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## The NEXUS criteria are insufficient to exclude cervical spine fractures in older blunt trauma patients

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### ABSTRACT

**Background and objective:** The National Emergency X-Radiography Utilization Study (NEXUS) criteria are used to assess the need for imaging to evaluate cervical spine integrity after injury. The aim of this study was to assess the sensitivity of the NEXUS criteria in older blunt trauma patients.

**Methods:** Patients aged 65 years or older presenting between 1st July 2010 and 30th June 2014 and diagnosed with cervical spine fractures were identified from the institutional trauma registry. Clinical examination findings were extracted from electronic medical records. Data on the NEXUS criteria were collected and sensitivity of the rule to exclude a fracture was calculated.

**Results:** Over the study period 231,018 patients presented to The Alfred Emergency & Trauma Centre, of whom 14,340 met the institutional trauma registry inclusion criteria and 4035 were aged  $\geq 65$  years old. Among these, 468 patients were diagnosed with cervical spine fractures, of whom 21 were determined to be NEXUS negative. The NEXUS criteria performed with a sensitivity of 94.8% [95% CI: 92.1%–96.7%] on complete case analysis in older blunt trauma patients. One-way sensitivity analysis resulted in a maximum sensitivity limit of 95.5% [95% CI: 93.2%–97.2%].

**Conclusion:** Compared with the general adult blunt trauma population, the NEXUS criteria are less sensitive in excluding cervical spine fractures in older blunt trauma patients. We therefore suggest that liberal imaging be considered for older patients regardless of history or examination findings and that the addition of an age criterion to the NEXUS criteria be investigated in future studies.

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### Introduction

The overall prevalence of cervical spine injury among trauma patients is estimated to be 2.8%–7.7% [1]. Timely and accurate detection of injury is imperative, as early intervention can prevent complications such as permanent neurological deficit/disability or death [2–5]. Numerous guidelines exist to assist clinicians in excluding cervical spine injury following blunt trauma [6–9]. Current best practice suggests the use of validated clinical decision rules, of which the most commonly applied are the National Emergency X-Radiography Utilization Study (NEXUS) criteria and the Canadian C-spine Rule (CCR) [7,10,11]. These rules were developed to safely increase the yield of cervical spine radiology,

while aiming to decrease the extremely liberal use of radiography by emergency clinicians [10,11].

The original validation studies for these clinical decision rules were conducted over a decade ago when the imaging modality of choice was primarily plain x-rays [10,11]. This varies significantly from current practice, where more advanced imaging techniques identify a greater proportion of missed cervical spine injury than plain x-rays otherwise would, decreasing the sensitivity of the clinical decision rules over time [12–16].

The original NEXUS criteria validation study reported a sensitivity of 99.0% across a heterogeneous group of adult blunt trauma patients [10]. However, missed cases of cervical spine injury in the setting of the low-risk NEXUS criteria have been reported in older patients, and serve as warning that injury may exist in this population without associated clinical symptoms and signs [17,18]. Previous attempts to validate the rule in older patients have resulted in conflicting reports [18–21]. A thorough exploration of the validity of the NEXUS criteria in this population is indicated. At present, the unique assessment requirements of

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older patients are not well addressed in cervical spine clearance guidelines [22].

The aim of this study was to determine the sensitivity of the NEXUS criteria to exclude cervical vertebral fractures among older injured patients. We hypothesised that the NEXUS criteria are inadequate for use in the older population and that reliance on this approach will lead to a considerable rate of missed injuries.

## Methods

### Setting

The state of Victoria in Australia has one paediatric and two adult Major Trauma Services located within the capital city of Melbourne, that service a population of approximately 6,000,000 people. The Victorian State Trauma System was established in 2000 and mandates that 85% of major trauma patients receive early definitive treatment at a Major Trauma Service. The Alfred Hospital is the largest Major Trauma Service in the state and consistently receives >50% adult major trauma. The Alfred Registry prospectively records pre-hospital and hospital data on all cases meeting the registry's inclusion criteria, which includes all major trauma patients, as well as a subset of minor trauma patients.

### Inclusion criteria

Patients aged  $\geq 65$  years of age admitted to <Name blinded> from 1st July 2010 to 30th June 2014 were retrospectively identified from the Alfred Trauma Registry. These patients were categorised as “elderly” for the purpose of this study in accordance with current trauma literature [23]. Those who had sustained a cervical spine fracture were included in the study. Cervical spine fracture was defined according to formal computed tomography (CT) or magnetic resonance imaging (MRI) findings, as reported by a radiologist. The Alfred Hospital Research and Ethics Committee approved this study.

