Traumatic Hemothorax and Pneumothorax detected by EFAST Compared with Chest Radiography at Siriraj Hospital

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ABSTRACT

Objective: EFAST is the evaluation of thoracoabdominal injury in trauma patients. This study aimed to evaluate the diagnostic utility of EFAST for detection of traumatic pneumothorax and hemothorax compared to standard routine chest radiography at Siriraj Hospital.

Methods: From January 2013 to April 2015, 119 patients who visited the Division of Trauma, Siriraj Hospital were included in the study. EFAST was performed during the initial resuscitation of the injured patients and plain chest radiographs were obtained as routine hospital protocols. Patients' charts were retrospectively reviewed and real-time EFAST examinations were compared to the results of chest radiographs. EFAST diagnosis was considered positive when there was absence of normal sliding lung signs (pneumothorax) and presence of free fluid above the diaphragm (hemothorax).

Results: The sensitivity, specificity, PPV, and NPV of EFAST for the diagnosis of pneumothorax and hemothorax were 76%, 100%, 100%, and 93%, respectively, whereas the sensitivity, specificity, PPV and NPV of plain chest radiographs were 80%, 100%, 100% and 94.9%, respectively.

Conclusion: EFAST shows similar diagnostic accuracy compared to plain supine AP chest radiograph. The results are operator-dependent and higher accuracy can be achieved by well-trained emergency health care personnel. EFAST can be performed during resuscitation, and still provides promising results which can lead to early treatment procedure. Under experienced hands, EFAST is considered effective. This study suggests that it should be used as a complimentary procedure in all thoracic injured patients' evaluations.

Keyword: EFAST

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INTRODUCTION

Siriraj Hospital serves as one of the level 1 trauma centers of Bangkok. Thoracic trauma is a common injury. During the decade 1997-2006, the statistics showed that there were up to 80-100 cases of thoracic injury per year with overall 5.1% mortality rate[1]. Blunt trauma was the major type of injury and traffic accidents were common causes[1]. Pneumothorax and hemothorax are major complications resulting from either blunt or penetrating thoracic injuries. Symptoms and severity are variable, and can be non-specific and could subsequently lead to respiratory distress, hemodynamic compromises, and traumatic arrest. Tension pneumothorax and massive hemothorax are life-threatening and require immediate diagnosis and management.

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Focused Assessment with Sonography for Trauma (FAST) is a screening ultrasonography in trauma patients in which abdominal organ injuries are suspected. It is used widely in every trauma center because of its efficacy, high sensitivity and specificity, non-invasiveness, and is less time-consuming[2], due to its ability to evaluate unstable patients during resuscitation. Therefore, extended focused assessment with sonography for trauma or EFAST has been introduced for thoracic injury assessment.

EFAST is recognized as a fast and accurate way to provide early assessment of life-threatening conditions of pneumothorax and hemothorax. It is an essential tool for emergency physicians to make decisions and management in trauma patients. EFAST has been introduced and performed in our center as an adjunct to primary survey in all seriously injured patients entering the trauma resuscitation room.

The purpose of this study is to determine the diagnostic performance of EFAST to detect pneumothorax and hemothorax at Siriraj Hospital compared to routine standard portable anteroposterior (AP) supine chest radiograph by means of sensitivity, specificity, negative predictive value, positive predictive value, accuracy, and additional values.

MATERIALS AND METHODS

At Siriraj Hospital, seriously injured patients would be resuscitated in the resuscitation room by the trauma team. Patients with thoraco-abdominal injury or suspected multiple organ injuries would have undergone an EFAST examination during primary survey.

This retrospective study was approved by the Ethics Committee (Si 444/2014) and performed at Siriraj Hospital between January 2013 and April 2015. A total of 121 patients received screening EFAST as an addition to FAST examination in order to determine the presence of pneumothorax and/or hemothorax. Two patients were excluded because one patient lacked subsequent plain chest radiograph, and another was due to lack of recorded information of the EFAST result. Thus, 119 patients were included in the study. All EFAST examinations were performed before portable plain chest radiographs.

EFAST examinations were performed by a senior general surgical resident who rotated at the Division of Trauma and familiar with the principle of FAST examination under supervision of an attending trauma staff.

