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Extended focused assessment with sonography for trauma (EFAST) in the diagnosis of pneumothorax: Experience at a community based level I trauma center

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ABSTRACT

Introduction: Early identification of pneumothorax is crucial to reduce the mortality in critically injured patients. The objective of our study is to investigate the utility of surgeon performed extended focused assessment with sonography for trauma (EFAST) in the diagnosis of pneumothorax.
Methods: We prospectively analysed 204 trauma patients in our level I trauma center over a period of 12 (06/2007-05/2008) months in whom EFAST was performed. The patients' demographics, type of injury, clinical examination findings (decreased air entry), CXR, EFAST and CT scan findings were entered into the data base. Sensitivity, specificity, positive (PPV) and negative predictive values (NPV) were calculated.
Results: Of 204 patients (mean age – 43.01 ± 19.5 years, sex – male 152, female 52) 21 (10.3%) patients had pneumothorax. Of 21 patients who had pneumothorax 12 were due to blunt trauma and 9 were due to penetrating trauma. The diagnosis of pneumothorax in 204 patients demonstrated the following: clinical examination was positive in 17 patients (true positive in 13/21, 62%; 4 were false positive and 8 were false negative), CXR was positive in 16 (true positive in 15/19, 79%; 1 false positive, 4 missed and 2 CXR not performed before chest tube) patients and EFAST was positive in 21 patients (20 were true positive [95.2%], 1 false positive and 1 false negative). In diagnosing pneumothorax EFAST has significantly higher sensitivity compared to the CXR ($P = 0.02$).
Conclusions: Surgeon performed trauma room extended FAST is simple and has higher sensitivity compared to the chest X-ray and clinical examination in detecting pneumothorax.

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Introduction

Pneumothorax is a common clinical condition affecting significant number of patients with polytrauma. The incidence of pneumothorax may be as high as 20%.[2] A small or medium pneumothorax may not be life threatening in a patient breathing spontaneously. However, tension pneumothorax often preceded by small or medium pneumothorax may lead to cardiac arrest.[10] Early diagnosis and treatment of pneumothorax are important to reduce the progression to tension pneumothorax.[14]

Initial clinical examination in the trauma room is important to identify the patients who are at high risk for pneumothorax. Clinical examination is true positive in only 60% of the patients.[1] Portable chest radiography (CXR) and computed tomography (CT scan) are the two important investigations commonly used for the diagnosis. However, CXR has been shown to miss over half of all post-traumatic pneumothoracis.[1] The CT scan is the gold standard for the detection of pneumothorax. However, it requires severely injured patients to be transported to the CT room, is time consuming and results in delayed diagnosis. Ultrasonography (US) is easily performed at the bedside in the trauma room and is incorporated into ATLS guidelines as FAST. FAST is used to perform rapid evaluation of severely injured patients.[3,5,7] The use of FAST to detect pneumothorax has been studied by few and shown to have a higher sensitivity and specificity when compared to CXR.[5,7]

We conducted this study to assess the role of bedside US (EFAST) performed by appropriately trained trauma physicians in the diagnosis of pneumothorax. EFAST was compared to CXR and chest CT scan.

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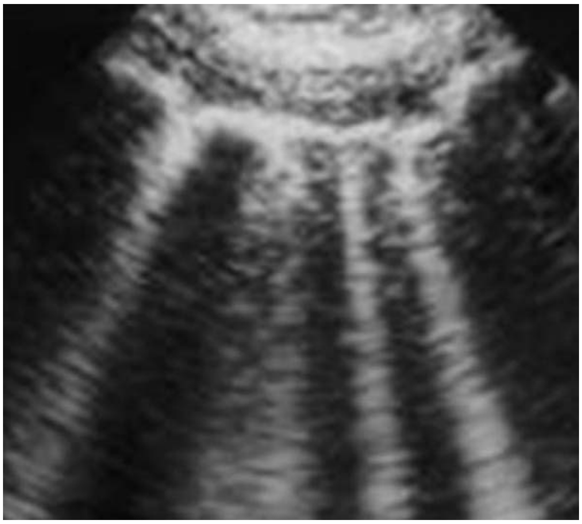

Fig. 1. Depicting comet-tail artefacts.