### Data

Patient demographic data, admission source, mechanism of injury, admission vital signs and pathology results were extracted from the The Alfred Trauma Registry. The site of injury and the NEXUS status of the patient were extracted from the medical records. In cases where NEXUS status had not been documented, or had been documented incompletely, the records were assessed for the presence of documentation of midline cervical tenderness, focal neurologic deficit, altered level of consciousness, evidence of intoxication or painful distracting injury in order to determine the NEXUS status retrospectively [10]. The primary outcome measure was the sensitivity of the NEXUS criteria.

### Analysis

Cases with clear documentation of the presence of any one or more of the NEXUS criteria were considered NEXUS positive. Cases with clear documentation of the absence of all the NEXUS criteria were considered NEXUS negative. Cases in which NEXUS status could not be determined due to information which was incomplete, missing or difficult to interpret (e.g. jargon, acronyms, poor quality photocopies, and indecipherable handwriting) were considered undocumented.

To calculate the point estimate of the sensitivity of the NEXUS criteria among included patients, undocumented cases were first handled by list-wise deletion (complete case analysis). The calculation was then repeated for two possible scenarios (one-way sensitivity analysis) in order to assess the impact that

undocumented cases would have on the previously calculated point estimate. Firstly, all undocumented cases were considered NEXUS positive then, all undocumented cases were considered NEXUS negative.

Descriptive analysis of the patient cohort was conducted. Continuous variables were expressed as mean and standard deviation for normally distributed variables, and median and interquartile range for non-normally distributed variables. Analysis was conducted using Stata v13.0 (College Station, Texas, USA). A p-value of <0.05 was considered statistically significant.

## Results

Over the 4-year data collection period, there were 231,018 presentations to The Alfred Hospital Emergency and Trauma Centre. Of these, 14,349 met the Alfred Trauma Registry inclusion criteria and 4035 patients were aged  $\geq 65$  years. Among these, 468 elderly patients with cervical spine fractures were identified and these formed the study sample (Fig. 1).

Patient injury and demographic data are described in Table 1. The majority of patients (n = 232 patients (49.6%)) were diagnosed with fractures of the second cervical vertebra (C2). The most common injury involved odontoid process fracture (n = 140 (30%)). Low falls from  $\leq 1$  m were the most common mechanism, accounting for 243 (51.9%) of cases.

There were 21 (4.5%) cases that were NEXUS negative, i.e. documented absence of all NEXUS criteria in patients with cervical vertebral fractures. In addition, there were 381 (81.4%) cases that were NEXUS positive and 66 (14.1%) cases that were considered to have their NEXUS status undocumented. A comparison of NEXUS negative and NEXUS positive patients is presented in Table 1.

Using complete case analysis, the point estimate of the sensitivity was calculated to be 94.8% [95% CI: 92.1%–96.7%]. When all undocumented cases were considered NEXUS positive, the upper sensitivity limit was calculated as 95.5% [95% CI: 93.2%–97.2%]. In the second scenario where all undocumented cases were considered NEXUS negative, the lower sensitivity limit was calculated as 81.4% [95% CI: 77.6%–84.8%] (Fig. 2).

