ORIGINAL ARTICLE

DIAGNOSTIC ACCURACY OF CHEST ULTRASONOGRAPHY IN THE EARLY DETECTION OF PNEUMOTHORAX TAKING CHEST CT SCAN AS GOLD STANDARD

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ABSTRACT

BACKGROUND: Early detection and treatment of pneumothorax is critically important. It often remains undiagnosed after trauma and may rapidly lead to tension pneumothorax and subsequently to cardiac arrest. A quick bedside chest ultrasound may expedite the diagnosis, treatment and resuscitation of patient. It is an easy and simple technique which does not require higher expertise. **OBJECTIVE:** To determine diagnostic accuracy of chest ultrasound in the detection of pneumothorax taking chest CT scan as gold standard. **METHODOLOGY:** The ultrasound chest performed on patient lying supine, scanning both lung fields. With use of high frequency linear probe one can clearly distinguish the visceral and parietal pleura, lung sliding and comet tail artifact representing normal lung. Absence of lung sliding and comet tail artifact representing pneumothorax. The results then compared with gold standard multislice (64) CT scan of chest. **RESULTS:** In our study, out of 275 cases, 65.82% (n=181) were between 18-40 years of age while 34.18% (n=94) were between 41-60 years of age, mean ± sd was calculated as 35.31 ± 8.96 years, 58.91% (n=162) were male and 41.09% (n=113) were females, frequency of pneumothorax on CT was recorded as 8.36% (n=23), the diagnostic accuracy of chest ultrasound to detect pneumothorax taking chest CT scan as gold standard shows sensitivity, specificity, positive predictive value, negative predictive value and accurate as 78.26%, 96.83%, 69.23%, 97.99% and 95.27% respectively. **CONCLUSION:** Chest ultrasound is a useful, radiation free, easy and rapid technique in the detection of pneumothorax as a bedside procedure in emergency trauma cases.

Keywords: Pneumothorax, chest ultrasonography, diagnostic accuracy, chest CT scan

Introduction

A trauma is any injury or damage that occurs due to external factors that is a one of the biggest causes of disability in young people and also it is the single greatest cause of years of life lost in the world. Trauma resulted in the death of more than 6000000 people in the world, during the year 2000.[1] Pneumothorax is a common finding in patients admitted in hospitals with trauma, barotrauma following mechanical ventilation and invasive procedure in hospitalized patients.[2] The incidence of pneumothorax in trauma patients is 7%.[3] In another study it is reported about 5% to 8% in trauma patients.[4] The diagnosis of pneumothorax is usually made in combination with clinical signs and symptoms, which may be non-specific, and plain chest radiography.[5] Supine AP chest radiograph remains insensitive examination in the diagnosis of pneumothorax in the patients admitted in the hospitals after trauma. The sensitivity of supine CXR for pneumothorax ranges from 28%-75% and specificity is 100%.[6]

Computed tomography is widely used as gold standard[7] for the diagnosis of pneumothorax however, it requi-

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res severely injured patients or patients having high suspicion of pneumothorax to be transported to the CT room which is usually time consuming and delays the diagnosis.[2,7] The sensitivity and specificity of CT being gold standard is 100% each.[7] CT scan facility is expensive, involves radiations and it is not easily available everywhere in our country especially in remote areas, that results further delay in diagnosis and gets potentially life threatening. Chest ultrasound has gained a well-established role in the diagnosis of pneumothorax and is still rapidly evolving. Ultra sound has been proposed as an alternative screening test for pneumothorax.[2] The use of ultrasound can reduce the time taken for diagnosis of pneumothorax hence allows early treatment.[1]

Sensitivity and specificity of thoracic ultrasonography is 53% and 95% in traumatic patients[8] while another study reported sensitivity and specificity was 86.2 and 97.2% respectively.[2]

The rationale of this study is to study the diagnostic accuracy of chest ultrasonography in our population as a lot of researches has been done but there is a controversy in their sensitivities (53% - 86.2%).[2,8] If we find high accuracy of ultrasound the in future we can use it in early detection of pneumothorax especially in our country where CT scan facility is not readily available, thus providing prompt diagnosis, early treatment and reducing the patient's mortality. Other benefits of this study is that USG is easy to perform, rapid, inexpensive, radiation free and does not require higher expertise, even a junior resident can diagnose in emergency case.

