The Potential Benefit of Emergency Ultrasound Plus MDCT for The Diagnosis of Major Chest Trauma … A Diagnostic Test Accuracy Study

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ABSTRACT
Background: Multidetector computed tomography (MDCT) has established itself as the preferred imaging modality for the evaluation of polytrauma patients owning to its significantly better ability in detecting tissue but patients are exposed to great amount of radiation during MDCT examination. Ultrasound has the benefits of being reliable, dynamic, rapid, noninvasive technique and freed from radiation.
Objective: This study aims to ascertain the role of transthoracic ultrasound for imaging blunt chest trauma patients and compared its sensitivity, specificity and accuracy to those of MDCT as a gold standard modality.
Patients and methods: This study was carried on 57 patients, 54 males (94.7%) and 3 were females (5.3%) and ages ranged from 5 to 60 years. All patients were exposed to major blunt chest trauma with or without associated polytrauma.
Results: With MDCT as the gold standard, the most common injury detected by ultrasound (US) was pleural in 89.5% of patients with 96% accuracy, chest wall lesions were found in 80.7% of patients with 95% diagnostic accuracy, parenchymal lesions were found in 64.9% of patients with 91% diagnostic accuracy and mediastinal lesions were detected in 3.5% with 91% diagnostic accuracy. The sensitivity and specificity of ultrasonography varied for detecting the subsequent pathologies: rib fracture (89% and 100%) subcutaneous emphysema (87% and100 %), hemothorax (94% and 100%), pneumothorax (89% and 100%), hydropneumothorax (81% and 100%), pulmonary contusions (82% and 100%), lung collapse (93% and 100%), lung laceration (100% and 100%) and hemopericardium (100% and100%), respectively.
Conclusions: Chest US proved its value for diagnosis of blunt thoracic injuries with acceptable sensitivity and high specificity, particularly for pleural, pericardial and parenchymal lung injuries.
Keywords: Chest, Blunt trauma, Ultrasound, Multidetector Computed tomography.

BACKGROUND

Chest trauma is the third most common in trauma patients, after trauma to the head and extremities[(1)]. Chest trauma is assessed to blunt or penetrating, with trauma being the explanation for most thoracic injuries (90%). the most difference lies within the presence of a gap to the inner thorax in penetrating injury, created by stabbing or gunshot wounds, which is absent in blunt chest trauma[(2)]. Traditionally, air has been considered the enemy of ultrasound and therefore the lung has been considered an organ not amenable to ultrasonography examination. Chest X-ray (CXR) and computed tomography (CT) scan are the routine chest tests. However, CT chest exposure gives the patient an efficient dose of eight millisievert (mSv), akin to four hundred chests x-rays. Thus, repeated follow-up examinations don't seem to be advisable [(3)]. Ultrasound (US) has been proved to be valuable for the evaluation of a good sort of chest diseases, especially[(3)] when the pleural cavity is involved. The benefits of US are that it is a relatively inexpensive, widely available, mobile and free from radiation. Chest US can supplement other imaging modalities of the chest and guides a range of diagnostic and therapeutic procedures [(4)].

This study aims to establish the role of transthoracic ultrasound as a bed-side, available, and affordable technique for imaging chest trauma patients and compared its sensitivity, specificity and accuracy for detecting chest trauma sequelae and complications to those of MDCT.

PATIENTS AND METHODS

Ethical approval:

Approval of the local ethical committee of Menoufia University was obtained, also obtaining written consents from patients to participate within the study were done and in cases who were intubated and had severe injuries, written consents were obtained from first degree relatives.

This study was done in the Radiodiagnosis Department Menoufia University Hospitals, from February 2020 to December 2020. The study was carried out on 57 patients, 54 males (94.7%) and 3 females (5.3%). The patients were included according to the following criteria:

Inclusion criteria: Patients from both sexes, ages ranged from 5 to 60 years, all cases included had major blunt chest trauma with or without associated polytrauma.

Exclusion criteria: Penetrating chest traumas, patients didn't undergo MDCT, and pregnant patients with minor trauma.

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All patients were subjected to the subsequent:

(1) Thorough clinical examination: The medical history was taken, and general and chest examinations were performed.

(2) The ultrasonography examination time ranged between (2-3) minutes and was done using Philips XD 11(USA) with a linear transducer of 3-12MHZ and convex transducer of 2-5MHZ and a LOGIQ E10 (Japan) with a linear transducer of 6-15MHZ and convex transducer of 1-6MHZ. (A) Focused assessment with sonography in trauma (FAST) was performed on all patients with multiple traumas or accompanying abdominal trauma, to look at the abdomen for any collection and organ injury. (B) Extended focused assessment with sonography in trauma (e-FAST) [Transthoracic ultrasound].