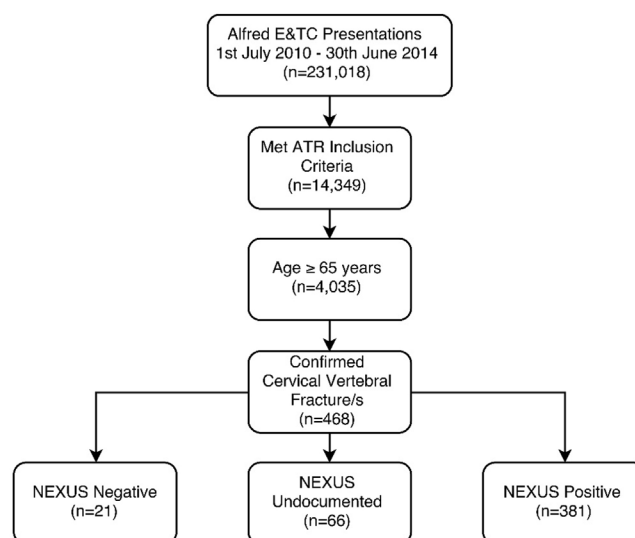


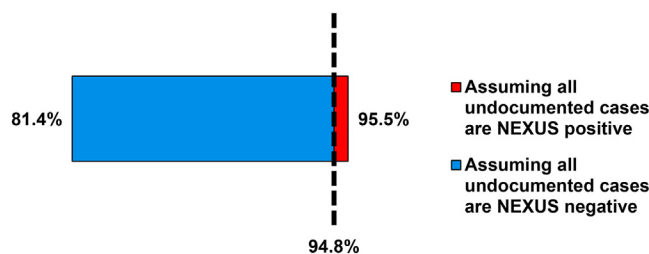
Fig. 1. Patient selection (E&TC = emergency and trauma centre, ATR = Alfred Trauma Registry).

**Table 1**  
Patient and injury characteristics.

	NEXUS negative (n = 21)	NEXUS positive (n = 381)	NEXUS undocumented (n = 66)
Age in years, mean (SD)	78.9 (9.1)	79.3 (8.0)	80.9 (7.9)
Male, No. (%)	10 (47.6)	204 (53.7)	36 (54.5)
GCS on arrival, median (IQR)	15 (15–15)	15 (14–15)	15 (15–15)
ISS, median (IQR)	14 (12–17)	12 (9–17)	9 (8–17)
Mechanism of Injury			
Low fall ( $\leq 1$ m)	8 (38.1%)	201 (52.8%)	34 (51.5%)
Motor vehicle driver	5 (23.8%)	81 (21.3%)	16 (24.2%)
High fall ( $> 1$ m)	2 (9.5%)	37 (9.7%)	6 (9.1%)
Motor vehicle passenger	4 (19.0%)	26 (6.8%)	3 (4.5%)
Pedestrian	0 (0.0%)	13 (3.4%)	4 (6.1%)
Other	2 (9.5%)	23 (6.0%)	3 (4.5%)
Vertebral level injured <sup>a</sup>			
C1	6 (28.6%)	65 (17.1%)	10 (15.2%)
C2	11 (52.4%)	186 (48.8%)	35 (53.0%)
–Odontoid process	8 (38.1%)	111 (29.1%)	21 (31.8%)
C3	1 (4.8%)	36 (9.4%)	3 (4.5%)
C4	1 (4.8%)	35 (9.2%)	4 (6.1%)
C5	1 (4.8%)	66 (17.3%)	8 (12.1%)
C6	3 (14.3%)	86 (22.6%)	14 (21.2%)
C7	4 (19.0%)	84 (22.0%)	12 (18.2%)

SD = standard deviation, GCS = Glasgow Coma Scale, IQR = interquartile range, ISS = Injury Severity Score, C = cervical vertebra.

<sup>a</sup> Note: a number of patients had fractures at multiple vertebral levels; hence the percentages add up to over 100%.



**Fig. 2.** One-way sensitivity analysis.

## Discussion

In a high volume adult major trauma centre, the NEXUS criteria performed with a sensitivity of 94.8% on complete case analysis, in contrast to the 99% reported by the original NEXUS investigators [10]. Further, the upper limit of the one-way sensitivity analysis, 95.5%, which represents the highest possible sensitivity, was likewise lower than reported in the original NEXUS study.

This suggests that the NEXUS criteria have inadequate sensitivity for the exclusion of cervical vertebral fractures in older blunt trauma patients, and that the risk of missed injury in this population may be high if relying on the NEXUS criteria alone to diagnose cervical vertebral fractures. The elderly are more vulnerable to the mechanical forces of trauma, and are thus more susceptible to injury than their younger counterparts [22,24–28]. Previous studies have compared elderly trauma patients and younger groups with the same injury mechanism and found that elderly patients tend to sustain more severe injuries, have worse clinical outcomes and disproportionately high healthcare costs [29,30]. This is likely due to a combination of factors including, but not limited to cognitive decline, musculoskeletal changes and alterations in cardiovascular and respiratory function, which influence the mechanism, distribution, assessment, severity and outcome of injury in older patients [31]. In particular, clinical

assessment is directly affected by these factors, which most likely explains the reduced sensitivity of the NEXUS criteria in this age group.