Table 1
Patient characteristics.

	Mean age	43.01 + 19.5
Sex	Male	152
	Female	52
Type of trauma		
Blunt trauma	Motor vehicle accident	85 (42%)
	Fall	38 (19%)
	Pedestrian struck	11 (5%)
	Assault	25 (12%)
Penetrating trauma	Gun shot wounds	15 (7%)
	Stab	30 (15%)
ISS		12.5 + 5.3
Time for investigation in minutes (median)	EFAST	0.95
	CXR	7
	CT scan	23

CXR – chest X-ray, EFAST – extended focused abdominal sonogram for trauma and ISSS – injury severity score.

Methods

This prospective study was performed at a community based level I trauma center between 06/2007 and 05/2008. The study was conducted in the trauma room by a FAST trained trauma team. We included the patients with polytrauma, blunt and penetrating trauma to the chest or thoraco-abdominal area. Extended FAST was performed in all patients who are undergoing FAST examination as a part of their secondary survey. CXR and CT scan are performed after initial primary and secondary survey. Patients who had chest tube placement without sonogram or CXR, patients with penetrating abdominal and extremity injuries were excluded from the study. Study variables include patient demographics (age and sex), mechanism of injury, clinical examination findings, CXR, EFAST, CT scan findings and placement of chest tube in patients with proven or suspected pneumothorax. The time needed to perform each investigation was also noted. CT scan is considered as gold standard for pneumothorax.

Senior resident (level V) or attending on the trauma team familiar with the principles of the FAST exam who had attended a formal ultrasound course performed the EFAST examination. These sonographers were instructed in the principles of thoracic ultrasound with hands-on demonstration of the normal ultrasound findings in models with normal lung anatomy (comet tail artefacts (Fig. 1) and pleural sliding sign). Finally, the majority of the residents viewed a prerecorded ultrasound examination of a patient with a pneumothorax that clearly demonstrated absent comet-tail artefacts and lack of pleural sliding sign.

Diagnosis of pneumothorax by lung ultrasonography

A portable ultrasound device is regularly available at any moment to perform the FAST exam in patients with multiple trauma. A 7.5 MHz linear probe is used. Patients were kept in a supine position and an examination of the anterior thorax was performed with the probe placed in the second intercostal space in the midclavicular line. Bilateral ultrasonographic images were obtained and compared. Pneumothorax was considered when the absence of both lung-sliding and comet-tail artefacts was noted.

Data were expressed as mean $\pm$ standard deviation and analysed by Statistical Software SPSS13.0 (SPSS Inc., Chicago, IL, USA). Sensitivity = true positive/(true positive + false negative); specificity = true negative/(true negative + false positive); positive predictive value = true positive/(true positive + false positive); negative predictive value = true negative/(true negative + false negative); false positive ratio = false positive/(true negative + false positive); false negative ratio = false negative/(true positive + false negative); diagnostic accuracy = (true positive + true negative)/(true positive + true negative + false positive + false negative). The diagnostic sensitivity, specificity, positive predictive value, negative predictive value and accuracy for US and CXR were calculated and then compared by Chi-square test or Fisher's exact test.

Results

Of the total 204 patients studied 152 were male and 52 were female. The mean age of our study population was 43.01 $\pm$ 19.5 years. Twenty one (10.3%) patients were diagnosed with pneumothorax. Of 21 patients who had pneumothorax 12 were due to blunt trauma and 9 were due to penetrating trauma (Table 1).

Of the 204 patients assessed, clinical examination was suggestive of pneumothorax in 17 patients (13 were true positive, 4 were false positive and 8 were false negative), CXR was positive in 16 (15 true positive, 4 missed, 1 false positive and in 2 patients chest tube was placed before CXR) patients and EFAST was positive in 21 (20 were true positive, 1 false positive and 1 false negative) patients. CT scan was performed in 181 patients and showed pneumothorax in 12 patients (9 patients chest tube was placed before CT scan, 11 cases sonogram was also positive for pneumothorax).

