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Original Article

Diagnostic Value of Sonography in Detecting Hemothorax and its Size in Blunt Trauma Patients

Hamid Reza Talari[1], Noushin Mousavi[1], Masoumeh Abedzadeh- Kalahroudi[1*], Hossein Akbari[1], Seyed Mohammad Hossein Tabatabai[1], Niloofar Ashtari[1]

[1] Trauma Research Center, Kashan University of Medical Sciences, Kashan, Iran

*** Corresponding Author:** Masoumeh Abedzadeh- Kalahroudi Associate Professor; Trauma Research Center, Kashan University of Medical Sciences, Kashan, Iran. Email: Abedzadeh@kaums.ac.ir

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Abstract

Introduction: Hemothorax is one of the most prevalent complications after thoracic trauma. Extended Focused Assessment with Sonography for Trauma (e-FAST) is one of the diagnostic methods for hemothorax assessment. This study aimed to assess the diagnostic value of e-FAST in detecting hemothorax and its size in patients with blunt thoracic trauma.

Methods: This cross-sectional diagnostic assessment was conducted on 400 adult patients with blunt trauma who needed a chest CT scan. Chest X-ray (CXR), sonography, and chest CT scans were performed and hemothorax size was assessed with sonography and CT-scan. Sensitivity, specificity, and positive or negative predictive values of sonography and CXR were calculated. Hemothorax size on sonography was compared with the results of CT-scan as the gold standard.

Results: The mean age of participants was 43.67±22.03. Based on CT scan findings, 176 participants (44%) had a hemothorax. The sensitivity, specificity, positive and negative predictive values, and correct classification rate of sonography were 79%, 99.1%, 98.6%, 85.7%, and 90.2%, respectively. The accuracy of sonography was 97.1% for small hemothorax, 46.9% for medium hemothorax, and 33.3% for large hemothorax.

Conclusion: Sonography is a sensitive diagnostic modality for the detection of hemothorax in multiple trauma patients but tends to underestimate moderate to large-sized hemothorax. Chest sonography can be an acceptable imaging modality if a CT scan is not available or desired.

Keywords: Hemothorax, sonography, trauma, e-FAST.

Introduction

Trauma is the leading cause of death in the fourth decade of life [1, 2]. Thoracic trauma occurs in up to 60% of multiple trauma patients [3]. Hemothorax and pneumothorax are the most common complications of thoracic trauma and are prevalent in 20% of blunt trauma patients [4, 5]. Early diagnosis and treatment of these complications reduce unfavorable outcomes, such as empyema [6,7]. The treatment of hemothorax traditionally has been managed with a chest tube insertion. However, observation of a small hemothorax less than 300 ml (1.5 cm pleural stripe) is recently considered acceptable and safe [8]. In these patients, chest drainage is usually not indicated. Thus, these patients are followed with interval imaging [9]. If the hemothorax increases in size, tube thoracotomy is usually indictable, but determining the progression of hemothorax or detection of a clotted hemothorax is difficult using only CXR (10). Although chest X-ray is easily accessible and noninvasive, it has low sensitivity in detecting intrathoracic injuries [11-14]. Moreover, in critically ill patients, chest X-ray is usually performed in the decubitus position, which can miss effusions as much as 1000 ml [15].

Computerized tomography (CT) scan is the gold standard for detecting trauma-induced thoracic injuries [16-18]. Despite its high sensitivity in detecting intrathoracic injuries, a CT scan exposes patients to high doses of ionizing radiation [19-21]. Moreover, unstable trauma patients and patients admitted to the intensive care station often cannot be transferred to the radiology unit.

These weaknesses have caused clinicians and researchers to think about other diagnostic methods [13, 14, 22].