FAST examinations were performed, followed by EFAST investigation. First, the convex transducer was placed laterally at the bilateral inferior edge of the thoracic cage to determine the hepatorenal and splenorenal pouch. The probe moved cephalad to obtain a view of the diaphragm, and to look for pleural free fluid within the thoracic cavity which was interpreted as a positive result for hemothorax. Second, the transducer was placed at both anterior upper thoracic regions at the 3rd-4th intercostal space and midclavicular line in sagittal view for evaluation of the absence of a normal "lung sliding" sign, and "comet tail artifacts". The absence of these signs was interpreted as a positive result of a pneumothorax. Both thoraces were examined as an internal control. The time needed to perform each examination was also noted.

Chest radiographs were interpreted later in every case, the results were recorded independently to the results of EFAST.

The gold standard for diagnosis of pneumothorax and/or hemothorax is a combination of either positive EFAST and/or plain chest radiograph plus a positive content, either air and/or blood, obtained through an inserted intercostal drainage. Chest and/or abdominal computed tomography (CT) was not used as a gold standard because only a few cases had undergone CT examinations which were not routinely included in the protocol. However, if there were available data of the CT scans, the results would have been included for diagnostic consideration. An occult pneumothorax is defined as the presence of pneumothorax and can be detected on a thoracic or thoracoabdominal CT scan, but not detected or suspected in the physical examination, EFAST, and plain radiograph.

Retrospective chart reviews were performed. The results of EFAST, plain chest radiograph and/or additional CT scan were interpreted by trauma staff and radiologists. The presence of blood or air obtained through the chest drainage tubes were collected. Demographic data of patients' age, sex, mechanism of injury either blunt or penetrating, cause of injury, and Injury Severity Score (ISS) were also noted.

Statistical analysis

Sample size was calculated by using standard software (nQuery Advisor 6.0), total number of calculated sample size was 114 cases based on prior study[4]. All available data were entered into a database and were analyzed with standard software (IBM SPSS Statistic version 18). Sensitivity, specificity, positive predictive value, negative predictive value, and accuracy were calculated respectively, as well as additional values of EFAST to standard plain chest radiographs. Statistical analyses were performed using McNemar-Bowker test to compare sensitivity and specificity between EFAST and chest radiograph.

RESULTS

Demographic data of all 119 patients included in this study showed that there were 97 male patients with mean age of 35 (18-83) years old, and 22 female patients with mean age of 45 (17-80) years old. Overall mean age was 37 years old.

Blunt and penetrating injuries were calculated as 88.2% (N=105) and 11.8% (N=14), respectively.

The most common cause of injury was traffic accident (N=59; 49.6%), followed by physical assaults including domestic violence (N=31; 26.1%), and falling injury (N=22, 18.5%). Pedestrian accidents and occupational hazards were also encountered. The mean Injury Severity Score (ISS) was 10.

Imaging procedures and findings

EFAST Findings: EFAST-Positive cases were defined as the absence of normal pleural sliding signs (pleural interface), loss of normal comet tail artifacts (Fig 1), and/or the presence of fluid in thoracic pleural cavity (Fig 2). This study, EFAST has proved to be a fast bedside assessment tool for early detection of possible pneumothorax or hemothorax during a patient's primary survey. Estimated time required for evaluation was approximately 3 minutes for both sides of thoracic regions.

Plain chest radiograph findings included visible pleural lines, peripheral radiolucency, or collapsed lung for diagnosis of pneumothorax, and presence of fluid opacity within the thoracic regions for diagnosis of hemothorax. Mean time for the digital image to be archived on the picture archiving and communication system (PACS)

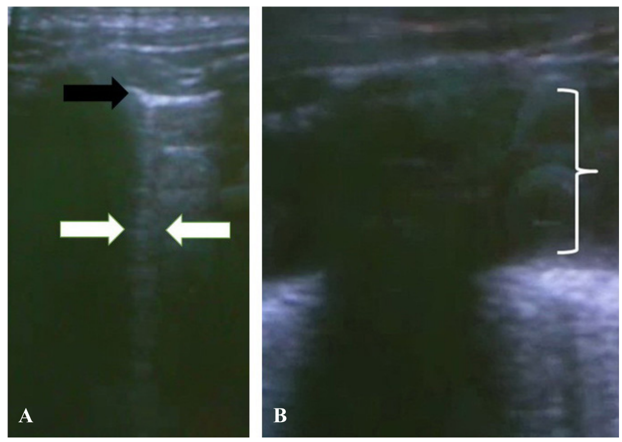

Fig 1. EFAST imaging shows
A. Black arrow: normal "lung sliding", white arrows: "comet tail artifact" B. Bracket: presence of pneumothorax (loss of "lung sliding")

