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Role of Chest Ultrasound in Detection of Pneumothorax in Critical Care Unit Patients

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Abstract

This is a typical condition in the intensive care unit, and the term "pneumothorax" refers to a collection of air that has built up between two pleurae, either on the parietal or visceral side, and is putting pressure on the lung. Pneumothoraxes are classified into two categories: traumatic and non-traumatic. Pneumothorax may be diagnosed in ICU patients utilising the least intrusive approaches without patient transfer by employing the standard sonographic findings in the form of lung sliding, a lung pulse, B lines and a lung point. Indications one through three are extremely indicative that there is no pneumothorax, whereas signs four through six are definitive. Our study's goal is to evaluate the usefulness of chest ultrasonography in diagnosing pneumothorax in intensive care unit (ICU) residents. Methods: A prospective study of 50 patients hospitalised to the Banha University Hospitals' critical care unit with clinical evidence or a history suggesting pneumothorax illness was done. In our research, we conducted a comprehensive history-taking, clinical examination, and investigation of each patient. A CT scan confirmed the diagnosis of pneumothorax in 42 of the patients (84 percent). 70 percent of the patients had pneumothorax discovered by ultrasound, while more than a third of the patients had pneumothorax diagnosed by chest X-ray (40 percent). 45.2 percent sensitivity, 87.5 percent specificity, PPV of 95 percent, NPV of 23.3 percent, and an overall accuracy of 52 percent were found in the chest x-ray. An overall accuracy rate of 82% was achieved using chest ultrasonography. The sensitivity was 80%, the specificity 87.5, the PPV was 97.1, and the NPV was 46.7. On the other hand, X-ray and ultrasound were only somewhat consistent when it came to their agreement with CT scans (Kappa = 0.505). Conclusion: Compared to CT chest and CXR, lung ultrasound is an appropriate diagnostic modality in the ICU population for the detection of pneumothorax with higher sensitivity than CXR. It is simple, affordable, and the best bedside test with minimum exposure to ionised radiation.

Key words: Homocysteine, Predictor, Early Neurological Deterioration, Acute Ischemic Stroke.

1.Introduction

A pneumothorax diagnosis might be tricky. The department may not have access to or be able to use the traditional gold-standard modalities. This potentially life-threatening condition may be swiftly ruled out with ultrasound guidance. [1]

Pneumothorax may be detected with computed tomography, however there are several limitations. Patients must be transported to the scanner, a radiation technician must conduct the scan, and a physician must analyse the results. This is the most radiation-intensive way of detection. A CT scan in the operating room cannot be performed while the patient is under a general anaesthesia. [2]

To identify pneumothorax in an upright patient, chest radiographs should be taken.

Anteroposterior supine radiographs may detect only a large pneumothorax, based on previous studies, because of the gravity-dependent appearance of the pneumothorax. 3

In one investigation, researchers found that supine chest radiographs missed more than half of the CT-detected traumatic pneumothoraxes.

[4] There are difficulties in obtaining chest radiographs in the trauma patient, particularly in the anterior/posterior and lateral directions. An evidence-based study was conducted to compare ultrasonography with chest radiography in the detection of traumatic pneumothoraxes. Supine chest radiography was shown to be less sensitive than bedside ultrasonography in this study in detecting pneumothorax in trauma patients. Diagnostic value of ultrasonography was comparable to that of a CT scan since it could distinguish between various diameters of pneumothoraxes. [6]

Ultrasonography provides various benefits when it comes to diagnosing pneumothorax. The most significant benefit is the significant reduction in diagnostic time. The time it took to identify a pneumothorax using ultrasonography, as opposed to x-rays, was stated to be (7) minutes in one study. There was a 66-minute standard deviation in the time it took to identify this potentially life-threatening issue in the x-ray group, according to the researchers. [5]

Our study's goal is to evaluate the usefulness of chest ultrasonography in diagnosing pneumothorax in intensive care unit (ICU) residents.

2. Patients and Methods

Methods

A prospective interventional design will be adopted to fulfill the purpose of the study

This study was conducted on fifty patients admitted to the critical care unit at Banha University Hospitals during period of 12 months starting from Jan 2021 to Dec 2021 with clinical data or history suggestive of pneumothorax disease with acute dyspnea as the primary complaint or developed acute dyspnea and or tachypnea during their ICU stay

General characteristics

The mean age of the studied patients was 48 ±15 years. There was a male predominance (70.0%). The mean BMI was 24.3 ±4.6 years. Near half of the patients (44%) were diabetics, and about one-third (30.0%) were hypertensive. Only 16% had COPD. The mean heart rate was 103 ±15 b/m. The mean systolic and diastolic blood pressure were 113 ±14 and 69 ±9, respectively.

