	–
False Positive	292	–	561	–	484	–
False Negative	4	–	0	–	0	–
Sensitivity	93.4	83.2–97.7	100.0	91.3–100.0	100.0	62.6–100.0
Specificity	52.3	48.2–56.3	8.3	6.4–10.9	20.9	17.8–24.4
NPV	98.8	96.6–99.6	100.0	91.3–100.0	100.0	96.4–100.0
PPV	16.3	12.7–20.7	9.8	7.6–12.5	11.2	8.7–14.2
NLR	0.1	0.05–0.3	0.0	NA	0.0	NA
PLR	2.0	1.8–2.2	1.1	1.1–1.1	1.3	1.2–1.3

Not applicable: The calculation cannot be performed because the values entered include one or more instances of zero

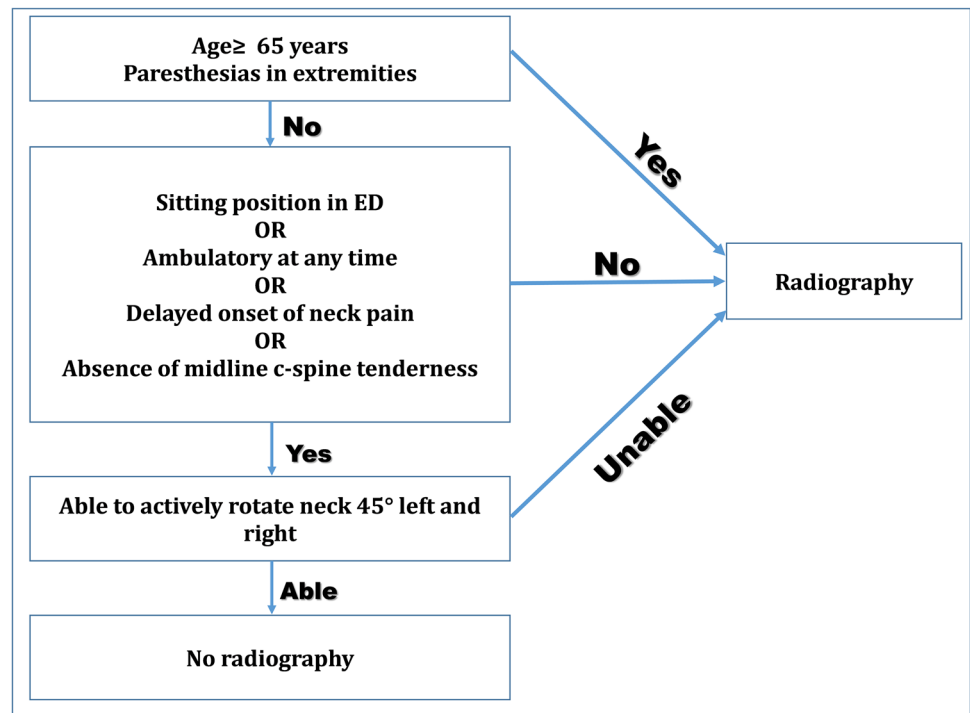
NA Not applicable; NPV Negative predictive value; PPV Positive predictive value; NLR: Negative likelihood ratio; PLR positive likelihood ratio

## Discussion

NEXUS and Canadian C-spine decision rules have been validated using large prospective studies. However, there was no consensus exist as to which rule should be endorsed. Therefore, we performed a prospective diagnostic study to compare the accuracy of the Canadian C-spine and NEXUS criteria in ruling out clinically important cervical spine injuries in trauma patients. The results of this

study showed that both the Canadian C-spine and modified Canadian C-spine are able to rule out all clinically important cervical spine injuries, while the NEXUS criteria missed four of these injuries (4 false negative). Therefore, the discriminatory power of the Canadian C-spine rule and the modified Canadian C-spine rule was higher than the NEXUS criteria. The AUC of Canadian C-spine, modified Canadian C-spine, and NEXUS were 0.78, 0.79, and 0.76, respectively ( $p = 0.57$ ). Since these three models are screening tests for subsequent investigations that may

**Fig. 2** Modified Canadian C-spine rule in rule out of imaging in cervical trauma patients



identify serious injury, high sensitivity is the most important criteria for evaluating the test performance. In line with our study, Stiell et al. 2003, who studied patients in Canada, showed that the Canadian C-spine rule was more sensitive than the NEXUS criteria. The sensitivity of the Canadian C-spine rule in identifying clinically important cervical injury was 99.4%, while this value was 90.7% for the NEXUS criteria [16]. In another study by Ala et al., which was carried out on Iranian patients, revealed that the sensitivities of the Canadian C-spine and NEXUS criteria were equal (sensitivity = 90.0%) [14]. As can be seen, the findings of the Ala et al. study were different from Stiell et al. and our study. This could be due to the low sample size in the Ala et al. study.

Our study had several limitations. First, Canadian C-spine imaging rule have the higher number of variables required for its calculation. In many developing countries, information such as fall from  $\geq 3$  Ft. or 5 stairs, axial load injury, high speed MVC/rollover/ejection, motorized recreational vehicle and a simple rear-end MVC are not recorded at the scene. Therefore, in some patients, the Canadian C-spine cannot be evaluated. We removed the two factors of the dangerous mechanism and rear-end MVC from the model. We excluded these two variables because in Iran, the recording of details of road traffic injuries at the scene of accident is not accurate. The findings suggest that the modified Canadian C-spine model has a similar value to the original Canadian C-spine in ruling out clinically important cervical spinal injury.

In addition, in the original Canadian C-spine imaging rule, there is no regard for intoxicated patients or patients with distracting injuries or focal neurological deficit. However, we have fitted a new model that incorporates the original Canadian C-spine imaging rule variables as well as intoxication, presence of distracting injuries and focal neurological deficit. In this situation, the area under the curve, sensitivity and specificity of the model in ruling out cervical injuries were 0.75, 100.0% and 26.5%, respectively (Supplement Fig. 1 and Supplement Table 1). Therefore, it seems that adding intoxication, presence of distracting injuries and focal neurological deficit does not change the performance of the model, which makes it even more difficult to use in the routine clinic. However, our effort is a derivation study and future studies are required to validate modified Canadian C-spine rule in various communities.

Using a convenience sampling approach is another limitation of present study. Therefore, there may be selection bias in present study. It is recommended that a consequence sampling method be adopted in future validation studies.

In conclusion, we found that the Canadian C-spine and the modified Canadian C-spine are preferable to the NEXUS criteria for ruling out clinically important cervical spinal injuries. Since the modified Canadian C-spine rule has fewer variables than the original Canadian C-spine rule and is entirely based on physical examination, it was easier to use in emergency departments in Iran, and performed as well as the full rule. Although, we suggest further validation studies, the modified rule may be useful in certain settings.



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## Compliance with ethical standards

**Conflict of interest** The authors declare that they have no competing interests.

**Ethics approval** The protocol of present study was approved by the Ethics Committee of the National Institute for Medical Research Development of Iran. In addition, written informed consent was obtained from all patients.

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