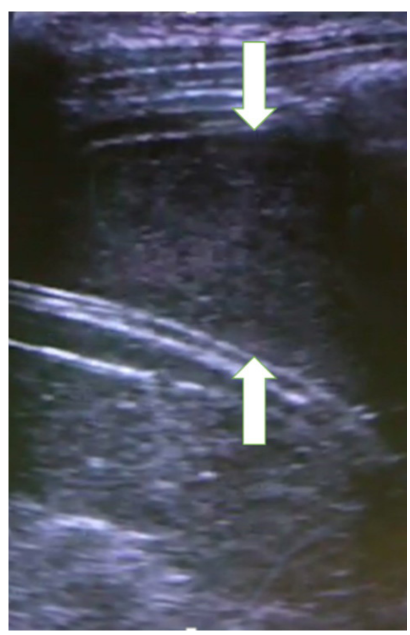

Fig 2. EFAST demonstrates intrathoracic fluid or hemothorax (between white arrows).

after portable chest radiograph was almost 15 minutes.

In 119 patients there were 2 cases in which EFAST showed superior diagnostic performance over plain chest radiographs. In contrast, there were 4 cases in which the chest imaging was better than EFAST. EFAST and plain chest radiographs showed the same results in 113 patients (110 cases with true positive or true negative diagnosis and 3 cases of false negative results).

Twenty five cases (21%) had either unilateral or bilateral pneumothorax or hemothorax. There were 12 cases of pneumohemothorax (10.1%), 12 cases of hemothorax (10.1%), and 1 case of pneumothorax (0.8%). EFAST was able to correctly detect pneumohemothorax in 18 out of 25 cases (72% sensitivity, 100% specificity, 100% positive predictive value, 93% negative predictive value and 94.1% accuracy). Plain chest radiographs showed slightly superior results in detection, 20 out of 25 cases (80% sensitivity, 100% specificity, 100% positive predictive value, 94.9% negative predictive value, 95.7% accuracy (Table 1).

One case with left hemothorax was diagnosed as negative initial bedside EFAST by a resident. Then a repeated examination was performed by an attending trauma physician who recorded the diagnosis of positive left hemothorax. Given this situation, the sensitivity of EFAST would increase up to 76%, 100% specificity, 100% positive predictive value, 94% negative predictive value, and 94.9% accuracy (Table 2).

No significant difference was found between sensitivity of EFAST compared to chest radiographs in detection of pneumothorax and hemothorax (P value = 1.0) as shown in Table 3.

DISCUSSION

Ultrasound is an accurate tool in the setting of trauma imaging. The portability, simplicity, repeatability, availability, absence of radiation and less time consumed prove its effectiveness.

TABLE 1. Sensitivity, Specificity, PPV, and NPV of chest radiograph compared to gold standard.

Sensitivity & Specificity	Diagnosis		Total
	Negative	Positive	
Negative	94 (100%)	5 (20%)	99 (83.2%)
Positive	0 (0%)	20 (80%)	20 (16.8%)
Total	94 (100%)	25 (100%)	119 (100%)
PPV & NPV	**Diagnosis**		**Total**
	Negative	**Positive**	
Negative	94 (94.9%)	5 (5.1%)	99 (100.0%)
Positive	0 (0.0%)	20 (100.0%)	20 (100.0%)
Total	94 (79.0%)	25 (21.0%)	119 (100.0%)

TABLE 2. Sensitivity, Specificity, PPV, and NPV of EFAST compared to gold standard.

Sensitivity & Specificity	Diagnosis		Total
	Negative	Positive	
Negative	94 (100%)	0 (0%)	100 (84.0%)
Positive	6 (24%)	19 (76%)	19 (16.0%)
Total	94 (100%)	25 (100%)	119 (100%)
PPV & NPV	**Diagnosis**		**Total**
	Negative	**Positive**	
Negative	94 (100%)	6 (6.0%)	100 (100.0%)
Positive	0 (0.0%)	19 (100.0%)	19 (100.0%)
Total	94 (79.0%)	25 (21.0%)	119 (100.0%)

TABLE 3. Comparison of EFAST and CXR.

EFAST	Chest radiograph		Total
	Negative	Positive	
Negative	3 (12.0%)	3 (12.0%)	6 (24.0%)
Positive	2 (8.0%)	17 (68.0%)	19 (76.0%)
Total	5 (20.0%)	20 (80.0%)	25 (100.0%)

Ultrasound can be used as interventional treatment given during resuscitation or as an adjunct tool for early diagnosis.