Inclusion criteria:

1. **Patients with clinical data or history that suspect pneumothorax disease eg,**
   - Sharp chest pain, made worse by a deep breath or cough.
   - Shortness of breath.
   - Nasal flaring.
   - Acute Hypotension.
   - Emphysema.
   - Desaturation of mechanically ventilated patients (barotrauma)
   - A larger pneumothorax results in chest tightness, rapid heart rate or cyanosis.[7]
   - Patients who are with a history of chest trauma.
2. **Patients who undergo procedures that may cause pneumothorax eg,**
   - Central venous line insertion.
   - Pleural sampling.

Exclusion criteria:

- Patients with Morbid obesity.
- Patients with long history of COPD.
- Patients that already clinically diagnosed to have tension pneumothorax.

All patient were subjective to the following:

- Initial clinical assessment with daily follow up for signs of improvement or deterioration .clinical assessment included: (blood pressure,heart rate ,temperature and oxygen saturation)
- Demographic data collection including age and gender
- Medical histories co morbidities.
- `CXR and ECG.
- Chest ultrasound (CUS) done immediately by critical care physicians.and then CXR.
- Laboratory examination (CBC- urea ,creatine , ABG)
- C.T chest.

- **Chest ultrasound methodology:-** Philips Ultrasound machine with triple probe was used for examination of patient. Examination was done using convex probe (bandwidth 2-5MHZ).the probe was placed vertically along each space of (mid-clavicular line “MCL”,anterior axillary line “AAL”,posterior axillary line “PAL”on both sides .. with its marker (groove) pointed cephalic and the scanning plane directed between adjacent ribs. Structures near the skin surface appeared close to the dot and deeper structures appeared lower on the screen. Data were displayed on screen.
- When no abnormalities were seen, systematically the probe was moved to the next several intercostals locations covering the anterior aspect of the chest.
- We compared these images to the anterior contra lateral side of the chest.
- After the anterior chest area has been scanned in several locations, we scanned the lateral and posterior aspect of the chest on the both sides.

Statistical methods

Data management and statistical analysis were done using SPSS version 28 (IBM, Armonk, New York, United States). Quantitative data were summarized as means and standard deviations. Categorical data were summarized as numbers and percentages. Diagnostic indices were calculated for chest X-ray and ultrasound using chest CT as a reference standard. Kappa measure of agreement was used to assess the agreement of X-ray and US with CT. Data were compared between those with and without pneumothorax using independent t-test for quantitative data and Chi-square or Fisher’s exact test for categorical data. All statistical tests were two-sided. P values less than 0.05 were considered significant.

3. Results

The mean age of the studied patients was 48 ±15 years. There was a male predominance (70.0%). The mean BMI was 24.3 ±4.6 years. Near half of the patients (44%) were diabetics, and about one-third (30.0%) were hypertensive. Only 16% had COPD. The mean heart rate was 103 ±15 b/m. The mean systolic and diastolic blood pressure were 113 ±14 and 69 ±9, respectively ***(Table 1).***

Table (1) General characteristics of the studied patients

General characteristics		
Age (years)	Mean ±SD	48 ±15
Sex	Males n (%)	35 (70.0)
	Females n (%)	15 (30.0)
BMI	Mean ±SD	24.3 ±4.6
Diabetes	n (%)	22 (44.0)
Hypertension	n (%)	15 (30.0)
COPD	n (%)	8 (16.0)
Heart rate	Mean ±SD	103 ±15

SBP (mmHg)	Mean ±SD	113 ±14
DBP (mmHg)	Mean ±SD	69 ±9

❖ ***Disease etiology***

The most frequent etiology was road traffic accident (40%), followed by spontaneous occurrence (20%), barotrauma (16.0%), iatrogenic (14%), and traumatic causes (10%) ***(Table 2).***

Table (2) Disease etiology in the studied patients.

		n (%)
Etiology	Barotrauma	8 (16.0)
	Iatrogenic	7 (14.0)
	Road traffic accident	20 (40.0)
	Spontaneous	10 (20.0)
	Traumatic	5 (10.0)

The mean pH was 7.37 ±0.05. The mean PCO_2 and PO_2 were 47 ±5 and 59 ±13, respectively. The mean Na^{++} and K^{+} were 136 ±6 and 3.8 ±0.6, respectively. The mean creatinine was 1.3 ±0.4 mg/dl. The mean hemoglobin and hematocrit were 10.5 ±1.7 g/dl and 30 ±4%, respectively. The mean platelets was 197 ±62. The mean total leukocyte count was 12.9 ±5.4. The mean albumin was 3.1 ±0.3. The mean CRP was 18 ±9 ***(Table 3).***

Table (3) Laboratory findings in the studied patients.

