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# Comparative study between bedside chest ultrasound and chest CT scan in the diagnosis of traumatic pneumothorax

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## Abstract

**Background:** Traumatic pneumothorax (PTx) is common in chest trauma. Its incidence ranges between 10 and 28%. Chest X-ray (CXR) is the traditional imaging for the potential traumatic PTx, while CT chest is considered the gold standard diagnostic tool. However, it requires that the patient to be transferred from the Emergency Department (ED) with its resuscitative facilities. Chest US (E-FAST) has emerged as a sensitive tool that can be used on bedside basis with much higher sensitivity than CXR. The objective of this study was to compare between accuracy and usefulness of the bedside US chest and CT chest in the diagnosis of traumatic PTx, as well as its ability to quantify its size. This was a prospective clinical study that included two hundred patients who have been admitted to the ED. The inclusion criteria included any patient with chest trauma. Exclusion criteria included patients with clinical surgical emphysema, patients with life threatening PTx, and patients who did not undergo CT chest.

**Results:** Forty-seven hemithoraces were proved positive for PTx by CT chest, while forty-five hemithoraces out of those 47 were confirmed by bedside chest US. The sensitivity for chest US is 95.74% in detection of traumatic PTx. No false-positive cases were diagnosed. All of the forty-five hemithoraces diagnosed by chest US have been confirmed by CT scan making a specificity of 100%.

**Conclusions:** Chest US is a useful rapid diagnostic tool in the diagnosis and quantification of the traumatic PTx at ED. It avoids the delay in transportation of the critically ill patients to perform CT chest.

**Keywords:** Traumatic pneumothorax, Chest US, CT chest, Chest trauma, E-FAST

## Background

Trauma is the neglected disease of the modern societies. Accidents were classified as the fourth most common cause of death in all age groups [1]. Chest trauma constitutes a considerable percentage of traumas globally. It accounts approximately for 10% of trauma admissions [2]. The variation in the types and severity degrees of chest trauma leads to encountering different injury lesions and consequently different outcomes that are reflected on the associated mortality rate [3].

In the trimodal distribution of trauma deaths (immediate, hours, and weeks following injury), chest injuries are responsible for the majority of deaths occurring at the scene of trauma (immediate deaths) and many of those occurring within few hours (early deaths). Early deaths are usually due to airway obstruction, tension pneumothorax (t-PTx), hemorrhage, or cardiac tamponade [4, 5].

PTx represents a common pathology in chest trauma, either blunt or penetrating. Its incidence is 10-28% or even higher. Occult PTx is a condition where the PTx cannot be detected on chest X-ray (CXR) but on CT chest. It is a concern, especially in patients who will

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receive positive pressure ventilation (PPV). Hence, its early detection is crucial [6].

Diagnosis of traumatic PTx needs a focused primary and secondary surveys coupled with radiological investigations. Evidence of labored breathing and hemodynamic compromise suggests a possible t-PTx that necessitates emergency decompression. Treatment should not be delayed if symptomatic PTx is suspected.

CXR is the traditional imaging for the potential traumatic PTx. However, due to the limitations like spinal immobilization in such patients; this examination often consists of antero-posterior (AP) supine films, in which radiographic features of PTx may be quite subtle. CT chest is considered the gold standard diagnostic tool for PTx. However, it requires transferring the patient from Emergency Department (ED) and its resuscitative facilities [5].

The use of the chest ultrasound (chest US) in the diagnosis of trauma patients is a well-established modality that has existed many years ago. The Focused Assessment with Sonography in Trauma (FAST) examination has now been modified to include lung imaging as part of the evaluation in trauma patients (E-FAST) [5].

In case of PTx, the contained air will rise to the least dependent area within the chest. In a supine trauma patient, this area corresponds to the anterior region of the chest approximately between the second and the fourth intercostal spaces at the mid-clavicular line in patients with mild PTx and it extends more posterolateral as the size of PTx increases as the lung tends to collapse in a quite predictable pattern after fresh PTx if no intervention, like aspiration or insertion of intercostals drain, has not been performed.