In recent years, chest sonography has received considerable attention as a reliable, safe, and inexpensive method for detecting injuries caused by thoracic trauma and is included in most level 1 trauma centers as an adjunct to radiographs [23-25]. Sonography can easily be used at patients' bedside under any conditions, without patient transfer to the radiology unit [26]. It can rapidly detect occult hemothorax and pneumothorax [13]. The precision of sonography and detection of parenchymal injuries depends on the operator's expertise. Also, the sonography is unable to detect parenchymal injuries [27]. Therefore, a chest ultrasound can be helpful for follow-up of patients with minor hemothorax, patientes without drainage. Also, the chest ultrasound is beneficial for the detection of retained clotted hemothorax in patients.

This study aimed to assess the diagnostic value of ultrasound in detecting hemothorax and the ability to determine its size in comparison to CT-scan in blunt trauma patients.

Methods

This diagnostic assessment study was conducted on 400 patients with blunt trauma. Sample size was determined based on the results of previous studies, reporting a sensitivity of 82.9% for sonography (P1) [5]. Accordingly, with a P2 of 20%, a confidence interval of 0.95%, a power of 90%, and an error tolerance (P1–P2) of 0.1, the following formula showed that 338 participants were needed:

$$n = \left(\left[Z_{1-\alpha/2} + Z_{1-\beta}\right]^2 \left[P_1(1 - P_1) + P_2(1 - P_2)\right]\right)/(\mu_1 - \mu_2)^2$$

The Ethics Committee of Kashan University of Medical Sciences, Kashan, Iran, approved this study (code: IR.KAUMS.MEDNT.REC.1397.078). All participants or their family were signed written informed consent, and they were ensured anout data confidentiality. Participants were consecutively recruited from 2018 to 2019 from Shahid Beheshti Hospital, Kashan, Iran. All multiple trauma patients who needed both CXR and CT scans based on the Advanced Trauma Life Support criteria were identified and assessed for eligibility. The indication for performing chest CT-scan was any suspicion to mediastinal injury (according to high energy trauma mechanism, i.e. motor vehicle accidents with more than 40 Km/h deceleration, falls from more than 6 meters' height and car to pedestrian trauma and/or clinical or paraclinical signs of mediastinal hematoma) [28]. Exclusion criteria were unstable vital signs, need for thoracostomy before complete imaging, ineligibility for diagnostic procedures and concomitant pneumothorax. All participants underwent sonography for hemothorax detection using the e-FAST protocol. The ultrasound machine (UEGO, Samsung, South Korea) and a 3.8–5 MHz deep probe were applied. All sonographic assessments were performed by one trained radiology resident for hemothorax detection. The most dependent area was assessed for hemothorax in the posterior axillary line at both sides. The hemothorax was considered as an anechoic or hypoechoic fluid between the diaphragm and the parietal pleura and in the costophrenic space. The size of hemothorax was determined based on the depth of hemothorax at the most dependent area in comparison to the length of the probe as follows: one probe: small hemothorax (100–500 milliliters); two probes: medium hemothorax (500–1500 milliliters); three probes or more: large hemothorax (more than 1500 milliliters) [29]. In addition to sonography, supine CXR and chest CT scan were performed. CT scan was performed using a sixteen-channel CT scan machine (Alexion, Toshiba, Japan) with 10 mm cuts. The size of hemothorax on CT scan was determined by the anterior-posterior diameter of the chest was divided into four sections. The number of involved sections was used for size determination as follows involvement of one quadrant as small, involvement of two quadrants as medium, and involvement of three or four quadrants as large. When the findings were equivocal, the maximum anterior-posterior diameter of hemothorax was used for size determination as follows less than three centimeters: small; 3–10 centimeters: medium; and more than ten centimeters: large [30]. CXR and CT scans were reported by two different radiologists, blinded to the results of sonography. Imaging findings, demographic data, such as age, gender and trauma mechanism were documented in a data sheet. Frequency tables were created to describe the data and diagnostic value indices. Sensitivity, specificity, positive and negative predictive values were calculated using the SPSS software (v. 16.0). McNemar's and Wilcoxon's tests were used to evaluate the relationship between the findings of the different hemothorax assessment methods. The level of significance was set at less than 0.05.