	Mean ±SD
pH	7.37 ±0.05
PCO_2	47 ±5
PO_2	59 ±13
Na^{++}	136 ±6
K^{+}	3.8 ±0.6
Creatinine (mg/dl)	1.3 ±0.4
Hemoglobin (g/dl)	10.5 ±1.7
Hematocrit (%)	30 ±4
Platelets	197 ±62
Total leucocyte count	12.9 ±5.4
Albumin	3.1 ±0.3
CRP	18 ±9

Forty-two patients (84%) had confirmed diagnosis of pneumothorax with CT. Ultrasound detected pneumothorax in 70% of the patients, while Chest X-ray detected pneumothorax in more than one-third of the patients (40%) ***(Table 4).***

Table (4) X-ray, ultrasound, and CT in detecting pneumothorax.

	n (%)
CT chest	42 (84.0)
Chest US	٣٥ (70.0)
Chest x-ray	20 (40.0)

Chest x-ray showed a sensitivity of 45.2%, a specificity of 87.5%, PPV of 95%, NPV of 23.3%, and an overall accuracy of 52%. Chest ultrasound showed a sensitivity of 81%, a specificity of 87.5%, PPV of 97.1%, NPV of 46.7%, and an overall accuracy of 82%. Regarding the degree of agreement with CT, X-ray showed poor agreement (Kappa = 0.155), while ultrasound showed moderate agreement (kappa = 0.505) ***(Table 5).***

Table (5) Diagnostic indices of X-ray and ultrasound.

	Diagnostic indices*					
	Sensitivity	**Specificity**	**PPV**	**NPV**	**OA**	**Kappa**
Chest X-ray	45.20%	87.50%	95%	23.30%	52%	0.155
Chest US	81.0%	87.5%	97.1%	46.7%	82%	0.505

*CT was used as a reference standard
PPV: Positive predictive value
NPV: Negative predictive value
OA: Overall accuracy

No significant differences were noted between those with and without pneumothorax regarding age (P = 0.350), sex (P = 0.614), body mass index (P = 0.763), diabetes (P = 0.439), hypertension (P = 0.239), heart rate (P = 0.890), systolic blood pressure (P = 0.655), and diastolic blood pressure (P = 0.961). Only COPD was significantly higher in those with no pneumothorax (50%) than those with pneumothorax (9.5%) (P = 0.004) ***(Table 6).***

Table (6) General characteristics according to pneumothorax status

		Confirmed pneumothorax		
		Yes (n = 42)	**No (n = 8)**	**P-value**
Age (years)	Mean ±SD	47 ±16	52 ±11	0.350
Sex	Males n (%)	30 (71.4)	5 (62.5)	0.614
	Females n (%)	12 (28.6)	3 (37.5)	
BMI	Mean ±SD	24.4 ±4.9	23.9 ±2.7	0.764
Diabetes	n (%)	20 (47.6)	2 (25.0)	0.439
Hypertension	n (%)	14 (33.3)	1 (12.5)	0.239
COPD	n (%)	4 (9.5)	4 (50.0)	0.004*
Heart rate	Mean ±SD	103 ±15	102 ±16	0.890
Systolic blood pressure	Mean ±SD	113 ±14	115 ±13	0.655
Diastolic blood pressure	Mean ±SD	69 ±9	69 ±10	0.961

Independent t-test was used for quantitative data. Chi-square or Fisher's exact test was used for categorical data
* Significant

No significant differences were observed between those with and without pneumothorax regarding pH (p = 0.623), PCO2 (P = 0.707), PO2 (P = 0.199), Na+ (P = 0.104), k+ (p = 0.423), creatinine (P = 0.236), hemoglobin (P = 0.436), hematocrit (P = 0.396), platelets (P = 0.988), total leucocyte count (P = 0.515), albumin (P = 0.812), and CRP (P = 0.328) ***(Table 7).***

Table (7) Laboratory parameters according to pneumothorax status.