OPERATIONAL DEFINITIONS

Pneumothorax on Ultrasonography:

It was defined by the absence of lung sliding and comet tail artifact. (done on patients arrival)

Lung sliding is a dynamic sign and can be identified on M-mode of ultrasound (image shown below in Fig. 1) as horizontal movement along the pleural line. The motionless portion of the chest above the pleural line creates horizontal "waves" and sliding below the pleural line creates a granular pattern, the "sand" resembling like waves crashing in onto the sand therefore called "seashore" sign and is repre-senting normal lung.[5]

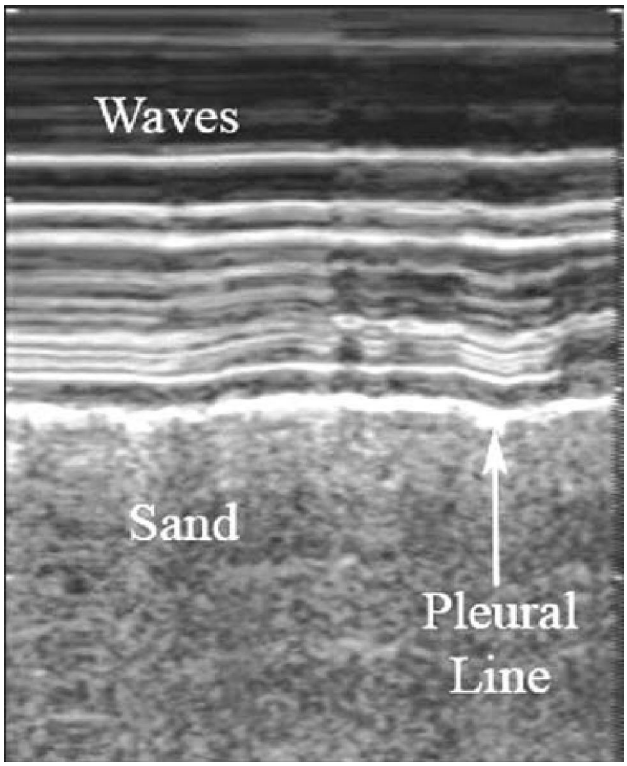

Figure 1: M-mode illustrating the 'seashore sign.' The pleural line divides the image in half: The motionless portion above the pleural line creates horizontal 'waves,' and the sliding line below it creates granular pattern, the 'sand'

Comet tail artifacts are reverberation artifacts that appear as hyper echoic vertical lines that extend from the pleura to the edge of the screen without fading.[5]

Pneumothorax on CT:

On CT it is manifested as a collection of air in the pleural cavity accumulating behind the ventral or medial thoracic wall. (Assessed on patients presentation)

DIAGNOSTIC ACCURACY

True Positive:

If Pneumothorax is positive on ultrasonography as well as Positive on CT

False Positive:

If Pneumothorax is positive on ultrasonography while it is negative on CT

False Negative:

If Pneumothorax is not found on ultrasonography while it is positive on CT

True Negative:
If Pneumothorax is negative on ultrasonography while it is positive on CT

Sensitivity $= \frac{a}{a+c} \times 100$

Specificity $= \frac{a}{b+d} \times 100$

Positive predictive value $= \frac{a}{a+b} \times 100$

Negative predictive value $= \frac{a}{c+d} \times 100$

Material and Methods

STUDY DESIGN:
Cross sectional study

SETTING:
This study was conducted at Radiology department, CMH Lahore.

DURATION OF STUDY:
The study was of 6 months duration after the approval of synopsis. From: 1-08-2015 to 31-01-2016

SAMPLE SIZE:
Sample size of 275 cases is calculated with 95% confidence level, 7% margin of error for sensitivity i.e 86.2%. 2% margin of error for specificity i.e 97.2% and taking expected percentage of pneumothorax i.e 7% of USG of lung to detect pneumothorax taking CT scan chest as gold standard.

SAMPLING TECHNIQUE:
Non-probability consecutive sampling

INCLUSION CRIETERIA
Patients aged 18-60 of either gender with chest trauma presenting at emergency department (respiratory rate <10 or > 29) i.e suspected cases of pneumothorax.

EXCLUSION CRITERIA
1. Patients who are developing tension pneumothorax or hemodynamic instable. (assessed clinically, tension pneumothorax chest x-ray finding mediastinal shifting and inverted diaphragm, hemodynamic unstable if systolic blood pressure < 90 mm/hg)
2. Patients having large consolidation, pulmonary fibrosis and pleural adhesion. (Assessed on CT).