Chest ultrasound technique:

Patients position: supine (23 patients) in critically ill patients with the head of the bed elevated slightly and sitting (34 patients) in patients who couldn‘t sleep in supine position because of pain. A convex probe was placed subcostally from the right for transhepatic examination with slight tilting in cranial direction, revealed the liver, hepatic veins, diaphragm, and reflection of the liver above the diaphragm, and the identical technique on the left subcostal aspect revealed the spleen, diaphragm and reflection of the spleen above the diaphragm. Moving the probe upwards allowed screening of the pleural recesses for effusion. A linear probe was placed parallel to the ribs within the intercostal space revealed the intercostal muscles, pleura and underlying lung parenchyma. This was done in both lung apices to exclude pneumothorax by observation of pleural sliding and B-lines, additionally to use of M-mode for detection of stratosphere sign, which is a straight horizontal lines above and beneath the pleural line in M-mode, indicates absence of pleural line movement denoting pneumothorax.

- If the patient is alert and has a localized chest pain complaint, a focused chest ultrasound was done at the location of pain.

(3) Multidetector Computed tomography (MDCT) of the chest without contrast was done as the gold standard for comparison with US.

MDCT was performed within the Emergency Radiology Unit by Toshiba Alexion a 16-multi-slice, (Japan) with the subsequent parameters: helical acquisition, 120 kV, 25 mA, helical thickness 1.25 mm, 1 mm interval and FOV 351 down from the level of the renal arteries up to root of the neck during a breath hold with a complete exposure time of 0.8 s. The mediastinal window and lung window axial images were obtained with coronal and sagittal reconstruction.

Statistical analysis

Data were analyzed using IBM© SPSS© version 23 (IBM© Corp., Armonk, NY, USA) and XLSTAT© Version 2016.02.28451 (Addinsoft©, Paris, France). Categorical variables are presented as counts and percentages. Diagnostic accuracy of US was calculated for each radiological abnormality using MDCT as the gold-standard for diagnosis. The subsequent diagnostic indices were calculated: sensitivity, specificity, positive and negative predictive values, positive and negative likelihood ratios and correct classification (accuracy) and misclassification rates. Inter-method agreement was examined using Cohen’s kappa coefficient (κ), Scott’s bias-adjusted kappa coefficient (BAK) and Bennett’s prevalence- and bias-adjusted kappa coefficient (PABAK).

RESULTS

Out of the 57 patients, 54 males (94.7%) and 3 females (5.3%) with age ranging from 5-60 years. 61.4% of the patients were within the age group 11-30 years. The most common mechanism for chest trauma was as a result of road traffic accidents 68.4% (n = 39 patients). The characteristics of patients and injury are shown in table 1.

Table (1): Characteristics of patients and injury

Variable		Count	%
Age (years)	0 - <10 years	7	12.3%
	10 - <20 years	19	33.3%
	20 - <30 years	16	28.1%
	30 - <40 years	6	10.5%
	40 - <50 years	4	7.0%
	50 - ≤60 years	5	8.8%
Sex	F	3	5.3%
	M	54	94.7%
Mechanism of injury	Motorcycle accident	20	35.1%
	Motor vehicle accident	19	33.3%
	Fall from height	17	29.8%
	Train accident	1	1.8%
Injured side	Left	21	36.8%
	Right	25	43.9%
	Bilateral	11	19.3%
Symptoms	Chest pain	57	100.0%
	Dyspnea	51	89.5%
	Local tenderness	57	100.0%
	Hemoptysis	22	38.6%
Intervention	Nil	18	31.6%
	Chest tube insertion	37	64.9%
	Endotracheal intubation	2	3.5%

Main results:

Using MDCT as a gold standard modality, positive radiological findings among patients in order of frequency are shown inn table 2.