		Confirmed pneumothorax		
		Yes (n = 42)	**No (n = 8)**	**P-value**
PH	Mean ±SD	7.37 ±0.05	7.38 ±0.06	0.623
PCO_2	Mean ±SD	47 ±5	48 ±5	0.707
PO_2	Mean ±SD	60 ±13	53 ±13	0.199
Na^{++}	Mean ±SD	135 ±6	139 ±5	0.104
K^+	Mean ±SD	3.8 ±0.7	3.6 ±0.6	0.423
Creatinine	Mean ±SD	1.3 ±0.4	1.2 ±0.2	0.236
Hemoglobin	Mean ±SD	10.4 ±1.7	10.9 ±1.5	0.436
Hematocrit	Mean ±SD	30 ±4	31 ±2	0.396
Platelets	Mean ±SD	197 ±65	197 ±50	0.988
Total leucocyte count	Mean ±SD	13.1 ±5.8	11.8 ±2.4	0.515
Albumin	Mean ±SD	3.1 ±0.3	3.1 ±0.3	0.812
CRP	Mean ±SD	19 ±9	15 ±6	0.328

Independent t-test was used

BMI was significantly lower in those with pneumothorax detected by X-ray (21.4) than those with pneumothorax not detected (26.3) (P < 0.001). Also, COPD was significantly lower in those with pneumothorax detected by X-ray (0%) than those with pneumothorax not detected (26.3%) (P < 0.001) ***(Table 8)***.

Table (8) BMI and COPD according to pneumothorax detection by X-ray

		Pneumothorax by X-ray		
		Yes	**No**	**P-value**
BMI	Mean ±SD	21.4 ±1.8	26.3 ±4.9	< 0.001*
COPD	Yes	0 (0.0)	8 (26.7)	0.015*

Independent t-test was used for BMI. Fisher's exact test was used for COPD
* Significant

4. Discussion

The average age of the people in our research was 48 years and 15 months, based on demographic comparisons. When it came to gender, there was a clear male dominance (70.0 percent). It was found that the average person had a body mass index (BMI) of 24.3 4.6. A diabetic and hypertensive patient population of 44% and 33%, respectively, comprised the majority of the patient population. Only 16% of those surveyed had COPD. The average heart rate was 103 beats per minute, with a standard deviation of 15 beats per minute. There was an average 113 14 systolic and 69 + 9 diastolic blood pressure.

Most often, road traffic accidents were the most common cause of PTx (40%) followed by spontaneous occurrence (20%), barotrauma (16.0%), iatrogenic (14%) and traumatic reasons (10). (10 percent).

The mean pH was 7.37 0.05, and the mean PCO2 and PO2 were 47 5 and 59 13, respectively, in all of our instances. As a result, the average Na++ and K+ concentrations were 136 and 3.0, respectively. The mean creatinine concentration was 1.3 0.4 mg/dl. There was an average haemoglobin concentration of 10.5 g/dl, whereas the hematocrit was 30 percent. The average platelet count was 197 62. " The average number of leukocytes was 12.9 5.4. C-reactive protein (CRP) was 18 9 and albumin 3.1 0.3 on average.

A CT scan confirmed the diagnosis of pneumothorax in 42 of the individuals studied in this research. 70 percent of the patients had pneumothorax discovered by ultrasound, while more than a third of the patients had pneumothorax diagnosed by chest X-ray (40 percent).

The sensitivity, specificity, and overall accuracy of the chest x-ray (CXR) were all 45.2 percent. The sensitivity of chest ultrasonography was 81 percent, the specificity was 87.5 percent, and the total accuracy was 82 percent. The E-FAST evaluation was carried out by trauma surgeons using a hand-held ultrasound instrument in one prospective investigation on patients with blunt or penetrating injuries [7]. A pneumothorax was diagnosed using thoracic ultrasonography, CXR, and the gold standard CT scanner. The E-FAST test exhibited a sensitivity of 58% and a specificity of 99.1% when compared to the composite standard.

It was shown that E-FAST had a greater sensitivity than CXR (48.8% vs. 20.9%) and a comparable specificity to CXR (99.5 and 98.7 percent, respectively) when utilising CT scans as the gold standard Ultrasound was shown to be more sensitive than CXR in detecting occult traumatic pneumathoraces, even if CT scans are still the gold standard [7]

Ball and his colleagues found that up to 76% of all traumatic pneumothoraces were overlooked by the routine supine AP chest film when evaluated by the trauma team in their prospective investigation [8]. An ultrasound at the patient's bedside before sending them to a CT scan may have helped diagnose them more quickly and accurately than their previous retrospective study's (55%). [9].

Ultrasound is superior than CXR in the ER when it comes to diagnosing pneumothorax, according to a number of previous studies. In certain investigations, the sensitivity of ultrasonography to identify pneumothorax was comparable to that of a CT scan, which is considered the gold standard [10].

In the present investigation, X-rays and ultrasounds both exhibited low agreement with CT, although ultrasounds showed reasonable agreement with CT. Rowan et al. found that US was more accurate and sensitive than supine chest radiography and as sensitive as thoracic CT in the diagnosis of pneumothoraces in 27 trauma patients [11].