These results indicate a need to maintain a high index of suspicion and a low threshold to image in older blunt trauma patients regardless of history or examination findings. Undiagnosed/missed cervical spine injury can have devastating consequences, including permanent neurologic deficit/disability or death.

This study is consistent with emerging literature that suggests that the NEXUS criteria may not provide adequate safety in ruling out cervical spine injury in older patients. In their 2014 single centre prospective study included 320 patients aged  $\geq 65$  years, Goode et al. reported a sensitivity of 66% and claimed that the NEXUS criteria are “no better than tossing a coin” regardless of age, suggesting that all cases of injury sustained due to “severe” mechanisms of injury require CT imaging of the cervical spine [18]. In light of the potential risks of radiation exposure to younger patients, such absolute assertions are difficult to incorporate into clinical practice. However, our results do echo a need to develop a more liberal imaging strategy for older patients at risk of cervical vertebral fractures.

Similarly, in their 2015 single centre prospective study of 169 patients over the age of 65 years, Denver et al. [19] reported that the NEXUS criteria demonstrated 88.9% sensitivity in detecting clinically significant cervical spine injury, and 81.8% sensitivity in detecting any cervical spine injury. This study however only included older patients presenting due to falls from sitting or standing height.

This study builds on the existing evidence by including patients regardless of their mechanism of injury, avoiding the potential selection bias of these two aforementioned studies [18,19]. Moreover, patients included in the study by Goode et al. were assessed using a lower quality CT resolution to confirm injury. In their study, Goode et al. used a 16-slice multi-detector CT with a standard protocol that included 2-mm axial cuts performed at 2-mm increments with sagittal multi-planar reformatted images. In our study, all patients were either transferred from a referral

hospital with a confirmed diagnosis of cervical vertebral fracture or had injury detected on a higher quality 64-slice multi-detector CT in which the helical cervical spine images are acquired with a beam of 40 mm, and detectors of 0.5 mm. The axial images are then reformatted to 0.625–1 mm from C0–T4/5. Denver et al. did not report the CT protocol used. This suggests that our institutional imaging protocol is likely to detect a higher proportion of cervical fractures, increasing confidence in our results.

Previous sub-group analyses of older blunt trauma patients conducted by Touger et al. and Ngo et al. reported very high sensitivities of 99% and 100% respectively [20,21]. These studies are, however, limited by a reliance on post-hoc analysis of the original NEXUS data, variation in imaging protocols across participating sites, and a heavy reliance on plain x-rays for confirmation of injury. Conversely, our study had a pre-specified focus on older patients. Moreover, it is likely that current imaging protocol used in our study identify more missed cervical spine injury than plain film otherwise would, further explaining the decrease in sensitivity of the rule over time.

In order to ensure accurate and timely identification of fracture in older patients, we propose that extra care needs to be taken in this age group and that the addition of an age criterion to the NEXUS criteria be investigated in future studies. This is likely to be an acceptable adjustment for clinicians balancing the risks of missed diagnosis with those of additional testing. Though the Canadian C-spine Rule (CCR) already has an age criterion (age  $\geq 65$  years), eliminating the need for such an adjustment, several studies have noted that the CCR is more difficult to learn, remember, and use than NEXUS. As a result, many hospitals, including our institution, opt to incorporate the NEXUS criteria into their cervical spine clearance protocols, despite the CCR having higher sensitivity and specificity [32,33].

This study is limited by a sample comprised of patients presenting to a single large major trauma service. Variability in demographic and injury data across other sites may limit the generalisability of our results to non-major trauma service settings. However, the baseline patient and injury characteristics in our study cohort indicate that the study population is most likely representative of older cervical fracture patients presenting elsewhere. In our population, >50% of cervical fractures were sustained from low falls of  $\leq 1$  m. These findings are in agreement with previous epidemiological studies, which indicate that falls, usually from standing or seated height, are the most frequent causative mechanism for cervical fractures in patients over 65 years of age [34–36]. Additionally, the high proportion of upper cervical spine fractures in our population, as well as a high incidence of odontoid process fractures, is consistent with published studies which suggests that the upper cervical spine is the most common site for cervical spine injury in this population [29].