Table (2): Summary of diagnostic accuracy of US

Statistic	Chest wall injury	Pleural injury	Lung parenchymal injury	Mediastinal injury
Accuracy	95%	96%	91%	91%
Misclassification	5%	4%	9%	9%
Sensitivity	94%	96%	88%	29%
Specificity	100%	100%	100%	100%
False positive rate	0%	0%	0%	0%
False negative rate	6%	4%	12%	71%
Prevalence	86%	93%	74%	12%
Positive predictive value	100%	100%	100%	100%
Negative predictive value	73%	67%	75%	91%
Positive likelihood ratio	-	-	-	-
Negative likelihood ratio	0.06	0.04	0.12	0.71
Relative risk	3.67	3.00	4.00	11.00
Odds ratio	-	-	-	-

Our US results showed excellent joint-probability of agreement for US diagnosis of lung collapse, lung laceration, and hemopericardium and good joint-probability of agreement for US diagnosis of rib fracture, surgical emphysema, hemothorax, pneumothorax, hydrothorax, and lung contusion (Table 3).

Table (3): Inter-method agreement for US and CT as regards diagnosis of specific thoracic injuries

Injury	Measure of agreement	Value	Lower 95% CI	Upper 95% CI
Rib fracture	Cohen's Kappa	0.771	0.585	0.958
	Scott's Bias Adjusted Kappa	0.769		
	Bennett's Prevalence and Bias Adjusted Kappa	0.825		
surgical emphysema	Cohen's Kappa	0.888	0.766	1.011
	Scott's Bias Adjusted Kappa	0.888		
	Bennett's Prevalence and Bias Adjusted Kappa	0.895		
Hemothorax	Cohen's Kappa	0.837	0.661	1.014
	Scott's Bias Adjusted Kappa	0.837		
	Bennett's Prevalence and Bias Adjusted Kappa	0.895		
Pneumothorax	Cohen's Kappa	0.894	0.778	1.010
	Scott's Bias Adjusted Kappa	0.894		
	Bennett's Prevalence and Bias Adjusted Kappa	0.895		
Hydrothorax	Cohen's Kappa	0.843	0.696	0.990
	Scott's Bias Adjusted Kappa	0.842		
	Bennett's Prevalence and Bias Adjusted Kappa	0.860		
Lung contusion	Cohen's Kappa	0.790	0.635	0.946
	Scott's Bias Adjusted Kappa	0.788		
	Bennett's Prevalence and Bias Adjusted Kappa	0.790		
Lung collapse	Cohen's Kappa	0.954	0.864	1.044
	Scott's Bias Adjusted Kappa	0.954		
	Bennett's Prevalence and Bias Adjusted Kappa	0.965		
Lung laceration	Cohen's Kappa	1.000	1.000	1.000
	Scott's Bias Adjusted Kappa	1.000		
	Bennett's Prevalence and Bias Adjusted Kappa	1.000		
Hemopericardium	Cohen's Kappa	1.000	1.000	1.000
	Scott's Bias Adjusted Kappa	1.000		
	Bennett's Prevalence and Bias Adjusted Kappa	1.000		

The main indices of accuracy for diagnosis of various chest injuries using US versus CT as the gold-standard for diagnosis are shown in table 4.

Table (4): Summary of main indices of accuracy for diagnosis of various chest injuries using US as contrasted versus CT as the gold-standard for diagnosis

Statistic	Rib fractures	Surgical emphysema	Hemothorax	Pneumothorax	Hydrothorax	Lung contusion	Lung collapse	Lung laceration	Hemopericardium
Accuracy	91%	95%	95%	95%	93%	89%	98%	100%	100%
Misclassification	9%	5%	5%	5%	7%	11%	2%	0%	0%
Sensitivity	89%	87%	94%	89%	81%	82%	93%	100%	100%
Specificity	100%	100%	100%	100%	100%	100%	100%	100%	100%
False positive rate	0%	0%	0%	0%	0%	0%	0%	0%	0%
False negative rate	11%	13%	6%	11%	19%	18%	7%	0%	0%
Prevalence	79%	40%	82%	47%	37%	60%	26%	5%	4%
Positive predictive value	100%	100%	100%	100%	100%	100%	100%	100%	100%
Negative predictive value	71%	92%	77%	91%	90%	79%	98%	100%	100%
Positive likelihood ratio	-	-	-	-	-	-	-	-	-
Negative likelihood ratio	0.11	0.13	0.06	0.11	0.19	0.18	0.07	0.00	0.00
Relative risk	3.40	12.33	4.33	11.00	10.00	4.83	43.00	-	-
Odds ratio	-	-	-	-	-	-	-	-	-

There were no false positive cases, which included cases detected by US and not detected by CT, in our study (Figure 1).

