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Original Article

Clinical predictors of abnormal chest CT scan findings following blunt chest trauma: A cross-sectional study

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ABSTRACT

Purpose: Some surgeons believe that chest computed tomography (CT) scan should be used more prudently in management of blunt chest trauma patients. This study aimed to evaluate the clinical predictors of abnormal chest CT scan findings in trauma patients.

Methods: This cross-sectional study was conducted on blunt chest trauma patients aged ≥18 years who were referred to the emergency departments of two educational hospitals and underwent chest CT scan. These patients were enrolled in the study using a non-probability sampling method. The exclusion criteria included: class III or IV hemodynamic shock, need for immediate surgical or neurosurgical interventions, penetrating trauma, lack of required information, and pregnancy. Demographic factors, accident details, trauma mechanism, vital signs, and level of consciousness in predicting abnormal chest CT scan findings were evaluated. Analysis was performed using IBM SPSS statistics 21.

Results: A total of 977 patients (male 51.5%, female 48.5%) with the mean age of (41.71 ± 14.24) years, range 18–88 years were studied; 34.2% of them with high energy trauma mechanism. With 334 (34.2%) patients had abnormal findings on chest X-ray (CXR) and 332 (34.0%) cases had an abnormal findings on chest CT scan (agreement rate was 99.4%). There was a significant correlation between male gender ($p < 0.0001$), GCS<15 ($p < 0.0001$), high energy trauma mechanism ($p < 0.0001$), unstable hemodynamics ($p < 0.01$), and clinical signs and symptoms ($p < 0.0001$) with chest CT findings. Chest wall deformity ($odds = 8$; $p < 0.0001$), generalized tenderness ($odds = 6.6$, $p < 0.0001$), and decreased cardiac sound ($odds = 3.8$, $p < 0.0001$) were the important and independent clinical predictors of abnormal chest CT scan findings.

Conclusion: Based on the findings, chest wall deformity, generalized tenderness, decreased cardiac sound, distracting pain, chest wall tenderness, high energy trauma mechanism, male gender, respiratory rate > 20 breathes/min, decreased pulmonary sound, and chest wall crepitation were independent clinical predictors of abnormal chest CT scan findings following blunt trauma.

Introduction

Trauma is a prominent clinical issue in medicine due to high rate of morality and life-long morbidity. Blunt thoracic trauma ranked third in the most common types of trauma after head and extremities trauma.[1,2] Following chest trauma, myocardial or thoracic aorta rupture lead to immediate death while pneumothorax, cardiac tamponade, airway obstruction and uncontrollable bleeding occur within 3 min to 3 h of trauma occurrence; these latter conditions are preventable.[3]

Chest X-ray (CXR) is a frequently used method to evaluate thoracic trauma but its efficiency has been challenged in diagnosis of thoracic injuries and determination of their severity.[4,5] It is unable to show symptoms of thoracic trauma in some cases, especially vascular injuries.[6] A number of studies have been published, which preferred to use chest computed tomography (CT) scan rather than CXR in evaluation of traumatic thoracic injuries.[7,8] Up to 42%–59% of patients were reported to have extra findings on CT scan, which were not identified on CXR.[7,9] On the other hand, Barriou et al.[10] reported only 6.2% alterations in clinical management for patients who had abnormal CT findings.

CT scan is an accurate, precise and fast method for diagnosis of trauma, but some problems such as high time consumption, inaccessibility in emergency department, and technical difficulties in severely injured patients limited the use of CT scan in chest trauma. On the other hand, if CT scan detected injuries that CXR could not detect, the time, cost and radiation of CT will be an overall benefit for the patient.

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These issues raise the question that which patients are suitable for chest CT in blunt thoracic trauma. Evidence-based indications for CT scan in blunt thoracic trauma were not extensively reviewed. In an attempt in this regard, Rodriguez et al.[11] showed that chest CT scan may forego in cases with normal CXR, and without rapid deceleration mechanism; scapular, thoracic spine, sternum, and chest wall tenderness; as well as distracting injury. Based on the above-mentioned points, this study aimed to evaluate the clinical predictors of chest CT scan findings following blunt thoracic trauma.