DATA COLLECTION PROCEDURE
The ultrasound chest was performed on patient lying supine, scanning both lung fields at second to fourth anterior intercostal spaces and sixth to eighth intercostal spaces in mid axillary line. When the transducer is placed across the rib longitudinally, a horizontal hyper echoic line could be appreciated between the upper and lower ribs representing the pleural line. With the use of higher frequency linear probe one can clearly distinguish the visceral and parietal pleura, lung sliding and comet tail artifact representing normal lung. Presence or absence of lung sliding and comet tail artifact was noted. Medison Sonoace Accuvix V20 was used for all patients with a 7.5 MHz high frequency linear array transducer. CT scan of chest was done of all patients using multislice (64) CT, with a collimation of 0.6 mm slice at 120 Kv and 300 mA. On CT it is manifested as a collection of air in the pleural cavity accumulating behind the ventral or medial thoracic wall.
All the relevant details were recorded separately for each patient.

STATISTICAL ANALYSIS
Using SPSS version 22 data was managed and analyzed. All qualitative variables like gender of pneumothorax on USG and CT was presented in the form of frequency (%). Mean and standard deviation was used to express the continuous variable like age. Sensitivity, specificity, positive predictive value and negative predictive value tests was used for diagnostic accuracy of chest USG and CT after making 2 x 2 tables. Data was stratified for age and gender. Post stratification chi-square test was used. P-value <0.05 was considered as significant.

Results

A total of 275 cases fulfilling the inclusion/exclusion criteria were enrolled to determine the diagnostic accuracy of chest ultrasound to detect the pneumothorax taking CT scan chest as gold standard.

AGE DISTRIBUTION:

Patients were distributed according to age of the patients, it shows that 65.82% (n=181) were between 18-40 years of age while 34.18% (n=94) were between 41-60 years of age, mean ± sd was calculated as 35.31 ± 8.96 years. (Tab. 1)

Age (in years)	No. of patients	%
18-40	181	65.82
41-60	94	34.18
Total	**275**	**100**
Mean ± SD	**35.31 ± 8.96**	

Table 1: Age Distribution (n=275)

GENDER DISTRIBUTION:

Gender distribution shows that 58.91% (n=162) were male and 41.09% (n=113) were females. (Tab. 2)

Gender	No. of patients	%
Male	162	58.91
Female	113	41.09
Total	**275**	**100**

Table 2: Gender Distribution (n=275)

FREQUENCY OF PNEUMOTHORAX:

Frequency of pneumothorax on CT was recorded as 8.36% (n=23) while 91.64% (n=252) had no findings of the morbidity. (Tab. 3)

Pneumothorax	No. of patients	%
Yes	23	8.36
No	252	91.64
Total	**275**	**100**

Table 3: Frequency of pneumothorax on CT (n=275)

DIAGNOSTIC ACCURACY OF ULTRASOUND:

Diagnostic accuracy of ultrasound of lung to detect the pneumothorax keeping CT scan chest as gold standard shows sensitivity, specificity, positive predictive value, negative predictive value and accurate as 78.26%, 96.83%, 69.23%, 97.99% and 95.27% respectively. (Tab. 4)

DATA STRATIFICATION:

The data was stratified for age and gender to control the effect modifiers, post stratification chi-square test was used. P-value ≤0.05 was considered as significant.

Ultrasound	Computed Tomography		Total
	Pneumothorax (Positive)	Pneumothorax (Negative)	
Positive	True positive(a) 18 (6.55%)	False positive (b) 8 (2.91%)	a + b 26(9.45%)
Negative	False negative(c) 5 (1.82%)	True negative (d) 244 (88.73%)	c + d 249 (90.55%)
Total	**a + c** **23 (%)**	**b + d** **252 (%)**	**275 (100%)**

Sensitivity = a / (a + c) x 100 =78.26%
Specificity = d / (d + b) x 100 = 96.83%
Positive predictive value = a / (a + b) x 100 =69.23%
Negative predictive value = d / (d + c) x 100 =97.99%
Accuracy rate = a + d / (a + d + b + c) x 100 = 95.27%

Table 4: Diagnostic accuracy of chest ultrasound in the detection of pneumothorax taking ct scan chest as gold standard (n=275)

18-40 years

Ultra-sound	Computed Tomography		P value
	Pneumothorax (Positive)	Pneumothorax (Negative)	
Positive	True positive(a) 9	False positive (b) 6	2.13
Negative	False negative(c) 3	True negative (d) 163	

Sensitivity = a / (a + c) x 100 =75%
Specificity = d / (d + b) x 100 =96.44
Positive predictive value = a / (a + b) x 100 =60%
Negative predictive value = d / (d + c) x 100 =98.19%
Accuracy rate = a + d / (a + d + b + c) x 100 = 95.02%