Scanning the chest using US focuses on finding one or more of sonographic signs which confirms or excludes PTx, such as lung sliding, lung pulse, comet tails, A-lines, and lung point of which lung sliding sign along with lung point sign are the main signs to be investigated to diagnose or exclude PTx. Lung sliding sign is 100% specific for PTx [6].

Absence of lung sliding and the presence of lung point sign in an adequately ventilated patient, either spontaneously or mechanically (after exclusion of right main bronchus intubation), confirms the presence of PTx. The aim of this study is to compare between the accuracy and the usefulness of the bedside chest US and CT chest in the diagnosis and quantification of traumatic PTx.

## Methods

This is a prospective clinical study approved by the Research Ethical Committee of the Faculty of Medicine (00007555). It included two hundred patients who have been admitted to the Emergency Department. The

inclusion criteria included any patient with either blunt or penetrating chest trauma regardless age or gender. Exclusion criteria included patients who presented with clinically detected surgical emphysema, patients who presented with a life threatening PTx, patients who have been already managed with insertion of intercostal drain, and patients who did not either undergo CT chest for not being stable for transportation or did not meet the American College of Radiology appropriateness criteria (ACR APPROPRIATENESS CRITERIA) [7].

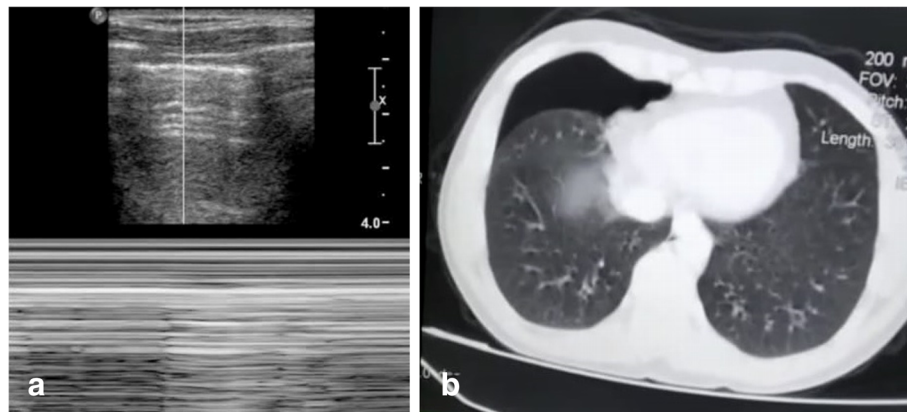
The included patients have been examined according to the primary survey described by the ATLS course [8], and they have been resuscitated as needed. The bedside chest US (E-FAST) was designed to be performed in such patients by senior emergency physicians who had more than 4-year experience in E-FAST Scan.

The chest was scanned, using the superficial probe 7.5 MHz type L7M-A of CHISON device model ECO 2, at four views for each hemithorax as the protocol used by Blaivas et al. [9]. The views included the anterior second intercostal space at the mid-clavicular line (view 1), the fourth intercostal space at the anterior axillary line (view 2), the sixth intercostal space at the mid-axillary line (view 3), and the sixth intercostal space at the posterior axillary line (view 4), to assess for the presence of a sliding lung sign. If the sliding lung sign was abolished in one or more of these views, a more posterior scan was performed to locate the lung point sign if present.

The presence or absence of the lung sliding or lung point sign classified the patient being either negative or positive for PTx. If positive, the absence of the sliding lung sign in view 1 and 2 will quantify PTx as mild one, the absence of it up to view 3 classified it as moderate PTx and its absence at the four views was translated as massive PTx. Then, patient was transferred to the surgical emergency unit where resuscitation was continued as required. The patients then were investigated with CT chest which was analyzed and reported by senior radiologist (Fig. 1). In addition, the degree of PTx has been calculated in CT chest using the method used by Collins et al. [10]. The results of the chest US and CT chest have been documented and compared to calculate the accuracy of chest US in detection of traumatic PTx against the CT chest, the gold standard modality.

## Statistical analysis

Quantitative data with normal distribution will be expressed as mean  $\pm$  SD. Categorical data will be expressed as frequency and percentages. The Spearman rank correlation coefficient will be used as a concordance measure between chest US and CT chest findings as a quantitative tool.