Methods

Study design and setting

This cross-sectional study was conducted on blunt trauma patients who were referred to emergency departments (EDs) of Shohadaye Tajrish and Imam Hossein Hospitals (two big educational trauma centers, Tehran, Iran), from January 2017 to July 2018. All patients underwent chest CT scan and the clinical variables (demographics, vital signs, findings of physical examination and history taking, accident details, trauma mechanism) in predicting the abnormal chest CT scan finding were evaluated. The study protocol was approved by ethics committee of Shahid Beheshti University of Medical Sciences (code: IR.SBMU.MSP.REC.1396.199) and researchers adhered to the recommendations of Helsinki declaration regarding the confidentiality of patient information. Written informed consent was obtained from all participants and the study was performed without any imposed additional financial burden on patients.

Participants

All the adult patients (≥18 years) with blunt chest trauma who were referred to the mentioned EDs and underwent chest CT scan based on the decision of emergency medicine or surgery service were enrolled in the study using a non-probability sampling method. Class III or IV hemodynamic shock, need for immediate surgical or neurosurgical interventions, penetrating traumas, lack of required information, and pregnancy were in exclusion criteria of the present study. Decision for performing chest CT scan in the studied EDs was based on the clinical judgment of in charge physicians, considering the absence of contraindications.

Data gathering

Checklists included demographic factors (age, gender), accident details, trauma mechanism (high or low energy), vital signs (heart rate, respiratory rate, blood pressure, O_2 saturation), level of consciousness based on Glasgow coma scale (GCS), findings of physical examination and history taking on presentation (dyspnea, decrease in lung sounds, decrease in cardiac sounds, chest wall deformity, distracting pain, generalized tenderness, chest wall tenderness, chest wall abrasion, crepitation, raised jugular vein pressure (JVP), chest wall pain), as well as chest CT scan findings were filled out for all studied subjects after primary diagnostic and therapeutic measures and stabilization of patients. Senior emergency medicine residents were responsible for data collection. All chest CT scans were interpreted by an expert radiologist who was blinded to the study. All chest CT scans were performed in the radiology unit using a multi slice 16 CT-Scan device.

Definitions

High energy trauma mechanism included falls >20 feet, high-risk car crash (intrusion, ejection from the car, death in same passenger compartment, vehicle telemetry data consistent with a high risk of injury), car versus pedestrian/bicyclist thrown, car rollover, ran over or significantly impacted, and motorcycle crash >20 mph.

Abnormal chest CT scan was considered as the presence of any of the following findings on CT scan: fracture, pneumothorax, hemothorax, pneumomediastinum, pericardial effusion and pneumohemothorax, mediastinal widening, grate vessel injuries, and ruptured diaphragm.

Unstable hemodynamic was included systolic blood pressure <90 mmHg, diastolic blood pressure <70 mmHg, heart rate >100 beats/min, respiratory rate ≥20 breathes/min, O_2 saturation <90%.

Clinical signs and symptoms of thoracic injury included dyspnea, decrease in lung sounds, decrease in cardiac sounds, chest wall deformity, distracting pain, generalized tenderness, chest wall tenderness, chest wall abrasion, crepitation, raised JVP, chest wall pain.

Statistical analysis

Analysis was performed using IBM SPSS statistics 21. Demographic parameters, clinical findings, injury mechanism and vital signs in predicting the presence of lesions in chest CT scan was analyzed using Mc Nemar's test. All significant variables in univariate analysis were entered to a multivariate logistic regression analysis to determine the independent clinical predictive factors of chest CT scan. For each independent variable, odds ratio with 95% confidence interval was calculated. Statistical significance was considered as $p < 0.05$. Findings were reported as mean ± standard deviation or frequency and percentage.

