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Original Contribution

Comparison of ultrasonography and computed tomography in the determination of traumatic thoracic injuries

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ABSTRACT

Objective: In this study, the accuracy of bedside thoracic ultrasonography (TUSG) performed by emergency physicians with patients in the supine position was compared with that of thoracic computed tomography (TCT) for the determination of thoracic injuries due to trauma.
Methods: Patients who suffered the multiple traumas, whose thoracic trauma was identified on physical examination or TCT imaging were included in the study. TUSG was performed following a physical examination by the emergency physician who managed the trauma patient. Subcutaneous emphysema, pneumothorax, pulmonary contusions (PCs), hemothorax, pericardial effusion and tamponade, sternal and clavicular fractures and rib fractures were identified by TUSG. TCT imaging was performed after the ultrasonography examination was completed.
Results: Eighty-one patients were included in the study. TCT scans showed subcutaneous emphysema in 16 (19.8%) patients, pneumothorax in 21 (25.9%), PCs in 27 (33.3%), hemothorax in 20 (24.7%), sternum and clavicular fractures in 6 (7.4%) and rib fractures in 21 (25.9%). The sensitivity and specificity of ultrasonography varied for detecting the following pathologies: subcutaneous emphysema (56% and 95%), pneumothorax (86% and 97%), hemothorax (45% and 98%), PCs (63% and 91%), sternal fractures (83% and 97%), clavicular fractures (83% and 100%) and rib fractures (67% and 98%), respectively.
Conclusion: In conclusion, ultrasound was found to be highly specific but only moderately sensitive for the identification of thoracic injuries.

1. Introduction

Trauma is the most important cause of death during the first four decades of life. Thoracic injuries account for 10.5% to 50% of deaths caused by trauma. Therefore, rapid identification of thoracic injuries may decrease mortality. Computed tomography (CT) is the gold standard for diagnosing patients with thoracic trauma [1-3]. Even though this diagnostic tool is very accurate for determining intrathoracic injuries, patients are exposed to a large amount of radiation during CT imaging. Moreover, unstable patients cannot be examined by CT owing to the long examination times required by CT scanners. Chest radiography (C-XR) is preferred because it is a cost-effective first-line diagnostic tool, has a low radiation dose, and can be performed in crowded emergency departments. However, recent studies have not identified high sensitivity and specificity for detecting thoracic injuries with C-XR [3-5].

Ultrasonography (USG) is used to evaluate many parts of the body because compared with conventional radiography, ultrasound (US) is easy to access, does not involve ionizing radiation and is portable. Abdominal, cardiothoracic, vascular and skeletal injuries are assessed in patients with acute traumas [6-10]. Hemorrhage and pneumothorax caused by trauma are diagnosed with extended focused assessment with sonography in trauma (E-FAST), which is performed during the first examination of trauma patients in the emergency department. In addition to detecting pneumothorax and hemothorax, the use of USG has been become widespread for assessing pulmonary contusions (PCs), bone fractures and cardiac dysfunction caused by trauma [10-13].

In this study, the effectiveness of bedside thoracic ultrasonography (TUSG) performed by emergency physicians with patients in the supine

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position was compared with that of thoracic computed tomography (TCT) for the determination of thoracic injuries due to trauma.

2. Methods

This prospective study was performed in the emergency department between June 01, 2015 and March 15, 2018 after the approval of the ethics committee of this tertiary hospital. The study protocol did not interfere with patients' therapeutic and diagnostic procedures, and patients were not exposed to any risks.

Patients who suffered the multiple traumas, whose thoracic trauma was identified on physical examination, and by TCT imaging were included in the study. Written consent was obtained from all the patients included in the study and their relatives. Patients who underwent TCT imaging at other medical centers before referral to the emergency department, pregnant patients and patients who did not provide written consent were not included in this study.