**Fig. 1** Radiological imaging for the same trauma patient diagnosed with moderate pneumothorax on the right side: (a) E-FAST image shows the sea shore sign (lung sliding sign) at the view 4 on the right hemithorax; (b) CT chest (pulmonary window), moderate right-sided pneumothorax

**Results**

Two hundred patients with inclusion criteria have been included in this study between November 2015 and September 2016. Around 80% of them were males. Meanwhile, up to 60% of the patients were around 30 years of age; median age is 27 years old. Demographic data of the included patients is demonstrated in Table 1.

Different types of trauma have been reported (Table 2). Sixty-seven percent of patients had motor vehicle collision (MVC), while falling from height (FFH) represented around 19%. Eighty-six patients out of the two hundred were intubated to support airway and/or breathing; and one of them underwent surgical airway in the form of cricothyrotomy followed by tracheostomy.

To simplify the statistics, we considered each hemithorax as a separate unit, hence; this study included four hundred hemithoraces for the included two hundred patients. Each hemithorax was considered as one unit.

The bedside chest US (E-FAST) was performed first; it verified PTx in 45 hemithoraces out of 47 cases that

were proved by CT chest. Nineteen cases out of 45 that have been diagnosed by chest US have received positive pressure ventilation (PPV). This result demonstrates a sensitivity of 95.74% for chest US in detection of PTx. No false positive results were recorded. All of the forty-five hemithoraces diagnosed by chest US have been confirmed by CT scan resulted in a specificity of 100% (Table 3). As a tool to quantify the size of traumatic PTx, chest US overestimated the size of PTx in one hemithorax which is demonstrated in Table 4.

**Discussion**

Tension PTx and open PTx are immediate life-threatening conditions that can be diagnosed clinically during the primary survey in traumatized patients. However, diagnosis or detection of smaller PTx may be clinically challenging and may require more investigations, e.g., CXR, chest US, and CT chest. Early detection of non-life-threatening PTx is important to avoid its progression into tension PTx especially in patients receiving PPV.

At the Main University Hospital of our institution, E-FAST protocol, including chest US, was adopted as a routine procedure to be performed for every trauma patient as an adjunct to the primary survey. Hence, it was

**Table 1** The demographic data of the patients included in the study

	No.	%
<b>Gender</b>		
Male	161	80.5
Female	39	19.5
<b>Age (years)</b>		
≤ 30	121	60.5
> 30	79	39.5
Min.-max.	2.0-74.0	
Mean ± SD.	29.05 ± 16.97	
Median	27.0	

**Table 2** Percentages of different types of chest trauma

Mode of trauma	No.	%
<b>MVC</b>	143	67.0
<b>FFH</b>	38	19.0
<b>Stab</b>	12	6.0
<b>FDS</b>	6	3.0
<b>Local trauma</b>	6	3.0
<b>Gunshot</b>	4	2.0

FFH falling from height, MVC motor vehicle collision, FDS falling downstairs

**Table 3** Results of chest US in comparison to the CT chest of the chest in detect traumatic pneumothorax

		CT hemithorax		Sensitivity	Specificity	PPV	NPV	Accuracy
		Free	Positive					
US	(Total n = 400)	(n = 353)	(n = 47)					
	Free	353	2	95.74	100.0	100.0	99.44	99.50
	Positive	0	45					

PPV positive predictive value, NPV negative predictive value

decided to study the diagnostic accuracy of bedside chest US in the diagnosis of traumatic PTx and in quantification of its size in comparison with the CT chest.

This study is a prospective clinical study which included a large number of patients, two hundred patients, in comparison to the other published research that studied the ability of chest US to diagnose PTx in clinical ED settings [9, 11–15]. Blaivas et al. [9] conducted a prospective study that included 176 adult patients with blunt trauma. In that study, chest US examination was performed by ER physician using a lower technology through using 2.4 MHz micro-convex probe because they consider that it is practical to scan both thoracic and abdominal cavities using the same probe and compensate it by adding the power Doppler function while scanning the chest to enhance the ability in detection of the lung sliding sign. Out of the fifty-three CT chest confirmed PTx, 52 cases have been detected by chest US. They have only one false negative case (sensitivity = 98.1%). They have also one false positive case (specificity = 99.2%). They explained their results by the presence of a large lung contusion detected on the CT chest, which is a questionable explanation because lung contusions make the exclusion of PTx easier.