A further limitation of our study is that we did not examine isolated discoligamentous injuries without fractures, which may constitute selection bias. However, this is likely to result in a bias towards higher sensitivity, which would further strengthen our conclusion. Moreover, as the vast majority of cervical spine injuries are fractures, the impact of this bias is likely to be minimal [20]. Likewise, we did not consider the clinical significance of injury. Accurate detection of cervical fractures, regardless of significance, is important for the prevention of secondary injury and complications. Clinical decisions in cervical spine fracture management in older patients should be balanced against potential harm from treatment, but can only be made after accurate diagnosis of injury.

The retrospective design of our study resulted in a high percentage of undocumented cases for which NEXUS status could not be determined. Moreover, the quality of the study is limited by the use of the list-wise deletion technique (complete case analysis)

for handling missing data. We reduced the impact of this constraint by performing a one-way sensitivity analysis in order to assess the impact of undocumented cases on the final sensitivity estimate.

## Conclusion

Results of this analysis demonstrate that the NEXUS criteria do not provide adequate safety in excluding cervical vertebral fractures in older blunt trauma patients. We suggest that clinicians maintain a high index of suspicion of cervical vertebral injury and a low threshold to image older blunt trauma patients.

## Conflicts of interest

Nil to declare.

## References

- [1] Milby AH, Halpern CH, Guo W, Stein SC. Prevalence of cervical spinal injury in trauma. *Neurosurg Focus* 2008;25(5):E10.
- [2] Platzter P, Hauswirth N, Jandl M, Chatwani S, Vecsei V, Gaebler C. Delayed or missed diagnosis of cervical spine injuries. *J Trauma* 2006;61(1):150–5.
- [3] Platzter P, Jandl M, Thalhammer G, Dittich S, Wieland T, Vecsei V, et al. Clearing the cervical spine in critically injured patients: a comprehensive C-spine protocol to avoid unnecessary delays in diagnosis. *Eur Spine J: Off Publ Eur Spine Soc Eur Spinal Deform Soc Eur Sect Cerv Spine Res Soc* 2006;15(12):1801–10.
- [4] Reid DC, Henderson R, Saboe L, Miller JD. Etiology and clinical course of missed spine fractures. *J Trauma* 1987;27(9):980–6.
- [5] Gerrelts BD, Petersen EU, Mabry J, Petersen SR. Delayed diagnosis of cervical spine injuries. *J Trauma* 1991;31(12):1622–6.
- [6] Daffner RH, Hackney DB. ACR Appropriateness Criteria on suspected spine trauma. *J Am Coll Radiol* 2007;4(11):762–75.
- [7] Como JJ, Diaz JJ, Dunham CM, Chiu WC, Duane TM, Capella JM, et al. Practice management guidelines for identification of cervical spine injuries following trauma: update from the eastern association for the surgery of trauma practice management guidelines committee. *J Trauma* 2009;67(3):651–9.
- [8] Saltzher TP, Fung Kon Jin PH, Beenen LF, Vandertop WP, Goslings JC. Diagnostic imaging of cervical spine injuries following blunt trauma: a review of the literature and practical guideline. *Injury* 2009;40(8):795–800.
- [9] Kanwar R, Delasobera BE, Hudson K, Frohna W. Emergency department evaluation and treatment of cervical spine injuries. *Emerg Med Clin N Am* 2015;33(2):241–82.
- [10] Hoffman JR, Mower WR, Wolfson AB, Todd KH, Zucker MI, National Emergency X-Radiography Utilization Study Group. Validity of a set of clinical criteria to rule out injury to the cervical spine in patients with blunt trauma. *N Engl J Med* 2000;343(2):94–9.
- [11] Stiell IG, Wells GA, Vandemheen KL, Clement CM, Lesiuk H, De Maio VJ, et al. The Canadian C-spine rule for radiography in alert and stable trauma patients. *JAMA* 2001;286(15):1841–8.
- [12] Diaz Jr. JJ, Gillman C, Morris Jr. JA, May AK, Carrillo YM, Guy J. Are five-view plain films of the cervical spine unreliable? A prospective evaluation in blunt trauma patients with altered mental status. *J Trauma* 2003;55(4):658–63 Discussion 63–64.
- [13] Gale SC, Gracias VH, Reilly PM, Schwab CW. The inefficiency of plain radiography to evaluate the cervical spine after blunt trauma. *J Trauma* 2005;59(5):1121–5.
- [14] Mathen R, Inaba K, Munera F, Teixeira PG, Rivas L, McKenney M, et al. Prospective evaluation of multislice computed tomography versus plain radiographic cervical spine clearance in trauma patients. *J Trauma* 2007;62(6):1427–31.
- [15] Fisher A, Young WF. Is the lateral cervical spine x-ray obsolete during the initial evaluation of patients with acute trauma? *Surg Neurol* 2008;70(1):53–7 Discussion 8.
- [16] Bailitz J, Starr F, Beecroft M, Bankoff J, Roberts R, Bokhari F, et al. CT should replace three-view radiographs as the initial screening test in patients at high, moderate, and low risk for blunt cervical spine injury: a prospective comparison. *J Trauma* 2009;66(6):1605–9.
- [17] Denver D, Shetty A, Unwin D. Falls and implementation of NEXUS in the elderly (The FINE study). *J Emerg Med* 2016;49(3):294–300.
- [18] Goode T, Young A, Wilson SP, Katzen J, Wolfe LG, Duane TM. Evaluation of cervical spine fracture in the elderly: can we trust our physical examination? *Am Surg* 2014;80(2):182–4.
- [19] Denver D, Shetty A, Unwin D. Falls and implementation of NEXUS in the elderly (The FINE study). *J Emerg Med* 2015;49(3):294–300.
- [20] Touger M, Gennis P, Nathanson N, Lowery DW, Pollack Jr. CV, Hoffman JR, et al. Validity of a decision rule to reduce cervical spine radiography in elderly patients with blunt trauma. *Ann Emerg Med* 2002;40(3):287–93.
- [21] Ngo B, Hoffman JR, Mower WR. Cervical spine injury in the very elderly. *Emerg Radiol* 2000;7(5):287–91.



