

TRAVMALI HASTALARDA KANADA SERVİKAL OMURGA KURALLARI VE NEXUS DÜŞÜK RİSK KRİTERLERİNİN GEÇERLİLİĞİ

The Validity of Canadian Cervical Spine Rules and the Nexus Low Risk Criteria in Trauma Patients

Bora KAYA¹ (0000-0001-8912-9078, Erkman SANRI² (0000-0002-7108-3304),
Haldun AKOĞLU² (0000-0002-1316-0308), Özlem GÜNEYSEL³ (0000-0002-1833-2199)

ÖZET

Giriş ve amaç: Künt servikal travma hastalarında klinik olarak anlamlı yaralanmaları tanımlamak için geliştirilen ilk karar kuralı National Emergency X-Radiography (NEXUS). NEXUS çalışmasında, negatif prediktif değer (NPV) % 99,8 olarak belirlenmiştir. Kanada Servikal Omurga Kurallarının (KSOK) duyarlılığı % 99,4, özgüllük % 45,1 ve NPV % 100 olarak bildirilmiştir. Bu çalışmanın amacı, servikal yaralanma riski olan Türk hasta popülasyonu için NEXUS ve KSOK'nın güvenilirliğini ve yararlılığını belirlemektir.

Gereç ve yöntem: Bu prospektif gözlemsel çalışmaya, 1 Ocak 2012 - 1 Nisan 2012 tarihleri arasında, akut travma geçiren ve ambulansla ya da kendi imkanlarıyla hastaneye başvuran, servikal travmaya yol açabilecek bir mekanizma ile yaralanan 16 yaşın üzerindeki, gebe olmayan, stabil, bilinçli hastaları kapsayan 225 hasta dahil edilmiştir. Bu hastalar daha sonra NEXUS ve CCR geçerliliği için değerlendirildi. Veriler güncel istatistik programında analiz edildi.

Bulgular: 225 hastanın 7'sinde servikal patoloji tespit edilmiştir. Patolojik görüntüleme bulgusu varlığını belirleme açısından NEXUS'un duyarlılığı %93(%95 GA 83-97) ve özgüllüğü %1,3(%95 GA 0,2-5,1) olarak bulunurken, KSOK'nin duyarlılığı %100 (%95 GA %56-100) ve özgüllüğü %3,2 (%95 GA %1,4-6,7) olarak tespit edildi.

Sonuç: KSOK ve NEXUS düşük risk kriterlerinin acil serviste servikal patolojilerin dışlanmasında faydalı olduğu, KSOK'nın, NEXUS düşük risk kriterleri ile karşılaştırıldığında daha güvenilir ve yararlı olduğu tespit edilmiştir.

Anahtar Sözcükler: NEXUS; Kanada servikal omurga kuralları; Servikal travma

ABSTRACT

Background: The first decision rule developed to identify clinically significant injuries in blunt cervical trauma patients is National Emergency X-Radiography Utilisation Study (NEXUS). In the NEXUS study, the negative predictive value (NPV) has been determined as 99.8%. Sensitivity of Canadian Cervical Spine Rules (CCR) was reported as 99.4%, specificity as 45.1% and NPV was reported as 100%. The objective of this study is to determine the reliability and utility of NEXUS and CCR for Turkish patient population that has a risk of cervical injury.

Methods: This prospective observational study included 225 patients, all stable, conscious patients over 16 years of age who had acute trauma and were brought to the hospital with ambulances or using their own means and who had been injured by a mechanism that may cause cervical trauma, and without exclusion criteria. The patients included in the study were then evaluated for NEXUS and CCR validity.

Results: When CCR was evaluated as a whole, it was determined that all pathological cases were identified using these rules. In terms of identifying the presence of pathological imaging finding the sensitivity of CCR was 100% (95% CI % 56-100) and specificity was 3.2% (95% CI 1.4-6.7%). NEXUS's sensitivity was calculated as 93% (95% CI 83-97) and specificity as 1.3%(95% CI 0.2-5.1).

