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Comparison of Diagnostic Accuracy of NEXUS Chest and Thoracic Injury Rule-Out Criteria in Patients with Blunt Trauma; A Cross-Sectional Study

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Abstract

Background: Blunt chest trauma is the third most important injury in patients with multiple trauma, thus the appropriate diagnosis is critical. Although chest X-rays (CXRs) are the most common diagnostic method, the physician should detect the imaging necessity and modality. Accordingly, NEXUS chest and thoracic injury rule-out criteria (TIRC) have been developed to prevent unnecessary radiographs in traumatized patients.
Objectives: In this study, the diagnostic accuracy of these two guidelines was compared in patients with multiple trauma.
Methods: In this cross-sectional study, eligible patients with chest blunt trauma, who referred to the Emergency Department of Imam Hossein Hospital from July 2016 to March 2018, were recruited. Demographic data, trauma and clinical information, and radiographic reports were recorded and the necessity of CXR was determined based on NEXUS chest and TIRC. Finally, the sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV) were also calculated for NEXUS chest and TIRC.
Results: In this study, 1925 patients with a mean age of 43.7 $\pm$ 9.16 years were evaluated (55% male). The sensitivity, specificity, PPV, NPV of TIRC in the diagnosis of traumatic chest injury were 93.6%, 84.9%, 24.03%, and 99.6%, respectively, and those of NEXUS in the diagnosis of traumatic chest injuries were 97.84%, 51.80%, 93.43%, and 99.79%, respectively. There was no significant difference in diagnostic accuracy between TIRC and NEXUS chest models.
Conclusions: This study showed that NEXUS chest and TIRC have equal values in predicting traumatized chest injuries. Parameters of TIRC are easily measurable in ED and do not require subjective assessments, such as mechanisms and velocity of trauma or fall height. Therefore, the TIRC model seems a better tool than NEXUS chest in detecting traumatic injury to the chest and reduce the risk of radiation exposure.

Keywords: Blunt Chest Trauma, Thoracic Injury Rule-Out Criteria, Diagnostic Imaging

1. Background

Injuries are one of the top 10 leading causes of mortality and morbidity, responsible for annual death of about 5 million victims worldwide (1, 2). Reports from the United States indicated an increasing trend in the frequency of trauma (3); meanwhile, it serves as a critical health issue in middle- and low-developed countries, mainly due to the high rate of road traffic injuries (4, 5). In Iran, trauma is ranked second in all-cause mortality (6).

Among injuries to different parts, chest injury, an important predictor of early death (7), is present in one-third of injury admissions and responsible for 25% - 50% of trauma-related death (8, 9). Chest trauma may be penetrating or blunt, associated with pneumothorax, hemopneumothorax, hemothorax, flail chest, the involvement of the major vessels, or diaphragm and early diagnosis is an important factor of outcome (10, 11). Chest X-ray (CXR), based on the Advanced Trauma Life Support® manual, is the first line diagnostic tool (12). Although chest radiographs can appropriately evaluate breathing difficulties and position of tubes (13), the dependency of its diagnostic accuracy to the interpreter (14), in addition to the risk of irradiating radiosensitive tissues and organs, such as thyroid, resulted in suggestion of more accurate instruments, including computed tomography (CT) (15-17) and ultrasonography (18-22). However, due to the time-consuming nature and controversy on the choice of imaging technique, it is suggested that clinicians divide patients into low- and high-risk group, to determine which patient requires ur-

gent treatment and which patient should undergo which imaging modality (23). This decision, can not only save the lives of patients requiring urgent treatment but also reduce the rate of unnecessary CXR (24). One of the instruments suggested to help clinicians for a correct decision is NEXUS chest with high sensitivity (98.8%), but with low specificity (13.3%) (25). Thoracic injury rule-out criteria (TIRC) is another instrument, suggesting different criteria with high sensitivity and specificity, to detect the necessity of CXR in chest trauma patients (26). Further research comparing these two instruments has shown that TIRC has a high specificity, higher than NEXUS chest, designed to detect major injuries by CTDI criteria (abnormal CXR, distracting injury, tenderness in the chest wall, sternum, thoracic spine, and scapula) with a sensitivity of 99.2% (27, 28). However, none of these instruments are commonly used by clinicians. Further research on the diagnostic accuracy of these instruments can take one step toward determining the superior instrument and help introduce it to the clinical setting.