Table 2
Statistics in whole study population.

	Pneumothorax (n = 21/204)	TP/FP/FN	Sensitivity	Specificity	PPV	NPV	DA
Clinical examination	17	13/4/8	62	98	76	95	94
CXR	16	15/1/4	79	99	94	98	97
EFAST	21	20/1/1	95	99	95	99	99

CXR – chest X-ray, EFAST – extended focused abdominal sonogram for trauma, TP – true positive, FP – false positive, FN – false negative, PPV – positive predictive value, NPV – negative predictive value and DA – diagnostic accuracy.

Table 3
Statistics in blunt trauma.

	Pneumothorax ($n = 12/159$)	TP/FP/FN	Sensitivity	Specificity	PPV	NPV	DA
Clinical examination	11	7/4/5	58	97	63	97	94
CXR	11	10/1/2	83	99	90	99	98
EFAST	13	12/1/0	100	99	92	100	99

CXR – chest X-ray, EFAST – extended focused abdominal sonogram for trauma, TP – true positive, FP – false positive, FN – false negative, PPV – positive predictive value, NPV – negative predictive value and DA – diagnostic accuracy.

Table 4
Statistics in penetrating trauma.

	Pneumothorax ($n = 9/45$)	TP/FP/FN	Sensitivity	Specificity	PPV	NPV	DA
Clinical examination	6	6/0/3	66	100	100	92	93
CXR	5	5/0/2	71	100	100	94	95
EFAST	8	8/0/1	89	100	100	97	98

CXR – chest X-ray, EFAST – extended focused abdominal sonogram for trauma, TP – true positive, FP – false positive, FN – false negative, PPV – positive predictive value, NPV – negative predictive value and DA – diagnostic accuracy.

Of total 21 patients with pneumothorax 19 underwent chest tube placement and in 2 patients pneumothorax was minimal and observed. Clinical examination was positive in 62% (13/21), CXR in 79% (15/19; in 2 CXR was not performed) and EFAST in 95.2% (20/21) cases. The diagnostic sensitivity, specificity, PPV and NPV were analysed in whole study population (Table 2). The study population were further divided into blunt ($n = 159$) and penetrating trauma ($n = 45$). The sensitivity, specificity, PPV and NPV were performed in blunt (Table 3) and penetrating (Table 4) trauma patients.

In our study of 21 pneumothorax, 4 were considered as occult pneumothorax (not recognised either clinical examination or CXR). Of the 4 pneumothoraces, 3 were diagnosed with EFAST and 1 was missed.

Discussion

In the past decade, focused abdominal sonogram in trauma has been part of the secondary survey in patients with blunt abdominal trauma.[4,6,11,12,15] Its role has been indispensable in early identification of intraabdominal pathology to facilitate appropriate and timely intervention.[9] However, most injuries in the polytrauma patient are multi-system involving more than one anatomic region. The chest is the other site commonly injured along with the abdomen in these patients. Pneumothorax has been one of the common causes of mortality in these patients with polytrauma.

Ultrasonagraphy of the chest is increasingly used in the initial ATLS assessment for exclusion of pneumothorax. The use of the sonogram in the evaluation of pneumothorax was first reported in 1986 in a veterinary journal. Later it was used in patients after lung biopsy. Dulchavsky et al.[3] initially evaluated the role of sonogram in trauma in 2001. The study included 382 trauma patients (281 blunt trauma, 22 gunshot wounds, 61 stab wounds, 18 spontaneous) over a period of 9 months. They were able to diagnose 37 of 39 pneumothoraces with ultrasound, with a sensitivity of 94%. The two false-negative studies were the result of significant subcutaneous emphysema leading to inadequate assessment. There were 343 true-negative examinations, with no false-positive studies. Their pioneering work opened a new area in the evaluation of pneumothorax especially in trauma patients. Similarly, Knudtson et al.[7] in 2004 reported that sonogram is reliable test in the diagnosis of pneumothorax with 99.7% specificity. They also reported that sonogram is an important adjuant role to clinical investigation in penetrating trauma. In our study also sonogram shown to have higher sensitivity and specificity compared to the clinical examination and chest X-ray.