Conclusion: CCR and the NEXUS were determined to be useful in the emergency department for the exclusion of cervical pathologies. CCR were more reliable and useful when compared with the NEXUS.

Keywords: NEXUS; Canadian rules; Cervical trauma

¹Kocaeli Sağlık Bilimleri Üniversitesi
Derince Eğitim Araştırma Hastanesi,
Acil Tıp Anabilim Dalı, Kocaeli

²Marmara Üniversitesi İstanbul Pendik
Eğitim ve Araştırma Hastanesi, Acil Tıp
Anabilim Dalı, İstanbul

³Maltepe Üniversitesi Tıp Fakültesi
Hastanesi, Acil Tıp Anabilim Dalı,
İstanbul

Bora KAYA, Uzm. Dr.
Erkman SANRI, Uzm. Dr.
Haldun AKOĞLU, Doç. Dr.
Özlem GÜNEYSEL, Prof. Dr.

İletişim:

Uzm. Dr. Bora KAYA,
Kocaeli Sağlık Bilimleri Üniversitesi
Derince Eğitim Araştırma Hastanesi,
Acil Tıp Kliniği, İbnisina Mah., SSK Hst.,
41900 Derince/Kocaeli
Tel: +90 262 317 80 00,
e-mail:
drborakaya@hotmail.com

Geliş tarihi/Received: 13.08.2018

Kabul tarihi/Accepted: 18.09.2018

DOI: 10.16919/bozoktip.453285

Bozok Tıp Derg 2019;9(1):100-7
Bozok Med J 2019;9(1):100-7

INTRODUCTION

Based on the relevant data in 2013, the number of living people with a suspected spinal injury during a course of a year is approximately 273,000 (1). Annual spinal cord injury and paralysis incidence has been reported as 40 in one million (2). For a representative person in 1988, the lifetime cost of living with complete paraplegia after injury at age 33 years was estimated to be 500,000 USD. For a complete quadriplegia incurred at age 27 years, the cost rose to 1 million USD (3).

The first decision rule developed to identify clinically significant injuries in blunt cervical trauma patients is National emergency X-Radiography Utilisation Study (NEXUS) and this is verified prospectively with a major, multi-centered observational study. According to the NEXUS study, in conscious patients who do not have any intoxication indication or confusion, any midline neck pain-tenderness, any other injury that may distract the attention and whose neurological examination is normal, the likelihood of cervical spine injury is low (4). In the NEXUS study, the negative predictive value of these five criteria for cervical spine injuries has been determined as 99.8 % (specificity 12.9%, sensitivity 99%).

Low specificity reported for NEXUS has been construed by some researchers to cause excess radiological investigations when these criteria are used. These researchers developed Canadian Cervical Spine Rules (CCR) which is a method based on 3 clinical questions and 25 associated variables (5). In a prospective study conducted in the emergency departments of 9 tertiary healthcare Canadian hospitals in 2003, cervical injury was detected in 169 of the 8289 patients for whom CCR was applied. The sensitivity of CCR was reported as 99.4%, specificity as 45.1% and negative predictive value was reported as 100% (6).

Another study which prospectively evaluated CCR and conducted in 12 centres demonstrated that if CCR is implemented actively, a reduction in the number of cervical spine imaging can be achieved without missing any spinal injury and causing any increase in the morbidity (7). CCR was shown to be used by triage nurses accurately and reliably and to have the potential to reduce patient dissatisfaction (8).

In the studies which report that NEXUS low risk criteria have lower sensitivity and specificity compared to those of CCR, patient inclusion criteria differ. In the study of Yealy et al, it was concluded that false negative results may increase and an increase in the sensitivity and specificity of CCR can be expected due to these differences. In the same study it was reported that there were some concerns that conducting prospective validation and derivation phases of the CCR study in the same center may cause to obtain better results than expected due to the familiarity with the rules (9). In the studies performed, it was shown that both criterions can be used for the decision for radiography. However, there are still discussions as to which criterion should be used. The objective of this study is to determine the reliability and utility of NEXUS Low Risk Criteria and Canadian Cervical Spine Rules for Turkish patient population when deciding on whether to have a cervical radiological evaluation for patients who come to emergency departments with a trauma history that has a risk of cervical injury.