Regarding the ability of chest US to estimate the size of PTx, in comparison with the CT chest, they use Spearman’s rank correlation that was 0.82% suggesting a good correlation but in 12 of the patients included; they consider PTx large in size in CT chest group, were based on a rush of air during intercostals drain insertion which is an exclusion criterion in our study as any intervention

was postponed until CT chest was performed to allow for correct comparison between the results of the chest US and CT chest.

Jalli et al. [12] prospectively compared 197 patients indicated for CT chest for various clinical settings. This comparison was conducted by an experienced radiologist using a high frequency linear array probe 7.5 MHz of Logic 7, GE, USA device. However, the sensitivity was lower than the previous study representing 79% for non-loculated PTx, 84% for loculated PTx with an overall sensitivity of 80% and a specificity of 89%.

Ianniello et al. [13] conducted a retrospective study that included 368 unstable patients with blunt trauma who were evaluated by radiologist using Esaute Mylab 75, Italy, 7.5 MHz. They demonstrated a sensitivity of 77% and specificity of 99.8%.

In this study, two parameters were investigated by chest US in the diagnosis of traumatic PTx. The first one is the diagnostic accuracy of the bedside chest US in the diagnosis of traumatic PTx and the second is the ability of chest US to quantify the size of PTx.

Chest US detected PTx in 45 hemithoraces while CT chest confirmed PTx in 47 hemithoraces. In our opinion, those two missed cases by the chest US were unavoidable because one patient had trivial PTx that was located behind the sternum (invisible to US) and the other patient had an apical trivial PTx that was located beyond the areas scanned by our protocol mentioned previously. This resulted in a sensitivity of 95.74% which was slightly lesser than that documented by Blaivas et al. [9] and slightly higher than that documented by Jalli et al. [12] and Ianniello et al. [13]. Meanwhile, there were no false positive cases; hence, the resulting specificity was 100% and this was the highest recorded specificity in comparison to the other published studies where the specificity ranged from 89 to 99.8% [9, 12, 13].

As a quantitative tool, the size of PTx on chest US and CT chest have been compared using Spearman correlation coefficient which was 0.987 reflecting a very good correlation (Table 4). PTx was over-estimated by chest US in one hemithorax from mild to moderate degree. This might be attributed to the long time passed between chest US examination and CT chest evaluation due to technical problems at radiology room. This by itself could change the pattern of lung collapse through

**Table 4** Quantification of the size of traumatic PTx by chest US and CT chest

Quantity of Pnx	Right	Left
<b>Chest US</b>	<b>No.</b>	<b>No.</b>
Minimal	5	14
Mild	13	6
Moderate	2	5
<b>CT chest</b>	<b>No.</b>	<b>No.</b>
Minimal	5	14
Mild	13	7
Moderate	2	4

inducing lung re-expansion and this could be a question for a further study.

### Limitations of the study

This study has some limitations that may include the inclusion of both blunt and penetrating thoracic injuries, and inclusion of all ages.

### Conclusions

In conclusion, chest US could be a useful rapid diagnostic tool not only in diagnosis but also in quantification of the traumatic PTx at ED. It avoids the delay in transportation of the critically ill patients to perform CT chest and minimize the inherited risk of intra-hospital transfer.

Only few situations could limit its use like untrained personnel, and the very minimal PTx that can be hidden below the bony structures like the sternum. However, these few limitations cannot actually diminish its real value in the rapidity and accuracy in the management of trauma patients.

### Abbreviations

PTx: Pneumothorax; CXR: Chest X-ray; ED: Emergency department; Chest US: Chest ultrasound; ATLS: Advanced trauma life support; ETC: Emergency Trauma Center; AP: Antero-posterior; E-FAST: Extended focused assessment with sonography in trauma; t-PTx: Tension pneumothorax; ACR: American College of Radiology; PPV: Positive pressure ventilation

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### Authors' contributions

All authors contributed to the study conception and design. Material preparation, data collection, and analysis were performed by M.A. and W.A. The first draft of the manuscript was written by M.A. and W.A. and all authors commented on previous versions of the manuscript. The authors read and approved the final manuscript.

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### Availability of data and materials

Available on request.