2. Objectives

This study aimed to determine the diagnostic accuracy of these two guidelines (TIRC and NEXUS chest) in patients with multiple trauma.

3. Methods

The present cross-sectional analytical study aimed to compare the diagnostic accuracy of NEXUS chest with TIRC in patients with multiple trauma. The protocol of the study was approved by the Ethics Committee of Tehran University of Medical Sciences (code: 92-01-38-21411). The study population consisted of all patients with accidental multiple trauma who referred to Imam Hossein Hospital from July 2016 to March 2018, recruited according to the inclusion/exclusion criteria, based on convenient sampling method. This hospital is one of the medical centers of Tehran with the highest number of EDs in the city and about 2000 ED admissions per month. The sample size was calculated, considering a 95% confidence interval (95% CI), α = 0.05, the power of 90% for two models of outcome prediction, at 1150 cases. All patients over 15 years old with accidental multiple trauma and stable conditions were recruited to the study and patients with incomplete records, unstable conditions, penetrating trauma, class III or IV shock, inability to perform CXR, or patients who required immediate surgical interventions or passed away, pregnant and lactating mothers were excluded from the study.

The study objectives were explained to the eligible patients and they were asked to sign the written informed consent for their participation in the study. This study was in compliance with Helsinki's declaration on human studies. Then the demographics, including age and sex, mechanism of trauma, consciousness level, Glasgow coma scale (GCS), and clinical findings of physical examination of the chest, including distracting pain, chest pain and tenderness, tachypnea, dyspnea, thoracic deformity, crepitation, reduced pulmonary sounds, abdominal/midline tenderness, radiologist's report of posterior-anterior (PA) CXR, medications, and paresthesia were recorded in the data collection checklist by an ED resident.

The necessity of CXR was determined based on NEXUS and TIRC items. The TIRC scores were considered positive for a traumatic chest injury if at least one of the following criteria was positive: unstable vital signs, chest trauma, loss of consciousness, reduced pulmonary sounds, chest pain and tenderness, dyspnea, age > 60, and chest skin scar. The NEXUS chest scores were considered positive for a traumatic chest injury if at least one of the following criteria was positive: age > 60, the mechanism of rapid deceleration, chest pain or tenderness, substance abuse, loss of consciousness, the presence of distracting pain. Finally, the reference and gold standard of diagnosis was considered the radiologist's report and the diagnostic accuracy of NEXUS and TIRC were then compared with it.

All chest X-rays were interpreted by one radiologist who was blind to the study and the observed lesion was recorded on the checklist. Positive CXR findings, including hemothorax, pneumothorax, pneumomediastinum, mediastinal dilatation, subcutaneous emphysema, rib/clavicle/scapular fractures, and pulmonary contusion were recorded. For assessment of the accuracy of CXR reports, the reported results were re-evaluated by another radiologist and inter-rater reliability was calculated. After the end of the study, a random sample of 100 patients was contacted by telephone for follow-up, who were asked whether they had further problems. In this assessment, only one reported an undiagnosed rib fracture.

3.1. Statistical Analysis

Descriptive analysis, including frequency (percentage) and mean $\pm$ standard deviation (SD). Radiographic results were reported as negative/positive and clinical and other findings were compared between the two groups with negative/positive results by chi-square test. Inter-rater reliability was calculated by Cohen's kappa coefficient. The diagnostic accuracy of TIRC and NEXUS chest were evaluated by drawing receiver operating characteristic (ROC) curve and defining the area under curve (AUC). Finally, specificity, sensitivity, positive, and negative predictive values were

calculated. All statistical analyses were performed by the statistical software IBM SPSS Statistics for Windows version 21.0 (IBM Corp. 2012. Armonk, NY: IBM Corp.). The P values of < 0.001 were considered statistically significant.