MATERIALS AND METHOD

This study was conducted between the dates of September 1st - March 1st 2011, 2012 as a prospective and observational study at the Emergency Clinic of Dr Lütfi Kırdar Kartal Training and Research Hospital after ethical approval (B104İSM4340029/1009/1) which provides emergency care to approximately 500,000 patients annually.

All stable, conscious (Glasgow Coma Score 15) patients over 16 years of age who had acute trauma and were brought to the hospital with ambulances or using their own means and who had been injured by a mechanism that may cause cervical trauma were included in the study. The patients included in the study were then evaluated for NEXUS and CCR validity. All trauma patients were evaluated within the first 4 hours.

Patients who had penetrating trauma, had had previous similar trauma, had a chronic disease which may affect the known cervical area (ankylosing spondylitis, cervical fusion operation etc.) and pregnant patients were excluded. Patients who were evaluated due to this pathology and patients who were sent to our hospital for further assessment were not included in the study.

All patients were examined by emergency specialist and residents who had minimum 1 hour of training on the NEXUS low risk criteria and CCR and who had worked minimum for 3 months in the emergency department.

Patients underwent primary and secondary examinations according to the ATLS guidelines. Patients' radiological examinations and medical consultations were done independent of the study. During this examination physicians ensured that patients filled out study registration forms. These filled out forms were controlled daily for integrity and missing parts were corrected by reporting these to the physician performing the examinations. Patients who did not fill out the form or complete missing parts were excluded from the study. In the following process, final reports were prepared by radiologists for all radiological examination of these patients. The physicians who wrote the reports in the radiology clinic were not informed about the study.

Based on computerised tomography (CT) and magnetic resonance imaging (MRI) results, patients who were found to have a cervical pathology and those who were not were compared according to all demographic, physical and radiological characteristics. It was ensured that all patients were re-assessed and monitored by the neurosurgery department at the emergency clinic or outpatient clinic. All patients who were admitted to and discharged from the hospital and who were asked to come for a follow up visit were monitored. Patients who were found to have a pathology based on consultation results were included in the pathology group. Patients who did not have any imaging done at the emergency department and who were not monitored at the neurosurgery outpatient clinic were excluded from the study.

RESULTS

225 patients with suspected cervical injuries were included in the study. The mean age of the patient were 35.46 ± 17.75 (95% CI 33.13-37.79) and the mean age of 151 male patients were 32.9 ± 15.3 (95% CI 30.4-35.3) and the mean age of 78 female patients were 40.73 ± 21.06 (95% CI 35.85-45.61) . When mean

ages of male and female patients were compared with a t-test, female patients were found to be in average 7.9 (95% CI 2.9-12.7) ages older than the male patients and this difference was considered to be statistically significant ($p=0.002$; t-test).

When injury mechanisms were evaluated, in-vehicle traffic accidents were the most common one with 38.7 percent. This was followed by falls with 18.2% in the dangerous mechanism category ("Dangerous Fall"). The percentages for finding pathology according to the mechanism were as follows: diving into water: 100%, in vehicle traffic accident: 2.3% dangerous fall: 4.9%, assault: 10%. Total injury frequency was 3.1 % (Table 1).