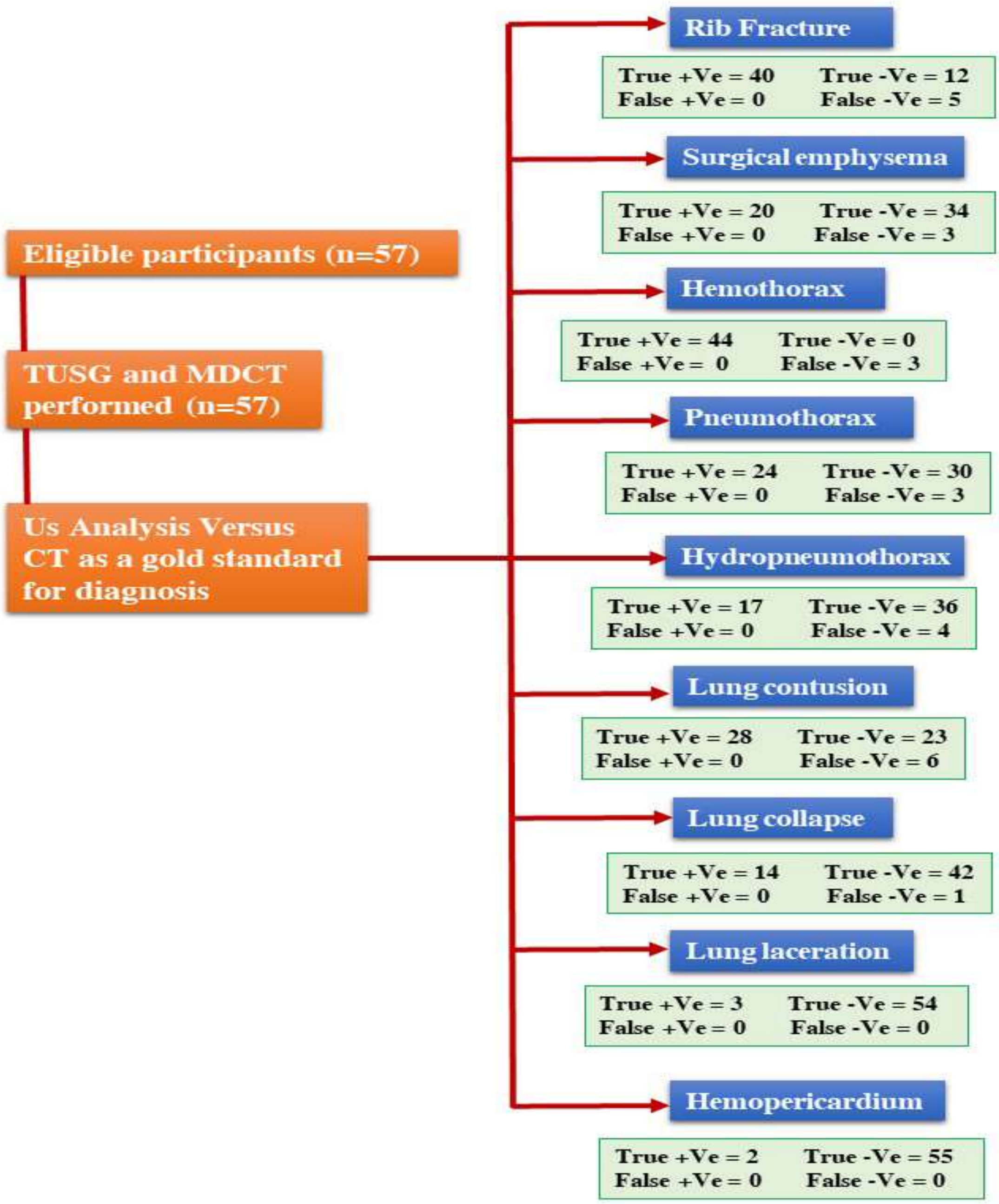

Figure (1): Our results profile

Description of false-negative cases which couldn't been detected by US and detected only by MDCT scan: In our study, 47 patients (82.5%) had hemothorax in MDCT scan. 44 of them were detected by US. Three patients (6%) weren't detected due to subcutaneous emphysema and minimal amounts of blood or those located posteriorly. Of 57 enrolled participants, 27 (47.4%) had pneumothorax in MDCT scan, 24 of them were detected by US. Occult pneumothorax was undetected in 3 of 27 patients (11%) by US and later were confirmed by MDCT. Occult pneumothorax is defined as a very small pneumothorax which will only be found by MDCT scan**.**

In the current study, 34 patients (59.45%) showed pulmonary contusions MDCT scan, and 28 (49.1%) of them were detected by US. False negative cases (18%) could also be because of central lesions, faint ground glass areas not detected by ultrasound, subcutaneous emphysema and obesity. Within the 45 patients (78.9%) who had rib fractures in MDCT scan, 40 of them (70.2%) were detected by US. Five patients (11%) weren't diagnosed by US. False negative cases may be also because of subcutaneous emphysema in this region, and also some cases were examined only from the anterolateral plane, not from the posterior plane due to pain.