Results

In total, 400 blunt trauma patients were studied. The mean age was 43.67±22.03 and 66.5% were male. The most common trauma mechanism was a car-to-car accident (26.5%). The results of CXR and CT scans were similar for hemothorax detection in only 36.9% of cases. Despite this, they were like respecting non-detection of hemothorax in 99.1% of cases. There was a significant relationship respecting hemothorax detection between the CXR and CT scans ($P < 0.001$; Table 1).

The results of sonography and CT scan were similar in 79% of cases for hemothorax detection. Also, the results of sonography and CT scan were like in 99.1% non-detection of hemothorax. There was a significant relationship between CT scans and sonography results ($P < 0.001$; Table 2).

Table 1. The frequency distribution of hemothorax based on the findings of CT scan and CXR

T scan / CXR	Positive hemothorax N (%)	Negative hemothorax N (%)	Total N (%)	P value*
Positive hemothorax	65 (36.9)	2 (0.9)	67 (16.8)	< 0.001
Negative hemothorax	111 (63.1)	222 (99.1)	333 (83.3)	
Total	176 (100)	224 (100)	400 (100)	

*: The results of the McNemar's test

Table 2. The frequency distribution of hemothorax based on the findings of CT scan and sonography

CT scan / Sonography	Positive hemothorax N (%)	Negative hemothorax N (%)	Total N (%)	P value*
Positive hemothorax	139 (79)	2 (0.9)	141 (35.3)	< 0.001
Negative hemothorax	37 (21)	222 (99.1)	259 (64.8)	
Total	176 (100)	224 (100)	400 (100)	

*: The results of the McNemar's test

The sensitivity, specificity, positive and negative predictive values, and correct classification rate of sonography were 79%, 99.1%, 98.6%, 85.7%, and 90.2%, respectively. For CXR, these values were 36.9%, 99.1%, 97%, 66.7%, and 71.7%, respectively (Table 3). he positive predictive value was 100% when CXR and sonography results were positive. Therefore, there was a definitive diagnosis of hemothorax (Table 4). The total positive predictive value was 97.3% which either sonography or CXR results confirmed hemothorax. The total negative predictive value of

concurrent CXR and sonography was only 66.1%.
Respecting hemothorax size, CT scan findings showed that 56% of participants did not have hemothorax, 34% had small hemothorax, 8% had medium hemothorax, and 1.5% had large hemothorax. Sonography accurately detected the absence of hemothorax in 99.1% of cases, small hemothorax in 71% of cases, medium hemothorax in 46.9% of cases, and large hemothorax in 33.3% of cases. The preciseness of sonography in determining hemothorax size reduced with increase in hemothorax size. The sonography and CT scan results were like in 84.3% of cases in the accuracy of sizing determined. The hemothorax size was underestimated in sonography in 14.5% participants. Also, the overestimated size was seen in 1.25% of cases (five patients). There was a significant relationship between sonography and CT scan results in the accuracy of sizing determined ($P < 0.001$; Table 5).

Table 3. Diagnostic value indices of CXR and sonography in detecting hemothorax

Indices / Method	Sensitivity	Specificity	Positive predictive value	Negative predictive value	Correct classification rate
CXR	36.9	99.1	97	66.7	71.7
Sonography	79	99.1	98.6	85.7	90.2

Table 4. The total diagnostic value indices of concurrent CXR and sonography in detecting hemothorax

Indices / Findings	Sensitivity	Specificity	Positive predictive value	Negative predictive value	Correct classification rate
The findings of at least one method are positive	81.3	98.2	97.3	86.9	90.8
The findings of both methods are positive	34.7	100	100	66.1	71.3