Table 1. Distribution of patients based on injury mechanisms

	Pathology -	Pathology +	TOTAL
Injury mechanism	N (%)	N (%)	N (%)
In Vehicle Traffic Accident	85 (39,0)	2 (28,6)	87 (38,7)
Dangerous Fall (≥ 1 m or 5 stairs)	39 (17,9)	2 (28,6)	41 (18,2)
Fall(<1m or 5 stairs)	33 (15,1)	-	33 (14,7)
Pedestrian struck	28 (12,8)	-	28 (12,4)
Motorcycle Accident	17 (7,8)	-	17 (7,6)
Assault	9 (4,1)	1 (14,3)	10 (4,4)
Falling Object From Height	7 (3,2)	-	7 (3,1)
Diving	-	2 (28,6)	2 (0,9)
TOTAL	218 (96,9)	7 (3,1)	225 (100)

When findings and symptoms were evaluated (Table 2), 5 out of 29 patients who had midline cervical tenderness (17.2%) and 2 out of 196 patients who did not have were found to have a pathology. Statistically, having midline cervical tenderness was determined as 71% sensitive and 89% specific examination finding to identify the presence of pathological imaging findings. The presence of this examination finding increases the possibility of pathologic imaging results by 16.9 times (Risk ratio [RR]) (95%CI: 3.4-83.1).

Table 2. Statistical analysis of findings and symptoms

Finding	Sensitivity % (95% CI)	Specificity % (95% CI)	Positive LR (95% CI)	Negative LR (95% CI)	Risk ratio (95% CI)	Odds ratio (95% CI)
Midline cervical tenderness	71 (30-94)	88 (83-92)	6,61 (3,55-11,84)	0,32 (0,09-1,03)	16,90 (3,43-83,09)	20,21 (3,71-109,94)
Side cervical tenderness	28 (5-69)	90 (85-94)	3,11 (0,89-10,79)	0,78 (0,49-1,25)	3,69 (0,76-17,91)	3,96 (0,72-21,74)
Focal Deficit	37 (10-74)	100 (97-100)	- (NaN)*	0,62 (0,36-1,06)	44,4 (18,6-105,6)	- (NaN)*
Paresthesia	25 (4-64)	99 (96-99)	27,12 (4,35-168,84)	0,75 (0,50-1,12)	18,41 (5,23-64,81)	35,83 (4,29-29,89)
45 degree neck rotation	42 (11-79)	96 (92-98)	11,67 (3,91-34,83)	0,59 (0,31-1,12)	14,59 (3,71-57,35)	19,68 (3,76-103,03)
Forward-backward motion of the neck	42 (11-79)	97 (94-99)	18,68 (5,53-63,13)	0,58 (0,3-1,11)	20,34 (5,43-76,10)	31,95 (5,60-182,01)
Severe neck pain	57 (20-88)	92 (88-95)	7,78 (3,51-17,26)	0,46 (0,19-1,08)	13,66 (3,28-56,81)	16,83 (3,46-81,81)

* NaN: Not a number

Three patients with focal deficit (1.3%) were also found to have a pathology and this difference was considered as statistically significant ($p < 0.001$; Fisher's exact test). A pathology was detected in all 3 patients with focal deficit (100%) and 4 of 222 patients without focal deficit (1.8%). Having focal deficit was determined as a 37% sensitive and 100% specific examination finding to identify the presence of pathological imaging findings.

At least one stabilisation appliance was used in 53.8% of the patients and stabilisation appliances were used in 85.7% of the patients with pathology. Pathology was detected in 6 out of 74 patients (8.1%) for whom spine boards were used and 1 out of 151 patients (0.7%) for whom no spine board was used and the difference was statistically significant ($p < 0.006$; Fisher's exact test). The probability of a patient with a pathology to be placed on a spine board when compared to a patient without any pathology was found to be 8.6 times higher.

Evaluation of CCR

Utility of each parameter and examination finding which constitute CCR was analysed and the results are shown in Table 3. No pathology was detected in any of patients over 65 years of age and all patients

who were found to have a pathology were younger than 65. 2 patients were found to have a pathology in each of the dangerous injury mechanisms, namely; in-vehicle traffic accident, dangerous fall and diving. 2 out of 4 patients with paresthesia (50%) were found to have a pathology. Midline cervical tenderness was detected in 5 out of 7 patients with a pathology (71.4%). This finding was determined as the most useful examination finding for diagnosis ($p < 0.001$). No pathology was detected in any of the patients who were either in a sitting or standing position during their examination in the emergency department however 1 out of 7 patients who were found to have a pathology was in a sitting position in the emergency department. 4 out of 7 patients with a pathology (57.1%) had severe neck pain and a pathology was found in 3 out of 11 patients who could not rotate their neck 45 degrees (27.2%) (Table 3).

