INTRODUCTION

Road traffic accidents (RTA) remain the most common cause of injuries accounting for 57 - 70% of chest trauma patient. Between 20 - 46% of deaths in poly-traumatic patients are due to chest injury.1,2

Pneumothorax is a common complication of blunt chest trauma.3 Rate of occurrence of tension pneumothorax is 10% while traumatic pneumothorax, iatrogenic pneumothorax and delayed pneumothorax occur in 33.6%, 18.1% and 12% traumatic population, respectively.3

Prompt and accurate diagnosis of a pneumothorax is essential in the management of a critical patient from progression into life-threatening situation.4 Trauma patients have benefited tremendously from rapid ultrasound-guided evaluation at the bedside as part of the initial examination, which is known as the focused assessment with sonography for trauma (FAST).5,8

Ultrasoundographic features used in the diagnosis of pneumothorax include absence of lung sliding, absence of comet-tail artifact, pleural lines and presence of lung point.2,5

Several prospective studies of traumatic patients have found ultrasound to be significantly more sensitive than supine chest radiographs for diagnosing pneumothorax,5,9-14 keeping CT scan as gold standard having 94% sensitivity and 100% specificity with negative predictive value of 93.4.5,6,15

The chest radiograph (CXR) is one of the initial imaging tests for all traumatic pneumothorax.16 It is inexpensive, non-invasive, easy to obtain. However, it may not always be feasible in critically ill patients.4,17 The sensitivity and specificity of chest X-ray in detection of pneumothorax was found to be 31.8% and 100%, respectively with negative predictive value of 79.2%.6

Computed tomography, the gold standard for the detection of pneumothorax, requires patients to be transported out of the clinical area, that effects their hemodynamic stability, delaying the diagnosis and effects prognosis and entails higher costs.5,8

The rationale of this study is to establish accuracy of bedside ultrasound and X-rays for traumatic pneumothorax. If it is reasonably significant then this imaging modality can be applied for trauma patients due to it’s being a rapid, portable, inexpensive, ionizing radiation-free at the bedside. Although the focused assessment with sonography in trauma (FAST) examination has been used for many years, the addition of pneumothorax evaluation to this imaging protocol to create the extended FAST (e-FAST) examination is a relatively new technique in traumatic patients.
The objective of this study was to compare the diagnostic accuracy of bedside ultrasound and supine chest radiography for the diagnosis of traumatic pneumothorax.

**METHODOLOGY**

This descriptive analytical study was carried out at the Department of Radiology, Pakistan Institute of Medical Sciences (PIMS), Islamabad and Pakistan Atomic Energy Commission General Hospital, Islamabad, from November 2014 to August 2015. The sample size was calculated by using WHO sample size calculator taking sensitivity 94%, specificity 100%, prevalence (pneumothorax) 33.6%, precision level of 10%, and 95% confidence level.

TOSHIBA ultrasound machine equipped with high frequency (5 - 10 MHz) linear probe was used, while performing the FAST. All traumatic (RTA assaults) patients with clinical suspicion of pneumothorax were included. Very unstable trauma patients who required emergency surgery, non-trauma patients, and pregnant women were excluded from this study. Identity and demographic profile were asked from each patient's attendant.

Patients were scanned in the supine position by B mode ultrasound machine, using the high-frequency linear probe (5 - 10 MHz) placed perpendicular to two ribs spaces in the anterior chest region in the midclavicular line in 2nd - 3rd intercostal spaces. The ribs were identified; these appeared hyperechoic, and their acoustic shadows appeared as hypoechoic rays, acted as fixed anatomical landmarks. This defined interspace just deep to the intercostal muscles and soft tissue, is the location of the pleural line as an echogenic line found at the inferior border of the space between two ribs. Pneumothorax was diagnosed by identifying sonological signs (Figures 1 - 4).

All included patients were subsequently scanned using X-rays and plain CT chest imaging modality and all results were interpreted by single consultant radiologist who was kept unknown of ultrasound results.

**Figure 1:** Absent of lung sliding in pneumothorax as a motionless parietal tissue over pleural line and seen a homogenous granular pattern below it (right image).

**Figure 2:** Comet-tail artifact (white bold arrow) are hyperechoic reverberation artifacts arising from the pleural line, lack of this sign is indicative of pneumothorax (black arrow).

**Figure 3:** ‘Lung point sign’ depicting the lung point. Sliding lung touching the chest wall (Left). The ‘seashore sign’ (white arrow) and the ‘stratosphere sign’ (dotted arrow) seen as the lung intermittently.

**Figure 4:** A patient with pneumothorax missed by chest X-rays and correctly diagnosed by CT scan and ultrasonography.
Validation parameters for USG and supine X-ray taking CT scan as gold standard.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Ultrasound</th>
<th>Supine X-rays</th>
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</thead>
<tbody>
<tr>
<td>Sensitivity</td>
<td>83.33%</td>
<td>54.76%</td>
</tr>
<tr>
<td>Specificity</td>
<td>100%</td>
<td>100%</td>
</tr>
<tr>
<td>Positive predictive value</td>
<td>100%</td>
<td>100%</td>
</tr>
<tr>
<td>Negative predictive value</td>
<td>36.36%</td>
<td>17.39%</td>
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<tr>
<td>Diagnostic accuracy</td>
<td>84.78%</td>
<td>58.69%</td>
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Statistical analysis was performed using SPSS version 17. Mean with standard deviation was calculated for quantitative variables. Frequency and percentages were calculated for qualitative variables. A 2 x 2 cross table was constructed to calculate sensitivity, specificity, PPV, NPV, and diagnostic accuracy of both imaging modalities.