Several studies of "Extended Focused Assessment with Sonography for Trauma" (EFAST) have shown its efficacy to evaluate the presence or absence of pneumothorax and hemothorax, especially in patients who require assisted mechanical ventilation. This condition may lead to the progression of life-threatening situations, such as tension pneumothorax or hemodynamic instability[5]. The presence of lung sliding and comet-tail artifacts at the pleural interface indicates apposition of the pleural surface[2] and possibility of air within the pleural surface is unlikely. The great advantage of EFAST is that it requires only a few minutes to perform and can be performed while other procedures or treatments are going on for patient's resuscitation. The main disadvantage of EFAST is that it is operator dependent and cannot detect other associated injuries. The original "FAST" itself is not as quick and sufficient compared with chest radiographs, for example, in fracture of ribs, clavicles, thoracolumbar vertebrae, widening mediastinum, pulmonary contusion, or even life-threatening conditions, such as flail chest. In addition, the severity of pneumothorax or hemothorax cannot be reliably evaluated solely with EFAST as it can be with the use of chest radiograph.

For plain AP supine chest radiograph, approximately about 30% of pneumothorax is still missed on plain supine chest radiograph[6].

In this study, no cases of pre-existing pleural diseases were presented. EFAST has proved to be a high specificity diagnostic tool while the sensitivity is slightly lower than expected. This could be the operator dependent nature of ultrasonography. This can be explained in one case in which the first recorded result of EFAST was negative but when EFAST was later performed by a trained attending physician, it showed positive result. Another explanation could be that patients who had a small amount of pneumothorax which the operator was not aware of, so they did not move the probe to the region. It is known that intermittent pleural sliding can be observed when the lung expands enough to touch the chest wall at the margin of the pneumothorax which is often used to evaluate the severity or approximate amount of pneumothorax called the "lung point" sign[7].

In bilateral pneumothorax, lack of internal control or differences between findings of bilateral thoraces can be misinterpreted as false-negative results by a less experienced operator.

Some patients' factors can also lead to difficult or false-negative interpretation of EFAST, probably due to limitation of ultrasonography in obese patients, open wounds, or other medical instruments placed over the thoracic regions. In this study, two of three false negative patients were obese. Moreover, the ultrasound machine that was used in this study was about 10 years old and may not have provided a good resolution.

In cases of occult pneumothorax, both EFAST and chest radiograph failed to detect the abnormality. Pneumothorax was later detected by follow-up chest radiograph at the ward. This strongly supports that in clinical-occult and imaging-occult thoracic or multi-organ injury cases, follow up imaging should be strongly considered. In our study, follow up bedside EFAST was not performed and only portable chest radiograph was done 6 hours apart from initial chest radiograph.

The results of this study showed insignificant different sensitivity, specificity, positive predictive value, and negative predictive value between EFAST and chest radiograph as described previously. On the other hand, there is additional

TABLE 4. Additional values of EFAST to CXR.

EFAST+CXR	Diagnosis		Total
	Negative	Positive	
Negative	94 (96.9%)	3 (3.1%)	97 (100.0%)
Positive	0 (0.0%)	22 (100.0%)	22 (100.0%)
Total	94 (79.0%)	25 (21.0%)	119 (100.0%)

value of EFAST performance in adjunct to chest radiograph which would increase the sensitivity for detecting pneumohemothorax up to 88%, 100% specificity and positive predictive value, 96.9% negative predictive value, and 94.7% accuracy (Table 4). We suggest that EFAST should be used as an adjunct with chest radiograph in trauma patients with possibility or suspicion of developing pneumohemothorax.

Limitation

Our study had a small number of patients and we combined pneumothorax and hemothorax as one diagnosis, so further study with larger population and separate diagnosis using EFAST is suggested.

CONCLUSION

EFAST is a fast and highly specific diagnostic tool. It can be performed at bedside for detection of pneumothorax and hemothorax in acute trauma. This study revealed high specificity and positive predictive value though its sensitivity and negative predictive value is less than expected and slightly less than that of chest radiographs. An additional value of EFAST used as complementary to chest radiographs is that it can increase the sensitivity of pneumothorax and hemothorax detections, which are essential for early treatment in serious life-threatening conditions. We suggest the use of EFAST is complementary to routine chest radiograph for patients who have indication for FAST and those with thoracic injury or polytrauma in which pneumohemothorax is suspected.

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