When CCR was evaluated as a whole, it was determined that all pathological cases were identified using these rules. In terms of identifying the presence of pathological imaging finding the sensitivity of CCR was 100% (95% CI % 56-100) and specificity was 3.2% (95% CI 1.4-6.7%) (Table 4).

Table 3. Univariate analysis of the variables that constitute Canadian Cervical Spine Rules

		Pathology (+) N (%)	Pathology (-) N (%)	p
Age	<65 years	7 (3,1)	202 (89,8)	>0,05
	>65 years	-	16 (7,1)	
Injury mechanism	In-Vehicle Traffic Accident	2 (28,6)	85 (39)	>0,05
	Dangerous Fall	2 (28,6)	39 (17,9)	
	Outside Vehicle Traffic Accident	-	28 (12,8)	
	Motorcycle Accident	-	17 (7,8)	
	Diving into Water	2 (28,6)	2 (28,6)	
Paresthesia	Yes	2 (0,9)	2 (0,9)	>0,05
	No	6 (2,7)	215 (95,6)	
Midline cervical tenderness	Yes	5 (2,2)	24 (10,7)	<0,001
	No	2 (0,9)	194 (86,2)	
Emergency Department standing-sitting	Standing-sitting	-	38 (16,9)	>0,05
	Lying	7 (3,1)	180 (80)	
Standing at any time point	Standing-sitting	1 (0,4)	68 (30,2)	>0,05
	Lying	6 (2,7)	150 (66,7)	
Severe neck pain	Yes	4 (1,8)	16 (7,1)	<0,001
	No	3 (1,3)	202 (89,8)	
45 degree neck rotation	Yes	4 (1,8)	210 (93,3)	0,003
	No	3 (1,3)	8 (3,6)	

Evaluation of NEXUS criteria

Although no radiography was required for 153 out of 225 patients according to the NEXUS criteria, a cervical pathology was detected in 2 of the patients who did not require radiography according to NEXUS. Of the 7 patients who were found to have a cervical pathology, in 5 patients (71.4%) Midline cervical tenderness, in 3 (42.8%) focal neurological deficit and in 1 patient (14.2%) another painful area in the body that distracts the attention was detected and none was found to have any intoxication indication (Table 5). When all low risk criteria were evaluated, NEXUS's sensitivity was calculated as 93% (95% CI 83-97) and specificity as 1.3%(95% CI 0.2-5.1) Positive LR (likelihood ratio=LR) calculated for NEXUS criteria was 0.94 and the negative

LR was 5.31 (Table 4). A pathology was detected in 3 patients with focal deficit and this was established as the most valuable finding with 100% sensitivity ratio. No pathology was found in 7 patients who had an intoxication indication and this was considered as statistically not important for the diagnosis (p>0.05).

Evaluations of patients with a pathology according to CCR and NEXUS were shown in Table 6. When clinical values of CCR and NEXUS were compared (Table 4), it was found that CCR had a higher sensitivity ratio and did not overlook any pathological patient.