### Declarations

#### Ethics approval and consent to participate

Study was approved from the Research Ethical Committee of Faculty of Medicine of Alexandria (No. 00007555), and each participated patient signed a written consent to participate.

#### Consent for publication

Not applicable.

#### Competing interests

None declared.

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### References

- Xu J, Kochanek KD, Murphy SL, Tejada-Vera B (2010) National vital statistics reports. *Natl Vital Stat Rep* 58(19):1–36
- Kortbeek JB, Al Turki SA, Ali J, Antoine JA, Bouillon B, Brasel K et al (2008 Jun 1) Advanced trauma life support, the evidence for change. *J Trauma Acute Care Surg.* 64(6):1638–1650. <https://doi.org/10.1097/TA.0b013e3181744b03>
- Ekpe EE, Eyo C (2014) Determinants of mortality in chest trauma patients. *Niger J Surg.* 20(1):30–34. <https://doi.org/10.4103/1117-6806.127107>
- Calhoun JH, Trinkle JK (1997) Pathophysiology of chest trauma. *Chest Surg Clin N Am* 7(2):199–211
- Husain LF, Hagopian L, Wayman D, Baker WE, Carmody KA (2012) Sonographic diagnosis of pneumothorax. *J Emerg Trauma Shock.* 5(1):76–81. <https://doi.org/10.4103/0974-2700.93116>
- Rowan K, Kirkpatrick A, Liu D, Forkheim K, Mayo J, Nicolaou S (2002) Traumatic pneumothorax detection with thoracic US: correlation with chest radiography and CT-initial experience. *Radiology* 225(1):210–214. <https://doi.org/10.1148/radiol.2251011102>
- American College of Radiology Website. ACR appropriateness criteria: background and development. [www.acr.org/SecondaryMainMenuCategories/quality\\_safety/app\\_criteria/BackgroundandDevelopment.aspx](http://www.acr.org/SecondaryMainMenuCategories/quality_safety/app_criteria/BackgroundandDevelopment.aspx). Accessed 9 Mar 2008
- ATLS (2018) advanced trauma life support program for doctors. 10th ed. American College of Surgeons, Chicago
- Blaivas M, Lyon M, Duggal S (2005) A prospective comparison of supine chest radiography and bedside ultrasound for the diagnosis of traumatic pneumothorax. *Acad Emerg Med.* 12(9):844–849. <https://doi.org/10.1197/jaem.2005.05.005>
- Collins CD, Lopez A, Mathie A, Wood V, Jackson JE, Roddie ME (1995) Quantification of pneumothorax size on chest radiographs using interpleural distances: regression analysis based on volume measurements from helical CT. *AJR. American journal of roentgenology.* Nov 165(5):1127–1130
- Neff MA, Monk JS, Peters K, Nihilesh A (2000) Detection of occult pneumothoraces on abdominal computed tomographic scans in trauma patients. *J Trauma* 49(2):281–285. <https://doi.org/10.1097/00005373-200008000-00015>
- Jalli R, Sefidbakht S, Jafari SH (2013) Value of ultrasound in diagnosis of pneumothorax: a prospective study. *Emerg Radiol.* 20(2):131–134. <https://doi.org/10.1007/s10140-012-1091-7>
- Ianniello S, Di Giacomo V, Sessa B, Miele V (2014) First-line sonographic diagnosis of pneumothorax in major trauma: accuracy of e-FAST and comparison with multidetector computed tomography. *Radiol Med (Torino).* 119(9):674–680. <https://doi.org/10.1007/s11547-014-0384-1>
- Jahanshir A, Moghari SM, Ahmadi A, Moghadam PZ, Bahreini M. Value of point-of-care ultrasonography compared with computed tomography scan in detecting potential life-threatening conditions in blunt chest trauma patients. *J. Ultrasound.* 2020; 12(1):1-0.
- Undziakiewicz A, Sekula M, Smoluchowski K, Sokół D, Świerczyńska B, Pieciewicz-Szczęśna H (2020) The use of lung ultrasound in the diagnosis of pneumothorax in trauma patients. *J. Educ. Health Sport* 10(9):332–337. <https://doi.org/10.12775/JEHS.2020.10.09.037>

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