4. Results

In this study, 1925 patients with a mean age of 43.7 $\pm$ 9.16 years were evaluated (55% male), and the mean age of 153 patients (7.9%) was > 60 years. The frequency of clinical manifestations was as follows: chest pain in 102 cases (5.3%), chest tenderness in 170 cases (8.8%), reduced pulmonary sounds in 31 cases (7%), crepitation in 3 cases (0.2%), scar of the thoracic skin in 45 cases (2.3%), and dyspnea in 8 (0.4%) patients. A total of 362 patients (18.8%) had positive CXR results, 154 cases (8%) had a rapid deceleration in NEXUS, 458 cases (28.1%) had distracting pain, 185 cases (9.6%) had consciousness disorders, and 51 patients (2.6%) had intoxication. To confirm the radiologist's report, 5% of samples were re-evaluated by another radiologist, which resulted in inter-rater reliability of 98%.

Based on the criteria described in methods, 36.8 patients (18.8%) had at least one of the described criteria and were suspected of having chest injury. Accordingly, there were 87 true positive cases, 1557 true negative cases, 275 false positive cases, and 6 false negative cases. The AUC in the diagnosis of chest injury was 89.27 (95% CI: 86.63 - 91.91) (Figure 1). The sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV) of TIRC in the diagnosis of traumatic chest injury were 93.6%, 84.9%, 24.03%, and 99.6%, respectively.

Based on the criteria described in methods, 974 patients (27.3%) had at least one of the described criteria and were suspected of having chest injury. Accordingly, there were 91 true positive cases, 949 true negative cases, 883 false positive cases, and 2 false negative cases. The sensitivity, specificity, PPV, and NPV of NEXUS in the diagnosis of traumatic chest injuries were 97.84%, 51.80%, 93.43%, and 99.79%, respectively (Table 1). Comparing the diagnostic accuracy of TIRC and NEXUS chest models in the diagnosis of traumatic chest injuries showed no significant difference between the AUC of NEXUS s and TIRC ($P < 0.001$).

Table 1. Diagnostic Accuracy of NEXUS Chest and Thoracic Injury Rule-Out Criteria

	Thoracic Injury Rule-Out Criteria	NEXUS Chest
True positive cases, No.	87	91
True negative cases, No.	1557	949
False positive cases, No.	275	883
False negative cases, No.	6	2
Sensitivity, %	93.6	97.84
Specificity, %	84.9	51.80
PPV, %	24.03	93.43
NPV, %	99.6	99.79

Abbreviations: NPV, negative predictive value; PPV, positive predictive value.

5. Discussion

The present study aimed to complete the previous study and evaluate and compare the diagnostic accuracy of the two instruments, namely NEXUS and TIRC, developed to reduce the rate of unnecessary radiographs in patients with chest trauma. Safari et al. (27) reported a similar study and recommended another survey with a larger sample size for better validation. The results of the present study on 1925 patients with blunt trauma indicated that CXR was unnecessary in 56.9% according to TIRC, and 54.4% according to NEXUS chest results, which confirm the results of previous studies. This indicated that validation of these instruments and application to the routine clinical setting can reduce the costs and overuse of radiographs and save the golden time for critical patients (25, 27, 28). The study by Safari et al. showed that 43.0% and 45.4% of CXRs were unnecessary, based on TIRC and NEXUS criteria (27), which is lower than the present study; however, confirms the results of the present study implying that a great percentage of CXRs are unnecessary and can be reduced by using these criteria.

Before the introduction of NEXUS chest in 2011, several studies have suggested different clinical manifestations to rule-out the necessity of CXR for patients with chest trauma (24, 29-32), while none had been included into routine care. Therefore, NEXUS chest was developed as a 7-item criteria to introduce all important criteria as one instrument (25), but one of the matters of concern is that it is also not perfect and different studies have reported different diagnostic values for them. As shown previously, the diagnosis of the trauma surgeon and ED specialist has a high diagnostic accuracy for the necessity of CXR (33, 34). Therefore, we compared the results of NEXUS with physician's judgment and the results showed the sensitivity, specificity, PPV, and NPV of NEXUS in the diagnosis of traumatic chest injuries were 97.84%, 51.80%, 93.43%, and 99.79%, respectively. Safari et al. reported these values at 98.61%, 59.94%, 19.97%, and 99.76%, respectively (27), which is close to the values obtained in the present study, except for PPV. Nevertheless, in the study validating NEXUS chest (Rodriguez et al., 2011), the sensitivity and specificity of NEXUS were much lower (13.3%) than our study; however, the sensitivity and NPV values were close (98.8% and 98.5%, respectively) (25).