- [22] Jacobs DG. Special considerations in geriatric injury. *Curr Opin Crit Care* 2003;9(6):535–9.
- [23] Calland JF, Ingraham AM, Martin N, Marshall GT, Schulman CI, Stapleton T, et al. Evaluation and management of geriatric trauma: an Eastern Association for the Surgery of Trauma practice management guideline. *J Trauma Acute Care Surg* 2012;73(5 Suppl. 4):S345–50.
- [24] Aschkenasy MT, Rothenhaus TC. Trauma and falls in the elderly. *Emerg Med Clin N Am* 2006;24(2):413–32 vii.
- [25] Goodmanson NW, Rosengart MR, Barnato AE, Sperry JL, Peitzman AB, Marshall GT. Defining geriatric trauma: when does age make a difference? *Surgery* 2012;152(4):668–74 Discussion 74–75.
- [26] Callaway DW, Wolfe R. Geriatric trauma. *Emerg Med Clin N Am* 2007;25(3) 837–60 x.
- [27] Keller JM, Sciadini MF, Sinclair E, O'Toole RV. Geriatric trauma: demographics, injuries, and mortality. *J Orthop Trauma* 2012;26(9):e161–5.
- [28] Devons CA. Comprehensive geriatric assessment: making the most of the aging years. *Curr Opin Clin Nutr Metab Care* 2002;5(1):19–24.
- [29] Wang H, Coppola M, Robinson RD, Scribner JT, Vithalani V, de Moor CE, et al. Geriatric trauma patients with cervical spine fractures due to ground level fall: five years experience in a level one trauma center. *J Clin Med Res* 2013;5(2):75–83.
- [30] Mitra B, Cameron PA. Optimising management of the elderly trauma patient. *Injury* 2012;43(7):973–5.
- [31] Pudelek B. Geriatric trauma: special needs for a special population. *AACN Clin Issues* 2002;13(1):61–72.
- [32] Brehaut JC, Stiell IG, Graham ID. Will a new clinical decision rule be widely used? The case of the Canadian C-spine rule. *Acad Emerg Med: Off J Soc Acad Emerg Med* 2006;13(4):413–20.
- [33] Weiner SG. The actual application of the NEXUS and Canadian C-spine rules by emergency physicians. *Internet J Emerg Med* 2009;5(2).
- [34] Weller SJ, Malek AM, Rossitch Jr. E. Cervical spine fractures in the elderly. *Surg Neurol* 1997;47(3):274–80 Discussion 80–81.
- [35] Spivak JM, Weiss MA, Cotler JM, Call M. Cervical spine injuries in patients 65 and older. *Spine* 1994;19(20):2302–6.
- [36] Lieberman IH, Webb JK. Cervical spine injuries in the elderly. *J Bone Jt Surg Br Vol* 1994;76(6):877–81.