Table 4. Comparison of CCR and NEXUS clinical assessment criteria

	CCR	NEXUS
Clinical Criterion	Value (95% CI)	Value (95% CI)
Sensitivity	%100 (56-100)	%93 (83-97)
Specificity	3,2 (1,4-6,7)	%1,3 (0,2-5,1)
Positive LR	1,03 (1,008-1,058)	0,94 (0,88-1,006)
Negative LR	0 (NaN)	5,3 (10,86-32,54)

Table 5. Univariate analysis of the variable constituting NEXUS criteria

		There is a pathology N (%)	There is no pathology N (%)	p
Midline cervical tenderness	Yes	5 (2,2)	24 (10,7)	<0,001
	No	2 (0,9)	194 (86,2)	
Intoxication symptom	Yes	-	7 (3,2)	>0,05
	No	7 (3,1)	211 (93,8)	
Focal neurological deficit	Yes	3 (1,3)	-	<0,001
	No	4 (1,8)	218 (96,9)	
Another painful injury	Yes	1 (0,4)	47 (20,9)	>0,05
	No	6 (2,7)	171 (76)	

Table 6. Assessment of pathological cases for CCR and NEXUS

		Gender	Accident Mechanism	CCR	NEXUS	Injury
1	25	M	Assault	Midline cervical tenderness	Midline cervical tenderness	Transverse process linear fracture at C6-7 left lamina, collapse at C7 anterior column
2	57	M	Dangerous Fall	Dangerous Mechanism	-	BT, C5 right lamina fissure style fracture
3	17	F	Dangerous Fall	Dangerous Mechanism	-	MRI loss on the height of C7 vertebrae corpus, acute partial compression
4	47	M	In Vehicle Traffic Accident	Dangerous Mechanism	Focal Deficit	MRI multiple discopathy
5	24	M	Diving	Dangerous Mechanism	Focal Deficit	C4-C5 dislocation, significant narrowing of spinal canal
6	19	M	Diving	Dangerous Mechanism	Focal Deficit	C4 burst fracture, dislocation between C4-5
7	28	M	In Vehicle Traffic Accident	Dangerous Mechanism 45 degree neck rotation	Another painful area is present	C2 corpus and left arcus, C7spinous, C5 pedicle and lamina fracture

DISCUSSION

This study attempted to demonstrate the value of Canadian Cervical Spine Rules and the NEXUS Low Risk Criteria in patients who came to our hospital with a cervical trauma possibility. When examination findings were assessed, patients with a midline cervical tenderness were found to have a pathology at a significantly higher percentage. In a similar study conducted by Stiell et al., tenderness was detected in 84% of the patients with a statistically significant pathology and 60.2% of the patients who did not have a pathology and this is consistent with the findings of our study. This difference was found to be statistically significant (7).

In another study done by Stiell et al. 35.6% of the patients were found to have midline cervical tenderness and the kappa value 0.56 (0.45-0.66 95% CI) which shows the coherence between this finding with the diagnosis of patients with a cervical pathology was at a significant level (9). Ackland et al., demonstrated that patients with a midline cervical tenderness might have sustained an injury detected with MRI although CT is normal (10). In the study of Stiell et al., 86.1% of the patients who had a clinically significant pathology and in 57.3% of the patients with no pathology had midline cervical tenderness and the difference was found to be statistically significant (6). In agreement with our study, Not having a midline cervical tenderness does not exclude cervical pathology was also demonstrated in the study of D'Costa et al (11). We could easily say that this finding which was useful statistically for diagnostic purposes but not to be used for exclusion should not be ignored and this examination must be performed. For most of the patients (53.8%) brought to our emergency department after a trauma in an ambulance at least one stabilization appliance was used and this percentage was 85.7% in patients who were found to have a pathology. Therefore, it can be said that even during the first stabilization of patients paramedics can correctly assess the patients with a higher likelihood of having a pathology and necessary measures can be taken. Cervical collars which are most critical and important part of cervical spinal immobilization were used in 89 patients and the fact that 5 of these patients were found to have a pathology and 2 out of 136

patients who did not use cervical collars were found to have a pathology can be considered as an indication that this method is still not used with sufficient care and attention.

The situation for the use of spine boards seems to be different. This stabilization appliance which was used with high percentage (32.9%) and 85.7% of the patients who were found to have a pathology in imaging and this was statistically significant at the same time ($p=0.006$; Fisher's exact test).