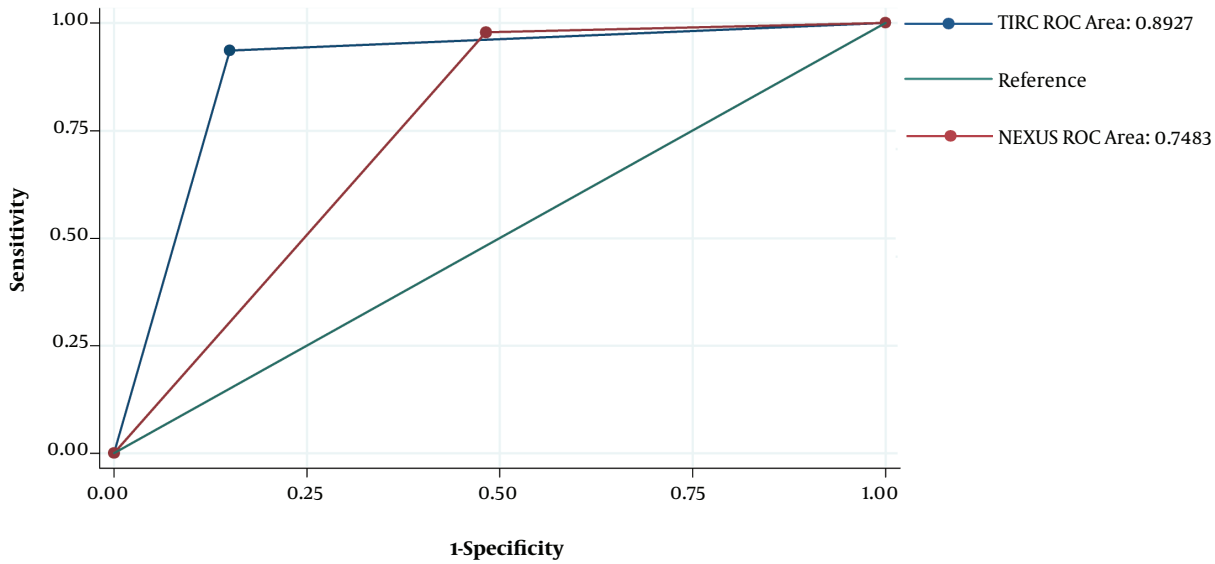

Figure 1. The ROC curve for diagnostic accuracy of TIRC and NEXUS in the diagnosis of chest trauma

This difference between the results of studies could be due to the different reference criteria used to compare the results with, as Rodriguez et al. used imaging, while we used the clinician's diagnosis as the reference criteria. In the present study, only 2 false negative cases (one pneumothorax and one hemothorax) were reported, which emphasizes the fact that although NEXUS is an appropriate instrument to reduce the unnecessary CXRs, it is also not perfect, like many other tests and the ultimate diagnosis should be made based on the clinician's judgment.

Estimating the sensitivity, specificity, PPV, and NPV of TIRC in the diagnosis of traumatic chest injuries in the present study resulted in the following values: 93.6%, 84.9%, 24.03%, and 99.6%, respectively. Forouzanfar et al. (26) designed TIRC with 6 items (fewer items than NEXUS) as a more appropriate instrument. Further research on TIRC showed the sensitivity, specificity, PPV, and NPV values of TIRC at 98.95%, 62.70%, 21.19%, and 99.83% (27), which are similar to the values obtained in the present study, while the same researchers reported a sensitivity of 100% for TIRC in another study (28). These variations among studies can be due to the frequency of different chest pathologies of patients studied. For instance, of the six false negative cases of TIRC in the present study, three had pneumothorax and three hemothorax.

The results of the present study showed a similar diagnostic accuracy between NEXUS and TIRC, indicating both as appropriate instruments. The results of the study by Safari et al. showed a higher specificity for TIRC than NEXUS (27), which was not consistent with the results of the present study; meanwhile, all parameters of TIRC were assessable in ED. Although we suggest that NEXUS chest requires subjective assessments such as the height of falling, velocity, and mechanism of trauma, Rodriguez et al. considered these parameters simple and part of standard trauma assessment. Therefore, we believe that TIRC seems a better instrument than NEXUS chest, suggested to be used in Iran, with a notably high rate of road accidents (6).