Table 5. Results of CT scan and sonography respecting hemothorax size

CT scan / Sonography	Small N (%)	Medium N (%)	Large N (%)	Total N (%)
Small	100(97.1)	17 (53.1)	1 (16.7)	118 (83.7)
Medium	3 (2.9)	15 (46.9)	3 (50)	21 (14.9)
Large	0	0	2 (33.3)	2 (1.4)
Total	103 (100)	32 (100)	6 (100)	141 (100)

*: The results of the Wilcoxon's test

Discussion

There are controversies about the diagnostic value of sonography in detecting hemothorax [31-34]. In previous studies, the sensitivity and specificity of sonography varied from 37% to 100% and from 75% to 100% [5, 12, 14, 27, 34-39] and the sensitivity and specificity of CXR

respectively varied from 25% to 92% and from 95% to 100% [5, 14, 27, 39, 40]. Rahimi Movaghar et al. showed that the sensitivity and specificity of sonography in hemothorax detection were 67% and 99%. Also, they demonstrated the sensitivity and specificity of CXR were 54% and 99%. Finally, they concluded that the sensitivity of sonography in hemothorax detection is greater than CXR. However, it is still at a moderate level [14]. Similarly, our results indicated that sonography has greater sensitivity than CXR in hemothorax detection. Also, both sonography and CXR have well in this area.
The total positive predictive value of concurrent CXR and sonography was 100%. Therefore, the diagnosis of hemothorax is definitive when that both methods show evidence of hemothorax.However, the total negative predictive value of concurrent CXR and sonography was low (66.1%). Thus, the that negative CXR and sonography cannot rule out the presence of a hemothorax.
According to the size of hemothorax, our results showed that sonography is a sensitive method for detecting a small hemothorax. However, it may underestimate the size of a medium to large hemothorax. Chung et al. evaluated the benefit of ultrasound in deciding between tube thoracostomy and conservative management in blunt chest trauma patients. Subsequently, ultrasound can accurately evaluate hemothorax size to avoid tube thoracostomy in patients. They stated that there was no tube drainage less than 500 ml in the group which was evaluated via ultrasound, in comparison to the control group, which was evaluated only by chest X-ray and clinical examination, revealing tube drainage of fewer than 500 ml in 40% of patients [41]. The development of delayed hemothorax was reported same in both groups. But there is an ambiguity about underestimation because no comparison was made with CT-scan. Remérand et al. revealed a very close relation between estimated effusion volume by sonography and CT-scan (r=0.90). They calculated the effusion volume was calculated by multiplying the paravertebral PE length by its area, measured at half the distance between the apical and caudal limits of the PE. This technique seems more accurate than simply measuring the "depth" of an effusion, but it is technically more difficult and time consuming.
As one of the strengths of this study was that all sonographic assessments were performed by one third-year medical resident in radiology. So, no confounding effects were respecting the expertise of different operators.
The limitation of the study was the technique for quantification of hemothorax size via sonography. There are several formulae for calculating the size of a hemothorax, but the two most accurate techniques (Goecke 1 and 2) have to be performed in the upright position. We preferred to use the easy method presented by Prina et al. as traumatic patients usually cannot be evaluated in the vertical position. Also, a quick and easy approach is preferable in the clinical setting. In addition, there were only six patients (1.5%) with large hemothorax, that should be considered in the interpretation of data. Further studies using other formulae and more comprehensive study with larg population could reveal more accurate results.

Conclusion

Sonography is a sensitive diagnostic modality for the detection of hemothorax in multiple trauma patients. It can be used to follow up and determine hemothorax size in patients with a small hemothorax and without tube thoracostomy. It should be kept in mind that sonography might underestimate the size of a hemothorax, but it can be an acceptable imaging modality if CT-scan is not available or desired.

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Conflict of Interest Disclosures

The authors declare that they have no conflicts of interest.

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Non

Authors' Contributions

All authors were contributed equally in this study.

Ethical Statement

The Ethics Committee of Kashan University of Medical Sciences, Kashan, Iran, approved this study (code: IR.KAUMS.MEDNT.REC.1397.078).

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