Results

A total of 977 patients with the mean age of (41.71 ± 14.24) years, range 18–88 years were studied (male 51.5%, female 48.5%). The most frequent mechanism of injury were motorcycle-car accident ($n = 346$, 35.4%), collision with a hard object ($n = 256$, 26.2%), pedestrian-car accident ($n = 233$, 23.8%), and fall ($n = 142$, 14.5%). Patients caused by high energy trauma mechanism account for 34.2%. There are 330 (33.8%) patients had abnormal findings on CXR and 331 (33.9%) cases had abnormal chest CT scan finding (99.8% agreement rate). According to CT scan, fracture was detected in 112 cases, hemothorax in 68, pneumothorax in 57, pneumomediastinum in 47, and pericardial effusion in 47. No case of mediastinal widening, grate vessel injuries, or ruptured diaphragm was reported.

Table 1 compared the baseline characteristics of patients with and without abnormal chest CT scan findings. There was a significant correlation between gender ($p < 0.0001$), loss of consciousness ($p < 0.0001$), high energy trauma mechanism ($p < 0.0001$), unstable hemodynamic ($p < 0.01$), and physical examination ($p < 0.0001$) with chest CT scan findings.

Based on the results of stepwise logistic regression analysis chest wall deformity ($p < 0.0001$), generalized tenderness ($p < 0.0001$), and decreased cardiac sound ($p < 0.0001$) were among the most important clinical predictors of abnormal chest CT findings (Table 2).

Discussion

The findings of this study showed an association between male gender, GCS <15, high energy trauma mechanism, unstable hemodynamics and clinical signs and symptoms of thoracic injury with abnormal chest CT scan findings. Based on multivariate analysis, chest wall deformity, generalized tenderness, decreased

Table 1
Comparison of the baseline characteristics of patients with and without abnormal chest computed tomography scan findings.

Parameters	Chest CT scan findings, *n* (%)		*p* value
	Normal	Abnormal	
Age (year)			0.517
<60	562 (66.5)	283 (33.5)	
≥60	84 (63.6)	48 (36.4)	
Gender			<0.0001
Female	358 (75.5)	116 (24.5)	
Male	288 (57.3)	215 (42.7)	
GCS			<0.0001
=15	363 (82.9)	75 (17.1)	
<15	283 (52.5)	256 (47.5)	
Trauma mechanism			<0.0001
High energy	533 (82.9)	110 (17.1)	
Low energy	113 (33.8)	221 (66.2)	
Abnormal CXR			<0.0001
No	646 (99.8)	1 (0.2)	
Yes	0 (0.0)	330 (100.0)	
Unstable hemodynamic			
Systolic blood pressure < 90 (mmHg)	1 (16.7)	5 (83.3)	0.010
Diastolic blood pressure < 70 (mmHg)	43 (37.7)	71 (2.3)	<0.0001
Heart rate >100 (beats/min)	44 (56.4)	34 (43.6)	0.059
Respiratory rate ≥ 20 (breathes/min)	164 (52.6)	148 (47.4)	<0.0001
O_2 saturation < 90 (%)	36 (25.5)	105 (74.5)	<0.0001
Sign and symptoms on thoracic injury			
Dyspnea	383 (57.9)	279 (42.1)	<0.0001
Decrease in lung sounds	308 (52.6)	277 (47.4)	<0.0001
Decrease in cardiac sounds	64 (25.9)	183 (74.1)	<0.0001
Chest wall deformity	40 (18.3)	178 (81.7)	<0.0001
Distracting pain	183 (44.1)	232 (55.9)	<0.0001
Generalized tenderness	424 (57.6)	315 (42.4)	<0.0001
Chest wall tenderness	309 (51.4)	292 (48.6)	<0.0001
Chest wall abrasion	513 (65.9)	265 (34.1)	0.812
Crepitation	119 (48.1)	215 (51.9)	<0.0001
Raised JVP	37 (21.9)	132 (78.1)	<0.0001
Chest wall pain	567 (65.3)	301 (34.7)	0.137

CT: computed tomography, CXR: chest X-ray, GCS: Glasgow coma scale, JVP: jugular vein pressure.