Physical examinations were performed by the emergency physician who completed the first examination of trauma patients. Bedside TUSG was performed by an emergency physician who was trained on TUSG. A standard US (ESAOTE/Firenze/ITALIA and Mindray DC-T6, Germany) with 2 probes, including a 7.5-MHz linear probe and a 3.5-MHz convex probe, was used for TUSG. Patients were in the supine position on stretchers during TUSG, and the anterolateral thorax was assessed from the front of the chest. Each hemithorax was divided into six areas with longitudinal lines that passed through the midsternal, midclavicular, and anterior axilla and with transverse lines that passed through the areola of the breast. These areas were evaluated with linear and convex transducers in longitudinal and transverse planes. Bony tissues were also evaluated in the same way in longitudinal and transverse planes. In our study, bone tissues were examined only in the anterolateral plane, not in the posterior plane, by TUSG. TUSG scanning was performed in the following steps:

1. Scanning for the presence of subcutaneous emphysema (SE); the presence of SE was accepted when E lines were detected. The linear probe was used to detect E lines. E lines are vertical lines that reach the edge of the screen but do not arise from the pleural line.
2. Scanning for the presence of sternal, clavicular and rib fractures; the linear probe was used to detect bone fractures. The sternal cortex, clavicular cortex and rib cortex in the longitudinal and transverse planes were scanned for the detection of fractures. Bone fractures were accepted when cortical impairment was detected.
3. Scanning for the presence of pneumothorax; the linear probe was used to detect B lines, lung sliding and lung pulse. B lines, lung sliding, lung pulse and "seashore" mark were also scanned. In the absence of these findings, the presence of pneumothorax was accepted.

B lines arise at the border between aerated and compressed lung and are described as multiple ray-like or comet-tail vertical lines extending from the pleural line to the lower edge of the screen without fading.

Lung sliding is a back and forth movement in the transverse plane of the bright parallel line on the US screen. Lung sliding occurs due to the sliding of pleural leaves during respiration.

Lung pulse is a vertical movement of the pleural line synchronous with the cardiac rhythm.

4. Scanning for the presence of PCs; the linear probe was used to detect B and C lines. The convex probe was used to detect hepatization and parenchymal disruption.

PC is diagnosed in the presence of the following features: alveolo-interstitial syndrome, ultrasonographically defined as the presence of multiple B lines; the presence a peripheral parenchymal lesion, defined as the observation of C lines; confluent consolidation (hepatization); or the presence of parenchymal disruption with localized pleural effusion.

5. Scanning for the presence of pericardial effusion and tamponade; the heart was evaluated by the convex probe in the subxiphoid area. The presence of cardiac tamponade was accepted when researchers revealed an anechoic pericardial effusion with collapse of the right atrium and right ventricle in the diastolic phase.
6. Scanning for the presence of hemothorax. The presence of hemothorax was considered when the anechoic area was detected in the pleural area with a convex probe.

TCT (HITACHI-ECLOS multislice 16 ch, Japanese) imaging was performed with the patient in the supine position with a CT scanner in the emergency department, following the ultrasonography examination. TCT images were interpreted by a single radiologist. TCT images were evaluated for the presence of SE; pneumothorax; PCs; hemothorax; pericardial effusion and tamponade; and scapular, sternal, rib and clavicular fractures. Treatment decisions made for the patients were made based on the TCT results.

2.1. Statistical analysis

SPSS 21 software was used for statistical analysis. Demographic data are reported as frequencies and medians with interquartile ranges for ordered nonnormally distributed data and as means with standard deviations for continuous normal data. The presence of SE, rib fractures and scapular fractures identified in the posterior area on TCT were not included in statistical analysis. We assessed the performance of TUSG based on characteristics including the sensitivity, specificity, and area. Values are reported with 95% confidence intervals.

3. Results

Eighty-one patients were included in this study; 64 (79%) patients were male, and 17 (21%) were female. The mean age of the patients was 38 ± 20 years old. Patients were injured for a variety of reasons, including 26 (32%) who were injured by falling down from height, 43 (53%) who had a motor vehicle accident, 10 (12%) who were injured with a sharp object and 2 (3%) who were assaulted with a blunt object (Table 1).