41-60 years

Ultra-sound	Computed Tomography		P value
	Pneumothorax (Positive)	Pneumothorax (Negative)	
Positive	True positive(a) 9	False positive (b) 2	2.72
Negative	False negative(c) 2	True negative (d) 81	

Sensitivity = a / (a + c) x 100 =81.82%
Specificity = d / (d + b) x 100 = 97.59%
Positive predictive value = a / (a + b) x 100 =81.82%
Negative predictive value = d / (d + c) x 100 =97.59%
Accuracy rate = a + d / (a + d + b + c) x 100 = 95.74%

Table 5: Stratification for age (n=275)

MALE

Ultra-sound	Computed Tomography		P value
	Pneumothorax (Positive)	Pneumothorax (Negative)	
Positive	True positive(a) 14	False positive (b) 5	5.66
Negative	False negative(c) 4	True negative (d) 139	

Sensitivity = a / (a + c) x 100 =77.78%
Specificity = d / (d + b) x 100 =96.52%
Positive predictive value = a / (a + b) x 100 =73.68%
Negative predictive value = d / (d + c) x 100 =97.20%
Accuracy rate = a + d / (a + d + b + c) x 100 = 94.44%

FEMALE

Ultra-sound	Computed Tomography		P value
	Pneumothorax (Positive)	Pneumothorax (Negative)	
Positive	True positive(a) 4	False positive (b) 3	0.00
Negative	False negative(c) 1	True negative (d) 105	

Sensitivity = a / (a + c) x 100 =80%
Specificity = d / (d + b) x 100 = 97.22%
Positive predictive value = a / (a + b) x 100 =57.14%
Negative predictive value = d / (d + c) x 100 =99.05%
Accuracy rate = a + d / (a + d + b + c) x 100 = 96.46%

Table 5: Stratification for gender (n=275)

Discussion

Early detection of pneumothorax is critically important. Several studies have shown that chest ultrasonography is a highly sensitive and specific tool. The benefits of USG is that it is radiation free, inexpensive, rapid and easy to perform even a junior resident can diagnose in emergency case.

This study was planned to determine the diagnostic accuracy of chest ultrasonography in our population as a lot of research has been done but there is a controversy in their sensitivities (53% - 86.2%).

In our study, out of 275 cases, 65.82% (n=181) were between 18-40 years of age while 34.18% (n=94) were between 41-60 years of age, mean ± sd was calculated as 35.31 ± 8.96 years, 58.91% (n=162) were male and 41.09% (n=113) were females, frequency of pneumothorax on CT was recorded as 8.36% (n=23), the diagnostic accuracy of ultrasound of lung to detect the pneumothorax keeping CT scan chest as gold standard shows sensitivity, specificity, positive predictive value, negative predictive value and accurate as 78.26%, 96.83%, 69.23%, 97.99% and 95.27% respectively.

The findings of our study are in agreement with Zhang M and others[2] who recorded the sensitivity and specificity as 86.2 and 97.2% respectively.[2]

Another study recorded that sensitivity and specificity of thoracic ultrasonography is 53% and 95% in traumatic patients which is in contrast with our results for sensitivity.

Ali Ebrahimi and others[9] in their meta-analysis designed to evaluate the diagnostic accuracy of chest ultrasonography and chest radiography (CXR) for detection of pneumothorax, they recorded that the pooled sensitivity and specificity of CUS were 0.87 (95% CI: 0.81-0.92; I2= 88.89, P<0.001) and 0.99 (95% CI: 0.98-0.99; I2= 86.46, P<0.001), respectively. The pooled sensitivity and specificity of CXR were 0.46 (95% CI: 0.36-0.56; I2= 85.34, P<0.001) and 1.0 (95% CI: 0.99-1.0; I2= 79.67, P<0.001), respectively. Meta regression showed that the sensitivity (0.88; 95% CI: 0.82 - 0.94) and specificity (0.99; 95% CI: 0.98 - 1.00) of ultrasound performed by emergency physician was higher than by non-emergency physician. Non-trauma setting was associated with higher pooled sensitivity (0.90; 95% CI: 0.83 - 0.98) and lower specificity (0.97; 95% CI: 0.95 - 0.99) and concluded that the diagnostic accuracy of Chest ultrasonography was higher than supine CXR for detection of pneumothorax. It seems that Chest ultrasonography is superior to CXR in detection of pneumothorax, even after adjusting for possible sources of heterogeneity.