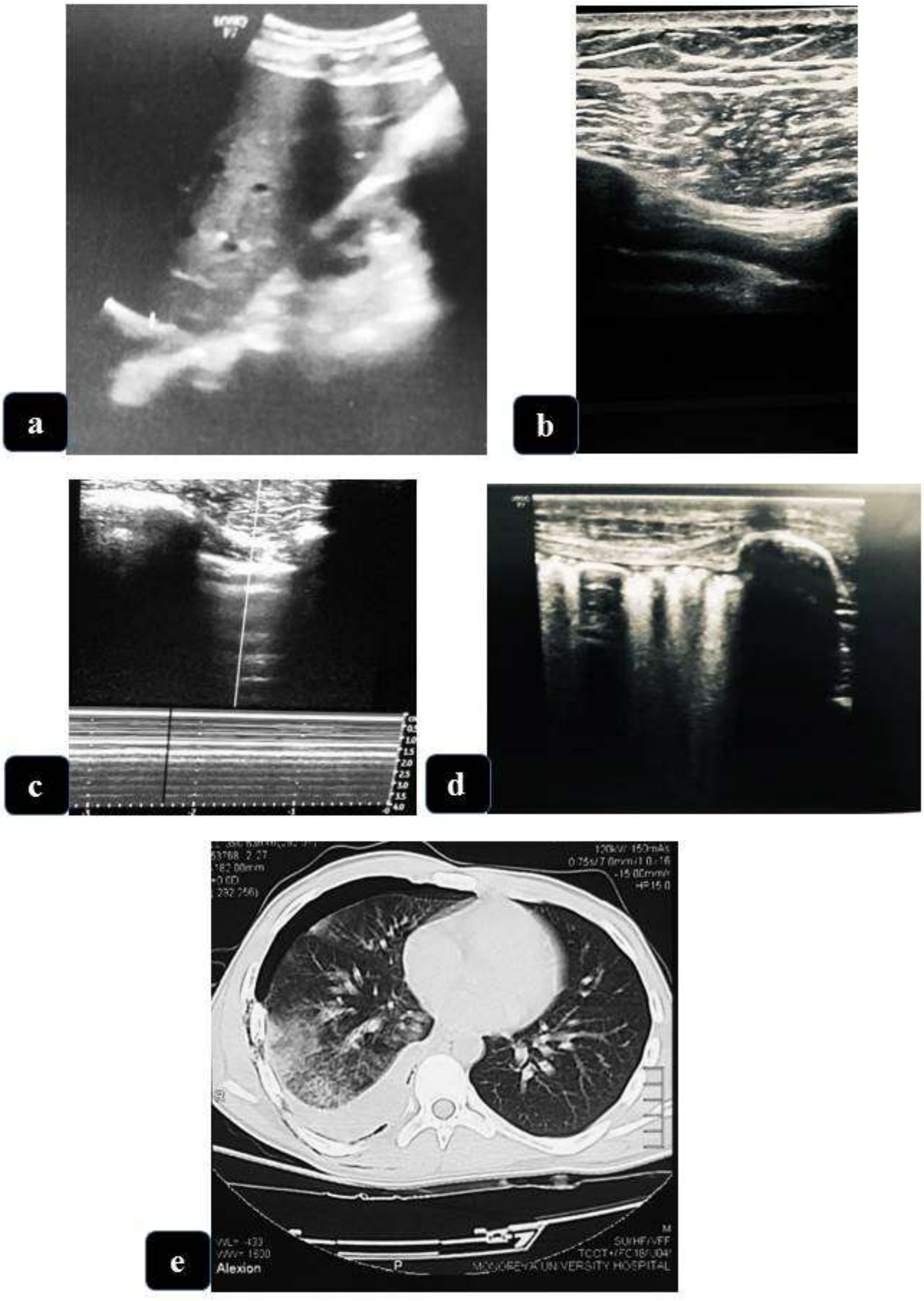

Figure (2): Male 38 year- old had motor vehicle accident. US examination showed right sided pleural effusion (hemothorax) by convex probe **(Figure a)** and linear probe **(Figure b)**, right sided apical absent pleural sliding with stratosphere sign in M mode denoting pneumothorax **(Figure c)** and right sided hemopneumothorax with convex upper border. It consisted of anechoic/hypoechoic pleural collection with hyperechoic regions of loculated air seen superior and posterior to it **(Figure d).** MDCT axial cut lung window **(Figure e)** shows right sided hemopneumothorax and multiple areas of right lung contusions.