Table 2
Independent predictors of blunt trauma patients' abnormal chest computed tomography findings based on multivariate logistic regression analysis.

Predictive factors	95% *CI*	*OR*	*p* value
Chest wall deformity	4.5–14.0	8.0	<0.0001
Generalized tenderness	3.4–12.7	6.6	<0.0001
Decreased cardiac sound	2.3–6.2	3.8	<0.0001
Distracting pain	1.4–4.5	2.5	0.002
Chest wall tenderness	1.6–4.0	2.5	<0.0001
High energy trauma mechanism	1.4–3.4	2.2	0.001
Male gender	1.5–3.3	2.2	<0.0001
Respiratory rate >20 (breathes/min)	1.2–2.7	1.8	0.005
Decreased pulmonary sound	1.1–2.7	1.8	0.010
Chest wall crepitation	0.3–0.8	0.5	0.011

CI: confidence interval, OR: odds ratio.

cardiac sound, distracting pain, chest wall tenderness, high energy trauma mechanism, male gender, respiratory rate >20 breathes/min, decreased pulmonary sound, and chest wall crepitation were among the independent clinical predictors of abnormal chest CT scan findings following blunt trauma.

Although the prevalence of life-threatening trauma has been constant during previous decades, with advancements in technology, CT scan has become more accessible to trauma patients, and the rate of CT scan use has grown significantly. Whole body CT scan has been used in many trauma centers for chest trauma evaluation. Some authors believe that these extensive CT scans do not offer any additional clinically relevant findings in comparison with CXR. Another point to consider is that majority of lesions found on CT do not change the management course of the patients, so the cost-benefit of CT scan must be taken into consideration when making clinical decisions.

Three main problematic issues associated with the use of CT scan in trauma patients are the potential increasing risk of cancer (mainly in young patients), high economical cost and high time consumption in emergency conditions.[12–14] Hospital stay in trauma visits with orders of CT scan and magnetic resonance imaging (MRI) was 126 min longer than visits without them.[15] On the other hand, if CT scan detected injuries that could not be detected without CT, the time, the cost and radiation of CT will be worth it for the patient.

So reaching an accurate clinical decision rule for CT use in blunt thoracic injuries is clinically important. For this purpose, in our study 977 traumatic patients with CXR and thoracic CT scan were evaluated. We found that 34.2% of patients had abnormal findings on CXR. And 99.4% of this group of patients had abnormal findings on CT scan, too. Whereas, only 0.2% of patients who did not have abnormal findings on CXR had abnormal findings on CT scan, which were minor and clinically irrelevant and did not alter patient's management. According to our findings, in cases with normal CXR, thoracic CT does not clinically change the course of management. In patients with abnormal CXR, thoracic CT confirmed the injuries in majority of patients and in only 0.6% of patients, the injuries were ruled out.

Barrios et al.[10] reported that as expected, normal-CXR patients had much lower rates of abnormal CT scan findings (25% vs. 81%). Out of the 143 patients who had abnormal CT findings, alterations in clinical management occurred in only 9 patients. Traub et al.[7] also stated that chest CT scan was more sensitive for identification of blunt thoracic trauma, when compared with CXR. In only 19% of patients, therapeutic processes were modified due to CT scan findings.