Saucier S and others[10] validated the use of ultrasound technology when compared with the use of standard chest radiography for detection of pneumothorax following chest tube removal and recorded that bedside ultrasound technology is as accurate as chest radiography in detecting pneumothorax following chest tube removal and can save institutions' time and money.

A recent study[11] by Lin Chen and others concluded that US represents a novel approach for the evaluation of pneumothorax, with advantages of timeliness, high accuracy and high reliability. The US skills should be incorporated into the standard training programs of physicians working at emergency and critical care settings. Because lung ultrasound is relatively new, there are many areas of active research. For example, new signs continue to be reported and defined. The technique to quantification of PTX size is still under investigation. Furthermore, the diagnosis of PTX under special conditions such as mechanical ventilation and patients with large pulmonary bullae are being reported. A typical signs such as “physiological lung point” and “pseudo-lung point” should be noted and carefully distinguished from true lung point.

Soldati G. et al[5] conducted 18 months prospective study to determine the diagnostic accuracy of lung ultrasonography in the emergency department (ED) in the diagnosis of radio-occult pneumothorax (PTX) and to define its ability to delineate PTX extension, compared with chest radiograph and computed tomo-

graphy (CT) scanning. A total of 109 conscious, spontaneously breathing patients who had been admitted to the ED for chest trauma were involved in the study. All patients underwent a standard anteroposterior supine chest radiograph and a spiral CT lung scans within 1 hour of ED admission. Lung US was carried out by an operator who was unaware of the other examination results, both for diagnosis and for the other quantitative delimitation of the PTX. From 109 participants, 25 traumatic PTXs were detected in the 218 hemi thoraxes evaluated by spiral CT scan. The findings from spiral CT scan were used as a reference standard. Out of these, only 13 were revealed by chest radiography (52% sensitivity, 100% specificity) while 23 participants were identified by Lung US with one false positive result (92% sensitivity and 99.4% specificity). In 20 of 25 cases, there was agreement on extension of the PTX between CT lung scan and lung US with a mean difference of 1.9 cm (range 0 – 45 cm) in the localization of retro parietal air extension; chest radiograph was not able to give quantitative results. Lung US scans carried out in the ED detected occult PTX and its extension with an accuracy that was almost as high as the reference standard (spiral CT scan).

In one prospective study a hand-held ultrasound device was used by trauma surgeons to perform the E-FAST examination in patients with blunt or penetrating trauma.[12] The utility of thoracic ultrasound for diagnosing a pneumothorax was compared to chest x-ray (CXR) alone, a composite standard (CXR, chest, and abdomen Computed tomography (CT) scans, clinical course, and invasive interventions), and to the gold standard CT scan (CT only). Their results showed that the E-FAST examination had a sensitivity of 58.9% with a positive likelihood ratio of 69.7 and a specificity of 99.1% when compared to the composite standard. The E-FAST was also compared to CXR, using CT scan as the gold standard, showing that ultrasound had a higher sensitivity than CXR, 48.8 and 20.9%, respectively, and a similar specificity of 99.6 and 98.7%, respectively. In addition, they noted that 63% of all pneumothoraxes diagnosed were occult. Traditionally, these would end up getting diagnosed later on a CT scan. Although CT scan remains the gold standard, they concluded that ultrasound was more sensitive in identifying occult traumatic pneumothoraxes compared to CXR.

Similarly, a prospective study by Ball et al.[13] noted that up to 76% of all traumatic pneumothoraxes were missed by the standard supine AP chest film when interpreted by the trauma team. This number was much higher than their prior retrospective study (55%), where image interpretation relied on radiologists. This stressed the poor sensitivity of CXR in a rushed trauma scenario and utility of performing a rapid bedside ultrasound, to possibly aid in the diagnosis, prior to sending a patient for a CT scan.[14]

Several other studies highlight the utility of ultrasound compared to CXR for the diagnosis of pneumothorax in the Emergency Department.[15-16] 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.[15] Lichtenstein et al.[17] have shown that ultrasound has a sensitivity of 95.3% and a specificity of 91.1% for detecting pneumothorax in intensive care unit (ICU) patients.

In summary, the findings of our study are supported with other international studies, and the higher accuracy of ultrasound and encourages its use in future for early detection of pneumothorax especially in our country where CT scan facility is not readily available, involves radiations and expensive, thus chest ultrasound provides prompt diagnosis, early treatment and reducing the patient's mortality.

Conclusion

We concluded that the diagnostic accuracy of chest ultrasound to detect pneumothorax taking CT scan chest as gold standard is higher and it will be very useful in future in our population as it is easy, inexpensive ,rapid, radiation free modality and does not require higher expertise.

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