Although the present study was conducted in a grand hospital and included a large sample size, one of the limitations of the present study was patient selection from one center, non-randomized recruitment of patients, and no control group for comparison, which increased the selection bias and the possibility of the effect of confounders on the results.

5.1. Conclusions

The present study's main objective was the comparison of two instruments developed to reduce the rate of unnecessary CXRs to determine the prior instrument and take a step toward paying more attention to these criteria. Unlike the previous studies (27), the present study all of the radiographs could be interpreted by a radiologist. The results showed that both instruments had a high and similar diagnostic accuracy, while the authors believe that TIRC is more applicable in Iranian population, as it does not require the assessment of trauma mechanism and other subjective criteria, and is purely based on objective criteria. Despite the validation of these instruments in various studies, they are

not included in the up-to-date guidelines in the trauma setting and not used by clinicians. Therefore, it seems necessary to increase physicians' awareness about the risks of CXR overuse and conduct more studies on these two modalities, taking the limitations of this study into consideration to help reduce the unnecessary costs, the workload of medical staff, and save patients' lives by providing time for implementation of appropriate treatment strategies.

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Footnotes

Authors' Contribution: Study concept and design, administrative, technical, and material support, and critical revision of the manuscript for important intellectual content: Nona Norouzi; analysis and interpretation of data, drafting of the manuscript, and study supervision: Hamidreza Hatamabadi; acquisition of data: Afshin Amini.

Conflict of Interests: The authors declare that they have no conflict of interest regarding this study.