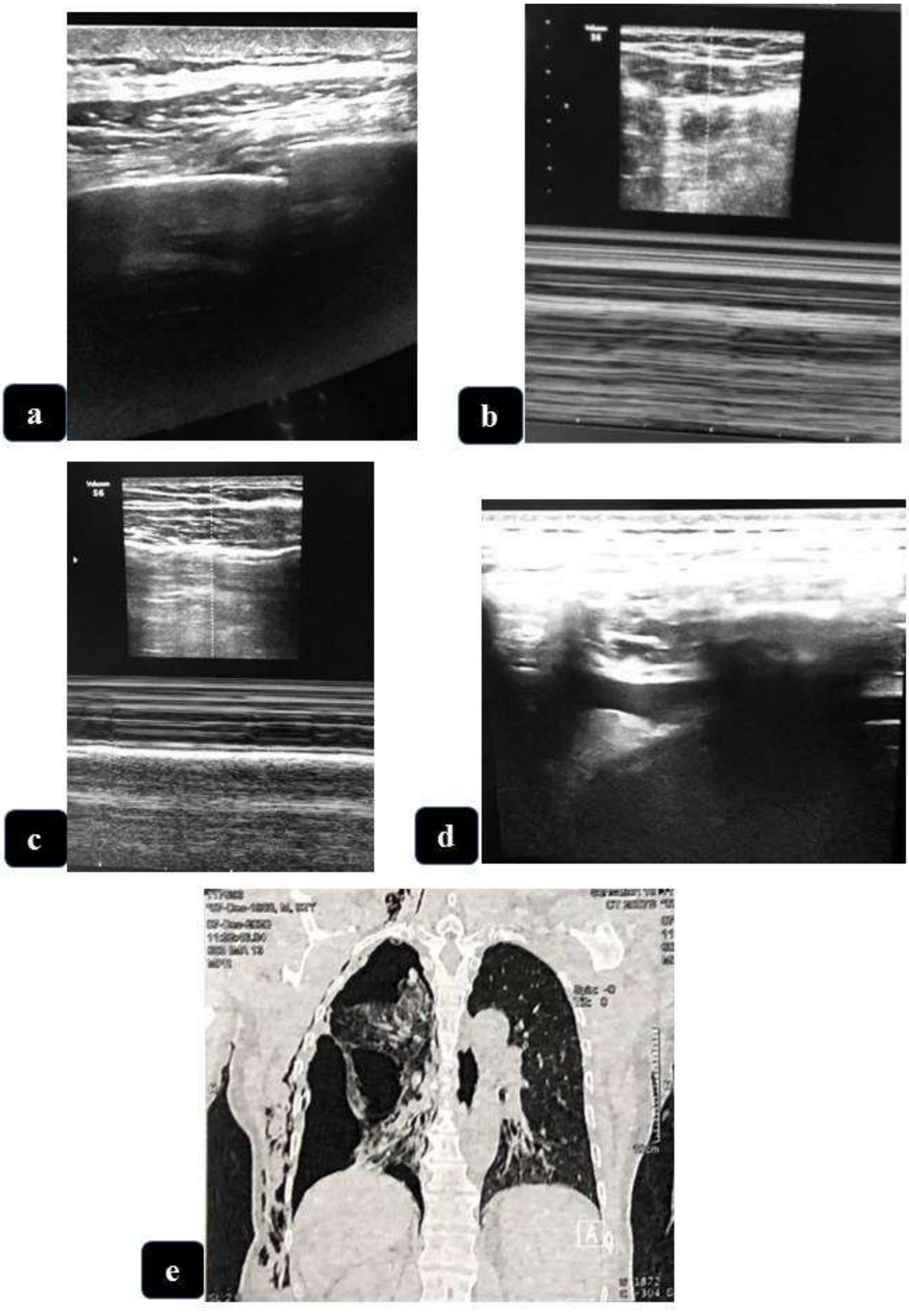

Figure (3): Male 46 year-old had motorcycle accident. US examination of the right 8^{th} rib revealed a fracture at its posterior aspect, with 7 mm displacement and fracture related hematoma **(Figure a).** Right sided apical and posterior, inter scapular and suprascapular, absent pleural sliding with stratosphere sign in M mode denoting pneumothorax **(Figure b).** Normal left lung sliding with sea-shore sign in M mode denoting absent pneumothorax **(Figure c).** Right basal lung collapse **(Figure d).** MDCT coronal reconstruction lung window shows massive right pneumothorax with underlying lung collapse and right 8^{th} rib fracture **(Figure e).**