However, both studies mentioned (Dulchavsky et al.[3] and Knudtson et al.[7]) above used CXR alone as the gold standard compare EFAST. CXR has been reported to miss the diagnosis in up to 30–40% of the cases.[1] These occult pneumothoraces are reported to progress to tension pneumothorax especially in multiple trauma patients who are on positive pressure ventilation. CT scan has been more commonly used to exclude pneumothorax and has been the investigation of choice in stable patients. Sonogram has been reported to have sensitivity comparable to CT scan. Kirkpatrick et al.[6] comparing EFAST directly to CXR, considering CT scan as gold standard reported that sonogram had higher sensitivity over CXR (48.8% versus 20.9%). Both exams had a very high specificity (99.6% and 98.7%). They also reported EFAST is sensitive in the diagnosis of occult pneumothorax. Recently, study reported by Soldati et al.[13] showed that only 13 of 25 PTXs (52%) were revealed by CXR (sensitivity, 52%; specificity, 100%), while 23 of 25 PTXs (92%) were identified by sonogram with one false-positive result (sensitivity, 92%; specificity, 99.4%). They also reported that sonogram has high sensitivity in diagnosis of occult pneumothorax. Similarly, in our study the sonogram and CT scan results were similar in 95% of the occasions. Sonogram missed pneumothorax in only one case. CXR and sonogram both were false positive in one case with large bullous disease of the lung. Sonogram was false negative in a patient with very small pneumothorax that was later found on CT scan. This patient was observed without placement of chest tube.

The ultrasonographic examination of the thorax in the trauma patient has the advantage of easy portability, immediate availability and it is non-invasive with a high sensitivity. It is less time consuming compared to the CXR and CT scan does not include ionising radiation and is an excellent adjunct to the clinical examination. In a recent study by Zhang et al.[16] reported that the time required to perform sonogram (2.3 ± 2.9 min) was significantly lower compared to the CXR (12.4 ± 6.7 min) and CT scan (16.3 ± 7.8 min). If time interval needed for transporting to CT scan and to obtain official reading also taken into consideration this time will be much longer. The median time required to perform sonogram in our study was 0.95 min (57 s) compared to the CXR (7 min) and CT scan (23 min). Our study reinforces the need to perform ultrasonography in the trauma bay since it is fast and may be quickly performed. It can avoid the delay in the management of pneumothorax which may be life threatening in patients with polytrauma.

Air in the pleural space has shown to collect in the apical paracardiac regions. Sonogram has been shown superior to CXR in the diagnosis of pneumothorax in supine trauma patients as these specific sites are well visualised. Performing single view sonogram has been criticised by certain authors due to reported false-negative examinations. However, certain studies showed that single view itself is sufficient with 91% sensitivity.[8] In our series also single view sonogram sensitivity was 95%. Our results support that single view sonogram is rapid and easy to perform, sufficient in the diagnosis of pneumothorax. Performing multiple views is time consuming in the trauma room and not reported to increase the sensitivity significantly in the literature.

In minority of studies size measurement of a pneumothorax used as a guide for treatment. We feel that the evolution of a pneumothorax is a dynamic process. Small pneumothoraces reported to increase in size and lead to respiratory distress. In our study CT scan was used to diagnose pneumothorax in 12 patients; only 10 patients underwent chest tube placement and 2 patients were observed. CXR and USG are also used in these patients but none these patients underwent immediate chest tube placement as these considered as small pneumothoraces. But all these patients later underwent chest tube placement when CT scan demonstrated larger pneumothoraces. These findings indicate that the size measurement with initial CXR does not correlate with CT scan findings.

Conclusion

Surgeon performed trauma room extended FAST is simple and has higher sensitivity compared to the chest X-ray and clinical examination in detecting pneumothorax. EFAST has a promising role in the management of polytrauma patients and may be included in the ATLS protocol.

Conflict of interest

There is no conflict of interest.

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