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References

1. Haagsma JA, Graetz N, Bolliger I, Naghavi M, Higashi H, Mullany EC, et al. The global burden of injury: Incidence, mortality, disability-adjusted life years and time trends from the global burden of disease study 2013. *Inj Prev*. 2016;**22**(1):3–18. doi: 10.1136/injuryprev-2015-041616. [PubMed: 26635210]. [PubMed Central: PMC4752630].
2. Krug EG, Sharma GK, Lozano R. The global burden of injuries. *Am J Public Health*. 2000;**90**(4):523–6. [PubMed: 10754963]. [PubMed Central: PMC1446200].
3. Rhee P, Joseph B, Pandit V, Aziz H, Vercruysse G, Kulvatunyou N, et al. Increasing trauma deaths in the United States. *Ann Surg*. 2014;**260**(1):13–21. doi: 10.1097/SLA.0000000000000600. [PubMed: 24651132].
4. Paniker J, Graham SM, Harrison JW. Global trauma: The great divide. *SICOT J*. 2015;**1**:19. doi: 10.1051/sicotj/2015019. [PubMed: 27163075]. [PubMed Central: PMC4849241].
5. Hofman K, Primack A, Keusch G, Hrynkow S. Addressing the growing burden of trauma and injury in low- and middle-income countries. *Am J Public Health*. 2005;**95**(1):13–7. doi: 10.2105/AJPH.2004.039354. [PubMed: 15623852]. [PubMed Central: PMC1449844].
6. Akbari ME, Naghavi M, Soori H. Epidemiology of deaths from injuries in the Islamic Republic of Iran. *East Mediterr Health J*. 2006;**12**(3-4):382–90. [PubMed: 17037707].
7. Gunst M, Ghaemmaghami V, Gruszecki A, Urban J, Frankel H, Shafi S. Changing epidemiology of trauma deaths leads to a bimodal distribution. *Proc (Bayl Univ Med Cent)*. 2010;**23**(4):349–54. [PubMed: 20944754]. [PubMed Central: PMC2943446].
8. Veysi VT, Nikolaou VS, Paliobeis C, Efstathopoulos N, Giannoudis PV. Prevalence of chest trauma, associated injuries and mortality: A level I trauma centre experience. *Int Orthop*. 2009;**33**(5):1425–33. doi: 10.1007/s00264-009-0746-9. [PubMed: 19266199]. [PubMed Central: PMC2899104].
9. Ekpe EE, Eyo C. Determinants of mortality in chest trauma patients. *Niger J Surg*. 2014;**20**(1):30–4. doi: 10.4103/1117-6806.127107. [PubMed: 24665200]. [PubMed Central: PMC3953631].
10. Farooq U, Raza W, Zia N, Hanif M, Khan MM. Classification and management of chest trauma. *J Coll Physicians Surg Pak*. 2006;**16**(2):101–3. [PubMed: 16499800].
11. Demirhan R, Onan B, Oz K, Halezeroglu S. Comprehensive analysis of 4205 patients with chest trauma: A 10-year experience. *Interact Cardiovasc Thorac Surg*. 2009;**9**(3):450–3. doi: 10.1510/icvts.2009.206599. [PubMed: 19541693].
12. ATLS Subcommittee; American College of Surgeons' Committee on Trauma; International ATLS Working Group. Advanced trauma life support (ATLS(R)): The ninth edition. *J Trauma Acute Care Surg*. 2013;**74**(5):1363–6. doi: 10.1097/TA.0b013e31828b82f5. [PubMed: 23609291].
13. Kool DR, Blickman JG. Advanced Trauma Life Support®. ABCDE from a radiological point of view. *Emerg Radiol*. 2007;**14**(3):135–41. doi: 10.1007/s10140-007-0633-x. [PubMed: 17564732]. [PubMed Central: PMC1914302].
14. Safari S, Baratloo A, Negida AS, Sanei Taheri M, Hashemi B, Hosseini Selkisari S. Comparing the interpretation of traumatic chest X-ray by emergency medicine specialists and radiologists. *Arch Trauma Res*. 2014;**3**(4). e22189. doi: 10.5812/atr.22189. [PubMed: 25738133]. [PubMed Central: PMC4329230].
15. Brink M, Deunk J, Dekker HM, Edwards MJ, Kool DR, van Vugt AB, et al. Criteria for the selective use of chest computed tomography in blunt trauma patients. *Eur Radiol*. 2010;**20**(4):818–28. doi: 10.1007/s00330-009-1608-y. [PubMed: 19760233]. [PubMed Central: PMC2835690].
16. Scaglione M, Pinto A, Pedrosa I, Sparano A, Romano L. Multi-detector row computed tomography and blunt chest trauma. *Eur J Radiol*. 2008;**65**(3):377–88. doi: 10.1016/j.ejrad.2007.09.023. [PubMed: 17954019].
17. Kaewlai R, Avery LL, Asrani AV, Novelline RA. Multidetector CT of blunt thoracic trauma. *Radiographics*. 2008;**28**(6):1555–70. doi: 10.1148/rg.286085510. [PubMed: 18936021].
18. Ebrahimi A, Yousefifard M, Kazemi HM, Rasouli HR, Asady H, Jafari AM, et al. [Diagnostic accuracy of chest ultrasonography versus chest radiography for identification of pneumothorax: A systematic review and meta-analysis]. *Tanaffos*. 2014;**13**(4):29. Persian.
19. Hosseini M, Ghelichkhani P, Baikpour M, Tafakhori A, Asady H, Haji Ghanbari MJ, et al. Diagnostic accuracy of ultrasonography and radiography in detection of pulmonary contusion: A systematic review and meta-analysis. *Emerg (Tehran)*. 2015;**3**(4):127–36. [PubMed: 26495401]. [PubMed Central: PMC4608349].
20. Rahimi-Movaghar V, Yousefifard M, Ghelichkhani P, Baikpour M, Tafakhori A, Asady H, et al. Application of ultrasonography and radiography in detection of hemothorax: A systematic review and meta-analysis. *Emerg (Tehran)*. 2016;**4**(3):116–26. [PubMed: 27299139]. [PubMed Central: PMC4902204].
21. Soldati G, Testa A, Sher S, Pignataro G, La Sala M, Silveri NG. Occult traumatic pneumothorax: Diagnostic accuracy of lung ultrasonography in the emergency department. *Chest*. 2008;**133**(1):204–11. doi: 10.1378/chest.07-1595. [PubMed: 17925411].
22. Yousefifard M, Baikpour M, Ghelichkhani P, Asady H, Darafarin A, Amini Esfahani MR, et al. Comparison of ultrasonography and radiography in detection of thoracic bone fractures: A systematic review and meta-analysis. *Emerg (Tehran)*. 2016;**4**(2):55–64. [PubMed: 27274514]. [PubMed Central: PMC4893752].