SE and pneumothorax were identified in most patient physical examinations focused on the thorax (Table 2).

No pericardial effusion was identified on TCT. PCs, pneumothorax and hemothorax were identified most frequently on TCT (Table 3). SE was identified by TCT in 16 patients; of these patients, 16 (81%) had pneumothorax, 8 (50%) had contusions, 9 (56%) had hemothorax and 6 (38%) had rib fractures. The presence of pneumothorax was identified

Table 1
Descriptive data of studied patients.

Age	18 ≥ 11 patients (14%)
	19–64: 61 patients (75%)
	65 ≤ 9 patients (11%)
Sex	17 female (21%)
	64 male (79%)
Mechanism of trauma	Penetrating wound: 10 (12%)
	Blunt trauma due to accident: 43 (53%)
	Blunt trauma due to falling: 26 (32%)
	Blunt trauma due to direct impact: 2 (3%)
GCS	14–15: 73 patients (89%)
	9–13: 2 patients (3%)
	3–8: 7 patients (9%)
Hemodynamic status	Stable: 64 patients (79%)
	Unstable: 17 patients (21%)

GCS: Glasgow Coma Scale.

Table 2
Physical examination findings.

Physical examination	N	(%)
Subcutaneous emphysema	15	18.5
Pneumothorax	12	14.8
Sternal fracture	2	2.5
Rib fracture	12	14.8
Clavicular facture	2	2.5
Hemothorax	3	3.7
Pulmonary contusion	11	13.6
Pericardial effusion	0	0

by TCT in 21 patients; of these patients, 13 (62%) had contusions, 12 (57%) had hemothorax, and 9 (45%) had rib fractures. Rib fractures were identified by TCT in 21 patients; of these patients, 10 (48%) had more than one rib fracture.

The highest sensitivity was 86% for identifying pneumothorax with TUSG. The second highest sensitivity of 83% was found for detecting trauma to bone structures, specifically for detecting clavicular and sternal fractures (Table 4, Fig. 1). TUSG detected a subcutaneous hematoma in one patient who had massive ecchymosis at the left breast level.

In this study, 45 (55%) patients had thoracic injuries, 13 (16%) had head injuries, 3 (4%) had vertebral fractures, 3 (4%) had solid organ injuries in the abdomen, and 7 (9%) had extremity injuries as a result of trauma. Overall, 30 (34%) patients were discharged from the emergency department after an 8-hour observation period, 27 (33%) were hospitalized in medical units, and 24 (30%) were hospitalized in the intensive care unit.

4. Discussion

Thoracic trauma involves fatal injuries. Therefore, the determination of fatal diagnoses may decrease both mortality and morbidity. The use of bedside USG has gradually become widespread in emergency departments because it provides rapid and accurate diagnoses. However, while there are advantages to USG, it cannot be always performed optimally. When air enters the subcutaneous soft tissue due to trauma, SE occurs. SE prevents imaging of deep tissues due to scattering of the US beam [14,15]. In this case, detecting other underlying pathologies may difficult. Therefore, identifying SE is important in the first step of TUSG. In our study, SE was identified with TUSG with 56% sensitivity and 95% specificity. Moreover, pain due to trauma may prevent an optimal USG examination. Additionally, E lines can be mixed with B lines. In this case, especially minimal SE may escape detection. Thus, the low sensitivity due to SE may make other pathologies easy to miss.

In our study, TUSG was most useful in diagnosing pneumothorax, with 86% sensitivity and 97% specificity, compared with detecting lung parenchymal injuries. Several studies have proved that emergency physicians are successful in diagnosing pneumothorax with TUSG. In these studies, the sensitivity and specificity vary between 81–99.5% and 97–100%, respectively [3,4,11,12]. Our results are consistent with the literature. However, E lines formed due to SE may be confused with B lines in diagnosis. For this reason, physicians are unable to diagnose especially small pneumothoraces. The success in diagnosing pneumothorax may be because air is easily detected by TUSG performed with patients in the supine position as air rises and is close to the skin surface because it is light.