RESULTS

A total of 46 patients (both genders, males and females) were included in this study. Thirty of whom were males (65.20%) with mean age of 25.13 ±9.619 and 16 were females (34.8%) with mean age of 31.81 ±11.64 years. All were traumatic patients referred to emergency department. All patients were with historical features (e.g., pleuritic pain, dyspnea) or examination findings (e.g., rib fracture) that place them at high risk for pneumothorax.

Thirty-five out of 46 (76.10%, n=46) above mentioned patients were positive on ultrasound for pneumothorax. In 27 out of 35 ultrasound demonstrates the loss of 'comet-tail artifacts' and absence of lung sliding sign (77.14%, n=35), and 31 out of 35 patients (88.47%, n=35) showed a pleural line and lung point sign on ultrasound. Two patients, where this sign was missing, were found to have total lung collapse. Sensitivity, specificity and diagnostic accuracy of ultrasound, keeping plain CT chest as the gold standard in detecting traumatic pneumothorax, were found to be 83.33%, 100% and 84.78%, respectively.

These traumatic patients then undergone supine chest X-rays. Twenty-three out of 46 (50% n=46) were found positive for pneumothorax. Thus sensitivity, specificity and diagnostic accuracy of supine chest X-rays, keeping plain CT chest as the gold standard, were found to be 54.76%, 100% and 58.69%, respectively for traumatic pneumothorax.

All these patients were subsequently correlated on plain CT chest for final confirmation. Forty-two out of 46 (91.30% n=46) were positive for pneumothorax on CT; the remaining 4 were found as false positive.

These results showed that the FAST examination had a sensitivity of 83.33% and a specificity of 100% when compared to the gold standard (plain CT chest). The FAST was also compared to CXR, using CT scan as the gold standard, showing that ultrasound had a higher sensitivity than CXR, 83.33% and 54.76%, respectively, and a similar specificity of 100% and 100%, respectively (Table I). In addition, we noted that 8.7% (n=4) of all traumatic patients with clinically suspicion and trauma history do not had pneumothorax that was finally diagnosed later on a CT scan.

DISCUSSION

The term pneumothorax was first coined by a French physician Itard, in 1803.19 Traumatic pneumothorax, the most common life-threatening outcome in blunt chest trauma, occurs in over 20% of patients with blunt injuries and about 40% with penetrating chest injuries.

The first reported use of ultrasound to detect pneumothorax in humans was by Wernecke et al., in 1987.20 In 2009, various studies found the overall sensitivity of transthoracic ultrasonography for the diagnosis of pneumothorax ranged from 58.9% to 100%, and the specificity ranged from 94% to 100%.21 The sensitivity of ultrasound in certain studies has been similar to that found in CT scan, which is still considered to be the gold standard for the detection of a pneumothorax.11,12

Several other studies highlighted the utility of ultrasound compared to CXR for the diagnosis of pneumothorax, with sensitivity and specificity was found to be 81.8% and 100%, respectively.5,11 For chest X-ray it came to be 31.8% and 100% respectively.6

With the use of ultrasound, 35 out of 46 pneumothoraces were detected keeping one of the reference sign of previous studies (absence of lung sliding, absence of comet-tail artifact, and presence of pleural line and of lung point).2 Of the 7 missed cases, 4 patients were present with severe dyspnea that caused interference in above mentioned ultrasound results, producing false positive results, and remaining the traumatic patients with clinical suspicion were not true positive.

Nineteen out of 42, i.e. (45.23%) of all traumatic pneumothoraces, were missed by the standard supine AP chest film. Similarly, a prospective study by Ball et al., noted that up to 76% of all traumatic pneumothoraces were missed by the standard supine AP chest film when interpreted by the trauma team.22 With the use of CT scanning, 42 pneumothoraces were detected among the 46 lung field's studies; these 4 false positive on clinical suspicion were found truly false negative on CT scan.

The diagnostic performance of ultrasound in this study was found to have a sensitivity of 83.33% and a specificity of 100% with diagnostic accuracy of 87.78%. Although ultrasonography may not be as diagnostically accurate as CT scanning, CT is limited in unstable patients, and this limitation can result in delayed diagnosis and treatment.
The current study was one of the very few attempts to validate e-FAST done in the local setting and at national level. The authors succeeded in enrolling a group of trauma population with suspected pneumothorax. We believe that keeping in mind the financial constraints, less health facilities and services in the developing countries like Pakistan, high resolution ultrasound has an important role and may continue as the first choice for the assessment of these patients.

The main limitation of this study is that the use of this ultrasound was in severely critical intubated patients, which could alter the diagnosis taken so care should be done while interpreting results in these circumstances. Moreover, in these special circumstances, patients should undergo definitive imaging with thoracic CT scanning, when stable.

CONCLUSION
Bedside ultrasound sonography as an e-FAST procedure is an accurate examination for diagnosing pneumothorax in trauma patients in emergency.

REFERENCES