23. Ludwig C, Koryllos A. Management of chest trauma. *J Thorac Dis*. 2017;**9**(Suppl 3):S172–7. doi: 10.21037/jtd.2017.03.52. [PubMed: 28446982]. [PubMed Central: PMC5392544].
24. Wisbach GG, Sise MJ, Sack DI, Swanson SM, Sundquist SM, Paci GM, et al. What is the role of chest X-ray in the initial assessment of stable trauma patients? *J Trauma*. 2007;**62**(1):74–8. discussion 78-9. doi: 10.1097/01.ta.0000251422.53368.a3. [PubMed: 17215736].
25. Rodriguez RM, Anglin D, Langdorf MI, Baumann BM, Hendey GW, Bradley RN, et al. NEXUS chest: Validation of a decision instrument for selective chest imaging in blunt trauma. *JAMA Surg*. 2013;**148**(10):940–6. doi: 10.1001/jamasurg.2013.2757. [PubMed: 23925583].
26. Forouzanfar MM, Safari S, Niazazari M, Baratloo A, Hashemi B, Hatamabadi HR, et al. Clinical decision rule to prevent unnecessary chest X-ray in patients with blunt multiple traumas. *Emerg Med Australas*. 2014;**26**(6):561–6. doi: 10.1111/1742-6723.12302. [PubMed: 25255821].
27. Safari S, Radfar F, Baratloo A. Thoracic injury rule out criteria and NEXUS chest in predicting the risk of traumatic intra-thoracic injuries: A diagnostic accuracy study. *Injury*. 2018;**49**(5):959–62. doi: 10.1016/j.injury.2018.01.031. [PubMed: 29402426].
28. Safari S, Yousefifard M, Baikpour M, Rahimi-Movaghar V, Abiri S, Falaki M, et al. Validation of thoracic injury rule out criteria as a decision instrument for screening of chest radiography in blunt thoracic trauma. *J Clin Orthop Trauma*. 2016;**7**(2):95–100. doi: 10.1016/j.jcot.2016.02.005. [PubMed: 27182146]. [PubMed Central: PMC4857163].
29. Bokhari F, Brakenridge S, Nagy K, Roberts R, Smith R, Joseph K, et al. Prospective evaluation of the sensitivity of physical examination in chest trauma. *J Trauma Acute Care Surg*. 2002;**53**(6):1135–8. doi: 10.1097/01.TA.0000033748.65011.23. [PubMed: 12478040].
30. Gittelman MA, Gonzalez-del-Rey J, Brody AS, DiGiulio GA. Clinical predictors for the selective use of chest radiographs in pediatric blunt trauma evaluations. *J Trauma*. 2003;**55**(4):670–6. doi: 10.1097/01.TA.0000057231.10802.CC. [PubMed: 14566121].
31. 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):94–9. doi: 10.1056/NEJM200007133430203. [PubMed: 10891516].
32. Ungar TC, Wolf SJ, Haukoos JS, Dyer DS, Moore EE. Derivation of a clinical decision rule to exclude thoracic aortic imaging in patients with blunt chest trauma after motor vehicle collisions. *J Trauma*. 2006;**61**(5):1150–5. doi: 10.1097/01.ta.0000239357.68782.30. [PubMed: 17099521].
33. Sears BW, Luchette FA, Esposito TJ, Dickson EL, Grant M, Santaniello JM, et al. Old fashion clinical judgment in the era of protocols: Is mandatory chest X-ray necessary in injured patients? *J Trauma*. 2005;**59**(2):324–30. discussion 330-2. [PubMed: 16294071].
34. Dillard E, Luchette FA, Sears BW, Norton J, Schermer CR, Reed R2, et al. Clinician vs mathematical statistical models: Which is better at predicting an abnormal chest radiograph finding in injured patients? *Am J Emerg Med*. 2007;**25**(7):823–30. doi: 10.1016/j.ajem.2006.12.009. [PubMed: 17870489].