Table 3
Thorax ultrasonography and thorax computerized tomography findings.

Results N = 76 patients	Thorax USG findings		Thorax CT findings	
	N	(%)	N	(%)
Subcutaneous emphysema	12	14.8	16	19.8
Pneumothorax	20	24.7	21	25.9
Sternal fracture	7	8.6	6	7.9
Clavicular fracture	5	6.2	6	7.4
Rib fracture	15	18.5	21	25.9
Hemothorax	10	11.8	20	24.7
Pulmonary contusion	22	27.2	27	33.3

Table 4
Sensitivity and specificity for ultrasound in diagnosis of thorax injuries.

Results N = 76 patients	Sensitivity	Specificity	AUC	95% CI
Subcutaneous emphysema	56	95	0.758	0.601–0.915
Pneumothorax	86	97	0.912	0.820–1.000
Sternal fracture	83	97	0.903	0.726–1.000
Clavicular fracture	83	100	0.917	0.739–1.000
Rib fracture	67	98	0.825	0.698–0.952
Hemothorax	45	98	0.717	0.567–0.867
Pulmonary contusion	63	91	0.769	0.648–0.889

AUC: the area under curve.

Pulmonary contusions, which are characterized by fluid and blood accumulations in lung tissue, are detected in 25% to 80% of patients. PCs may be located in the deepest layers of the chest cavity. Imaging of deep tissues or tissues in posterior areas may not be possible as trauma patients may not be in suitable positions. In this case, the use of low-frequency US probes increases the chances of diagnosing PCs. In previous studies, the second highest diagnosis rates after those for detecting pneumothorax were found for detecting PCs [16,17]. The sensitivity and specificity of TUSG for detecting PCs in a meta-analysis were 0.92 and 0.89, respectively [18]. In our study, the sensitivity and specificity of TUSG for detecting PCs were 63% and 91%, respectively. The sensitivity was low in our study compared with that in other studies. This result may be because the assessment of a patient with TUSG was performed only from the anterolateral surface. Moreover, the inclusion of all traumatic pathologies in this study might have prevented imaging of PCs due to SE and pneumothorax. Therefore, in our study, PCs were detected in 47% of patients diagnosed with SE and 59% of patients diagnosed with pneumothorax on TCT.

Unlike the successful detection of pneumothorax and PCs with TUSG in patients with thoracic trauma, the same has not been reported for the detection of hemothorax [3,11,12,19]. The area under the curve (AUC) was 0.91 (95% CI: 0.86–0.96) for pneumothorax, 0.86 (95% CI: 0.78–0.94) for hemothorax and 0.80 (95% CI: 0.736–0.88) for PCs in a study in which traumatic intrathoracic injuries were assessed [3]. Similar to other studies, in our study, the rates for hemothorax were lower in accordance with those fore pneumothorax and PC. The AUC was 0.912 for pneumothorax, 0.769 for PCs and 0.717 for hemothorax. Additionally, the sensitivity and specificity of TUSG for diagnosing hemothorax were 45% and 98%, respectively. The different sensitivities and specificities for detecting hemothorax among these studies may be due to the variability in the number of patients with hemothorax.