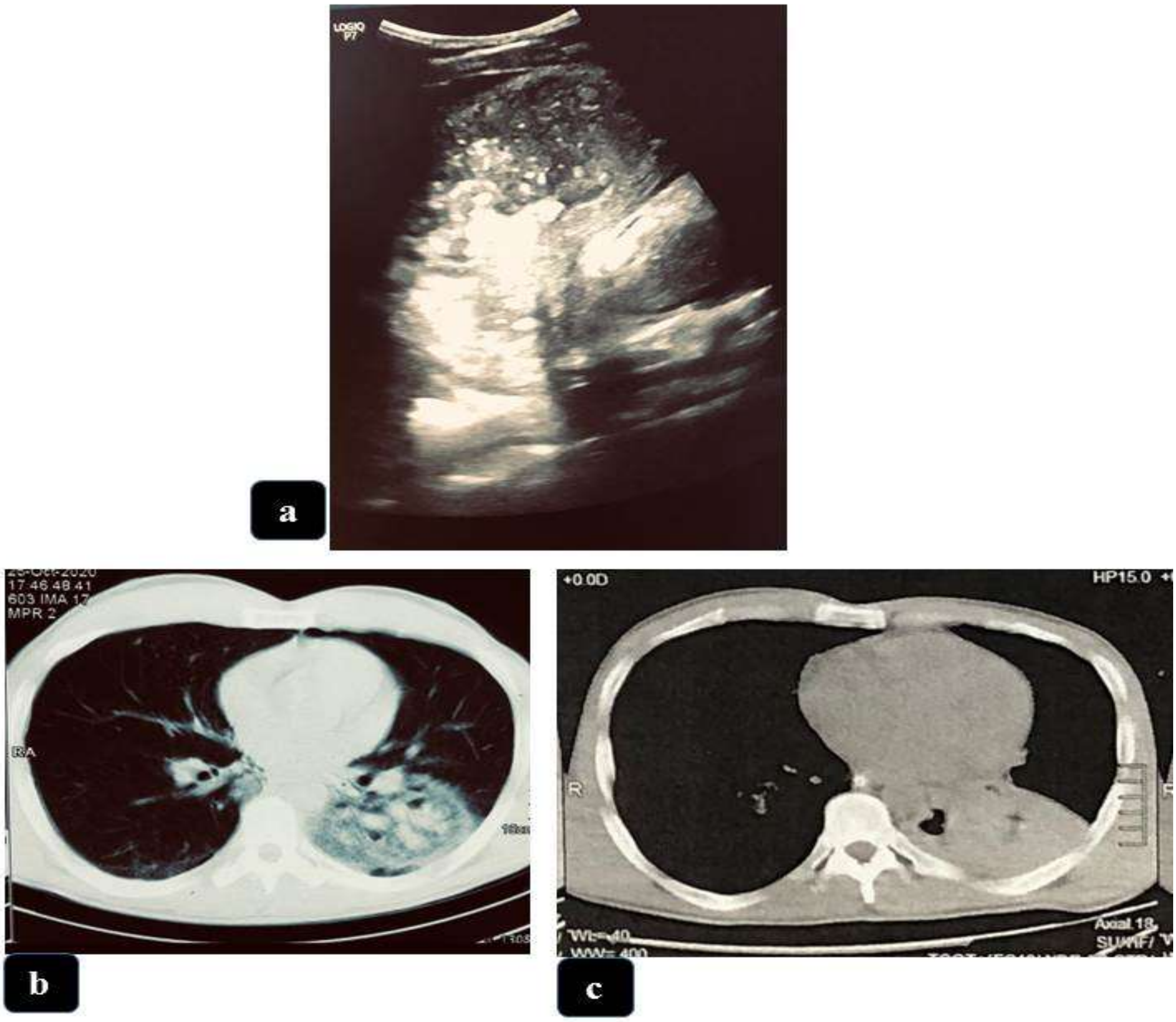

Figure (4): 21 year-old male patient had falling from height. US examination showed left sided hemothorax and the diaphragmatic slip delineates the spleen from the dense lower lobe consolidation (hepatization of the lung) with air–fluid level (laceration) **(Figure a).** MDCT chest axial cuts lung and mediastinal windows (**Figure b and c)** show the left-sided pleural collection with an air loculus and lower lobe consolidation.