Although not included in the NEXUS and CRR content, forward and backward motion of neck was also evaluated in the examination and- though not as useful as 45 degrees rotation - they were found to be useful for diagnosis with a specificity of 96% (92-98). In the study conducted by Stiell et al. 4.1% of the patients with a clinically significant cervical pathology and 51.6% of the patients who did not have any pathology could move their heads backwards and forwards and this difference was found to be statistically significant. Although this finding was found to be useful for diagnosis in our study, it was determined to be not useful for exclusion. Therefore, it does not seem possible to include this to decision making process effectively.

There were some restrictions due to the method of this study and the results should be evaluated accordingly. A full standardisation was not available in radiography indications since this was an observational study. Although all physicians participating to this study had had training on this subject before the study, compatibility of the treatment plans of the same patients was not evaluated with a kappa analysis. Since the data obtained in terms of the details of vehicle accidents (whether the vehicle was travelling under 100 km/h and the vehicle speed which is included in the fast vehicle collision criteria for pedestrians) were not objective, all in vehicle accidents were accepted as dangerous mechanism. Therefore some patients who required no radiography if the accident details had been known were assigned to the group of patients who required radiography and some patients who should have been true negative might have been

categorised as false negative. This mistake is likely to contribute to the low level of specificity found for the test. In order to reduce unnecessary use of radiography, paramedics should try to obtain detailed information about accident mechanisms and transfer this information to emergency departments to help to eliminate this mistake in the future studies.

CONCLUSION

As a result, Canadian Cervical Spine Rules and the NEXUS Low Risk Criteria were determined to be useful in the emergency department for the exclusion of cervical pathologies. Canadian Cervical Spine Rules were more reliable and useful when compared with the NEXUS Low Risk Criteria.

REFERENCES

1. Spinal Cord Injury Facts and Figures at a Glance. The Journal of Spinal Cord Medicine. 2014;37(4):479-480.
2. Goodnight TJ, Helmer SD, Dort JM, Nold RJ, Smith RS. A comparison of flexion and extension radiographs with computed tomography of the cervical spine in blunt trauma. *Am Surg*. 2008;74(9):855-857.
3. Sala F, Dvorak J, Faccioli F. Cost effectiveness of multimodal intraoperative monitoring during spine surgery. *Eur Spine J*. 2007;16(Suppl 2):S229-S231.
4. Hoffman JR, Mower WR, Wolfson AB, Todd KH, Zucker MI. Validity of a set of clinical criteria to rule out injury to the cervical spine in patients with blunt trauma. National Emergency X-Radiography Utilization Study Group. *N Engl J Med*. 2000;343(2):94-99.
5. Stiell IG, Wells GA, Vandemheen KL, et al. The Canadian C-spine rule for radiography in alert and stable trauma patients. *JAMA*. 2001;286(15):1841-1848.
6. Stiell IG, Clement CM, McKnight RD, et al. The Canadian C-spine rule versus the NEXUS low-risk criteria in patients with trauma. *N Engl J Med*. 2003;349(26):2510-2518.
7. Stiell IG, Clement CM, Grimshaw J, et al. Implementation of the Canadian C-Spine Rule: prospective 12 centre cluster randomised trial. *BMJ*. 2009;339:b4146.
8. Stiell IG, Clement CM, O'Connor A, et al. Multicentre prospective validation of use of the Canadian C-Spine Rule by triage nurses in the emergency department. *CMAJ*. 2010;182(11):1173-1179.
9. Yealy DM, Auble TE. Choosing between clinical prediction rules. *N Engl J Med*. 2003;349(26):2553-2555.
10. Ackland HM, Cameron PA, Varma DK, et al. Cervical spine magnetic resonance imaging in alert, neurologically intact trauma patients with persistent midline tenderness and negative computed tomography results. *Ann Emerg Med*. 2011;58(6):521-530.
11. D'Costa H, George G, Parry M, et al. Pitfalls in the clinical diagnosis of vertebral fractures: a case series in which posterior midline tenderness was absent. *Emerg Med J*. 2005;22(5):330-332.