Rib, clavicular, scapular and sternal fractures may occur secondary to thoracic trauma. These fractures are important as they can lead to life-threatening intrathoracic, cardiac, spinal and intraabdominal injuries. Several studies have shown that the sensitivity and specificity of USG is high for detecting fractures caused by trauma [20,21]. USG imaging of rib, clavicular, scapular and sternal fractures caused by thoracic trauma is easy to perform as these fractures are found subcutaneously. A sensitivity and specificity reaching 100% have been reported for USG determination of fractures in the thorax in previous studies [22-26]. In contrast to these studies, in our study, bones other than the scapula were assessed. Rib fractures were frequently identified. Nonetheless, the highest sensitivity and specificity were found for sternal and clavicular fractures. The low specificity and sensitivity for detecting rib fractures on imaging may be due to SE in this region. Moreover, in our study, fractures were identified in more than one rib in 48% of patients with rib fractures. Although rib fractures are assessed during TUSG, the adjacent ribs should be assessed at the point of the fracture. Compared with the specificity and sensitivity of other studies, the specificity

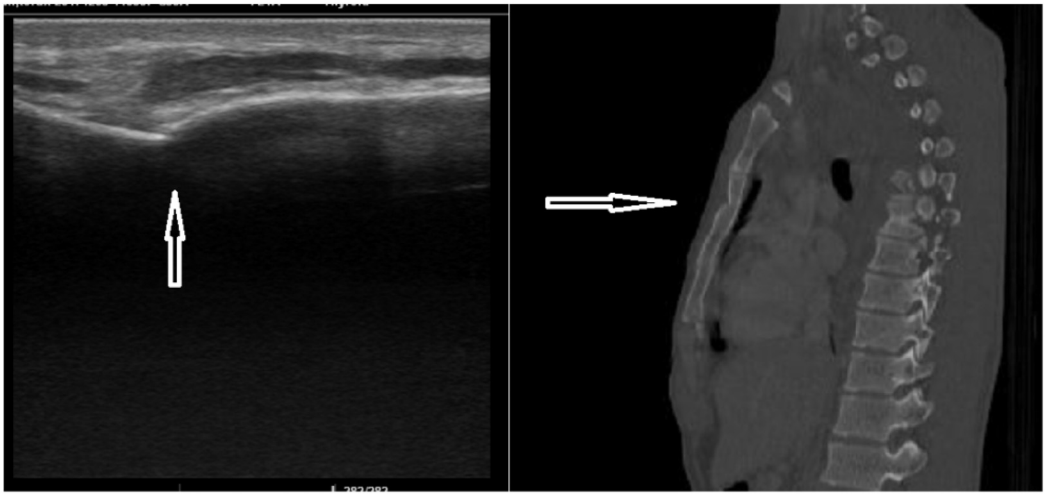

Fig. 1. Twenty-three year old male patient admitted to emergency department with trauma in his head and thorax which occurred traffic accident. Sternum fracture was determined by thorax ultrasonography and thorax computerized tomography.

and sensitivity of our study were generally low. In our study, bone tissues were scanned only from the anterolateral plane, not from the posterior plane, by TUSG. This situation was due to the inability to appropriately position patients with multiple traumas. In addition, during TUSG, patient pain, depending on the type of injury, may have prevented imaging. Moreover, other systemic injuries may have diverted the physician's attention. Therefore, in our study, we identified 45 (55%) patients with thoracic injuries, 13 (16%) with head injuries, 3 (4%) with vertebral fractures, 3 (4%) with solid organ injuries in the abdomen and 7 (9%) with extremity injuries as a result of trauma.

5. Conclusion

In conclusion, ultrasound was found to be highly specific but only moderately sensitive for the identification of thoracic injuries. The highest sensitivity was observed for detecting pneumothorax, clavicular and sternal fractures. The lowest sensitivity was observed for detecting subcutaneous emphysema and hemothorax. During this imaging, inappropriate positioning, presence of SE, physician ability and patient pain restrict the determination of injuries. However, TUSG may be used as an alternative diagnosis method in emergency departments as it can be easily learned and performed, and both bone tissue and soft tissue may be assessed together with the heart and lung parenchyma.

Declaration of interests

None.

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NK and MA were responsible for the integrity of the work as a whole from inception to publication. EA and TP contributed to the interpretation of data. MO and IE contributed to the conception and design of the article. ED was responsible for analyzing the data. OFK, NK and MA contributed to data acquisition.

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