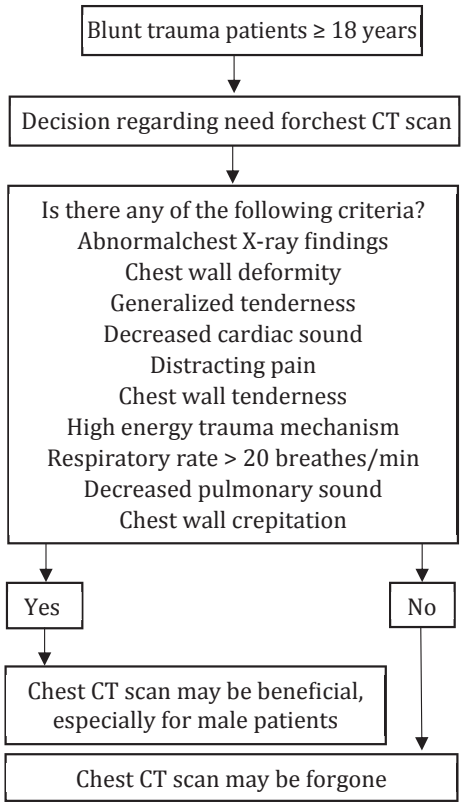

Fig. 1. Approach to selecting adult patients who benefit from chest CT scan following blunt trauma.

Bingol et al.[16] reported that in 61.4% of performed CT scans, at least one clinically relevant injury was found and the most common pathologic findings were pulmonary contusion and fractures. In contrast to our study, Trupka et al.[17] stated that CT scan found major thoracic lesions in 67 patients (65%) who were normal on CXR. CT scan findings changed the management plan in 41% of patients. This study suggests that CT scan is significantly more efficacious for detecting pulmonary contusions, pneumothorax and hemothorax in comparison to CXR.

One of the most common tools for making a decision regarding performing thoracic CT scan in emergency is NEXUS chest CT. Rodriguez et al.[11] published two versions of this tool in 2015. Based on their findings, chest CT scan may forego in cases with normal CXR and without any of following criteria: rapid deceleration mechanism of trauma, scapular, thoracic spine, sternum, and chest wall tenderness; as well as distracting injury.

There is a lot of similarity between the findings of present study and NEXUS chest CT criteria. The focus of each criterion is on trauma mechanism, presence of some signs and symptoms of thoracic injury such as thoracic bones tenderness, and presence of distracting pains.

In our analysis some clinical signs such chest wall deformity, decreased cardiac and pulmonary sound, hemodynamic instability, and chest wall crepitation are weighted in predicting the trauma patients in need of chest CT scan. It may be due to some differences regarding the study population, type of traumas, and situation of patient managements. Patients' transportation time from scene to the emergency department is longer in developing countries and it may be explain the presence of some progressive signs of thoracic injuries such as decreased cardiac and pulmonary sound as well as chest wall crepitation at the time of presenting to hospital.

It seems that we can screen trauma patients who need of chest CT scan based on some clinical and simple imaging modalities such as CXR and ultrasonography (Fig. 1). It should be declared that clinical judgment of the in charge physician is very important in making a decision regarding doing or omitting chest CT scan for blunt chest trauma patients.

The most important limitation of our study was not considering the cases with contusion. Of course, a large number of the studies had concomitant fracture or other pathologies, which marks them as cases with positive chest CT. Based on the findings and shortcomings of the present study we are running a multicenter registry of these cases for a more accurate study in near future.

The findings of this study showed an association between male gender, GCS <15, high energy trauma mechanism, unstable hemodynamics and clinical signs and symptoms of thoracic injury with abnormal chest CT scan findings. Based on multivariate analysis, chest wall deformity, generalized tenderness, decreased cardiac sound, distracting pain, chest wall tenderness, high energy trauma mechanism, male gender, respiratory rate >20 breathes/minute, decreased pulmonary sound, and chest wall crepitation were among the independent clinical predictors of abnormal chest CT scan findings following blunt trauma.

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Ethical Statement

The study protocol was approved by ethics committee of Shahid Beheshti University of Medical Sciences (code: IR.SBMU.MSP.REC.1396.199) and researchers adhered to the recommendations of Helsinki declaration regarding the confidentiality of patient information. Written informed consent was obtained from all participants and the study was performed without any imposed additional financial burden on patients.

Declaration of Competing Interest

The authors declare that they have no conflicts of interest.

Author contribution

All authors pass the four criteria for authorship contribution based on the International Committee of Medical Journal Editors (ICMJE) recommendations.

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