DISCUSSION

Thoracic trauma involves fatal injuries. Therefore, the determination of fatal diagnoses may decrease both mortality and morbidity. The employment of bedside ultrasonography has gradually become widespread in emergency departments [(5)]. Ultrasonography provides detailed information about the chest wall, lungs, pleura, heart and mediastinal structures, and it reduces the quantity of chest X-rays and MDCT scans [(6)]. As the MDCT scan is the method of choice and therefore the gold standard for imaging chest trauma [(5)], a MDCT was performed on all patients, and also the results were compared to the US results.

In this study hemothorax was the foremost common pleural injury detected by US. Hemothorax was found in 40 patients (70.2%) by US. These results coincided with **Sabri *et al.*** [(6)] as they found that hemothorax occurs in 56.1% of patients. In our study the sensitivity of US for detection of hemothorax was 94%. Our results coincided with **Sabri *et al.*** [(6)] **and Istasy *et al.*** [(7)]**.** In these studies the US sensitivity for hemothorax was 92.65% and 90.6% respectively. Moreover, **Ali *et al.*** [(8)] reported a better sensitivity result of 97.1%. However, **Kozaci *et al.*** [(5)] **and Jahanshir *et al.*** [(9)] reported lower sensitivity results of 45% and 45.40% respectively.

In our study pneumothorax was detected by US in 24 patients (42.1%). These results coincided with **Jahanshir's study** [(9)] who found that pneumothorax occurs in 35.6% of patients. In our study the sensitivity of US for pneumothorax was 89%. Our results coincided with **Abdallah *et al.*** [(10)] **and Kozaci *et al.*** [(5)]**.** In these studies the sensitivity was 86.1% and 86% respectively. **Sabri *et al.*** [(6)] **and Ianniello *et al.*** [(11)] reported higher sensitivity results of 93.5% and 93.6% respectively. However, **Vasquez *et al.*** [(12)] **and Jahanshir *et al.*** [(9)] reported lower sensitivity results of 45.5% and 75% respectively.

In our study, rib fractures were the most common chest wall injury detected by US. It was found in 40 patients (70.2%). These results coincided with **Çelik *et al.*** [13] who found that rib fractures are the common complications of blunt chest trauma. In our study the sensitivity of US for rib fractures was 89%. Our results coincided with **Çelik *et al.*** [13] and **Schmid *et al.*** [14]**.** In these studies the sensitivity was 91% and 91.2% respectively. Moreover, **Pishbin *et al.***[15] reported a higher sensitivity result of 98.3%, and also **Sabri *et al.***[6] showed 19 fractured ribs in 9 patients but MDCT revealed this injury in 8 patients leading to 100% sensitivity for diagnosing rib fracture. However, **Kozaci *et al.*** [5] reported a lower sensitivity result of 67%.

In this study, pulmonary contusions were the foremost common parenchymal lung injury detected by US. It was found in 28 patients (49.1%). This can be accepted by **Sabri *et al.*** [6] who found pulmonary contusions in 29 patients (27.1%). In our study the sensitivity of US for pulmonary contusions was 82%. Our results coincided with **Nazerian *et al.***[16] who reported that lung ultrasonography could be a reliable diagnostic tool for the bedside diagnosis of lung consolidation and located that lung ultrasound was appropriate altogether for patients with 82.8% sensitivity. Moreover, **Helmy *et al.*** [17]**, Soldati *et al.*** [18] **and Ali *et al.*** [8] reported higher sensitivity results of 97.5%, 94.6% and 88.9% respectively. However, **Sabri *et al.*** [6] **and Jahanshir *et al.*** [9] reported lower sensitivity results of 49.09% and 58.1% respectively.

Limitations: Study sample size is small and US had limitations more than CT in the detection of scapular fractures, pneumomediastinum and dorsal vertebral fractures, which are serious conditions. In addition, we couldn't determine the expansion of simple pneumothorax to tension pneumothorax.

CONCLUSION

Chest ultrasound could be a bedside, reliable, dynamic, rapid, noninvasive technique and may be of a major value within the diagnosis of complications of blunt chest trauma. It should be used as another diagnosis method in emergency departments because it can be easily learned and performed, and both bone tissue and soft tissue could also be assessed together with the heart and lung parenchyma.

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