Another 13 instances of pneumothorax were found during CT-guided biopsy, according to other researchers. In this group of patients, US was more sensitive than erect chest radiography in detecting pneumothorax. Both had a definiteness of one hundred percent [12].

In comparison to a standard X-ray, US was determined to be more sensitive by some, but not as sensitive as a CT scan by others. A possible explanation for this variation in outcomes is that this research had a higher number of patients. False negative instances included those with loculated pneumothoraces, which were difficult to identify by US, particularly near the apices of the lungs with inadequate US windows. As a result, despite the fact that US may identify free pneumothoraces as well as CT, there are certain difficulties in the situations with loculated pneumothoraces. However, compared to chest X-rays, ultrasound is much more efficient in detecting loculated pneumothoraces (21 out of 25 cases) [13].

Dente et al. found that the accuracy of US was affected by the time interval in which it was conducted. To treat a traumatic pneumothorax, researchers looked at 14 patients who had a thoracostomy tube in place throughout their stay in the hospital. Serial delayed bedside US was performed on patients. After the first 24-hour development of a pneumothorax, there was a significant decrease in US sensitivity and specificity. For the first 24 hours after the thoracostomy tube was inserted, US assessment of pneumothorax was shown to be extremely accurate [14].

Another research comprised 200 patients with blunt trauma, and two chest US characteristics were used to diagnose traumatic PTx in the study. There are two aspects to consider when using chest X-rays: the capacity to accurately diagnose traumatic PTx, and the ability to quantify the extent of PTx. These findings are consistent with previous published research [15], which showed specificity ranges from 89% to 99.8%; nevertheless, this study's results are the highest recorded specificity in comparison to other published studies [15].

Pulmonary ultrasonography is an accurate diagnostic tool for the detection of pleural effusions and consolidation, while the diagnostic accuracy for pneumothorax and interstitial syndrome is significantly lower. However, lung ultrasonography properly diagnosed all clinically relevant pneumothoraces [17].

Our research revealed that 42 patients had confirmed pneumothorax and 8 patients did not, and that there were no significant differences in age, sex, BMI, diabetes, hypertension, heart rate, systolic blood pressure, and diastolic blood pressure between those with and without pneumothorax. Only individuals with COPD who had no pneumothorax had a 50% greater risk of the disease than those who had a pneumothorax. Males are more likely to develop a spontaneous pneumothorax than females, a finding that contradicts previous population-based research in England and Taiwan (approximately 3 to 6-fold greater than in females). Recurrence rates of up to 30 percent to 50 percent are associated with gender, age, and smoking status (18; (19)." [20]. In addition, if DM was present in another trial, there was no significant difference in lung cancer development between the spontaneous pneumothorax and comparison groups [21].

This is comparable, but somewhat lower, than the ratios of 9:1 reported in two Asian cohorts [23], where men predominate in a cohort study by a ratio of 4:1 [21, 24].

PSP patients who received intercostal tube drainage (ICD) were found to have higher systolic blood pressure and body mass index (BMI) than those who did not have PSP, although these characteristics were not connected with the length of ICD therapy [25].

One or more of the following variables were shown to be related with recurrent PSP: therapeutic options. Recurrence of PSP was more likely when it occurred at home and there were bubbles on a chest CT scan [26].

It has been found that patients with spontaneous pneumothorax are more likely to be elderly due to the prevalence of chronic lung diseases like emphysema and bronchitis, as well as malignancies such as lung cancer and tuberculosis (TB), as well as asthma and chronic obstructive pulmonary disease (COPD) (21).

Aside from haemoglobin, hematocrit, platelets, total leucocyte count, albumin and C-reactive protein (CRP), there were no significant variations in our study's laboratory data between patients with and without pneumothorax. Other studies have shown that patients with lung damage have lower oxygen saturation, arterial partial pressure of oxygen, P/F and greater PaO2 Deficit, AaDO2, AaDO2 augmentation than individuals who have not suffered from lung injury. Lung damage after blunt chest trauma may be accurately predicted by measuring PaO2, AaDO2, and AaDO2 augmentation [27].

According to other studies, the decreased lung function that occurs as a consequence of a spontaneous pneumothorax (SP) alters blood gas levels. SP has been the cause of 70 individuals being treated with pleural drainage and other conservative methods. PCO2 levels in patients before and after therapy did not change significantly. Both groups had low pO2 pressures [28].

Lymphoma and increased inflammatory markers, including CRP, LDH, Ferritin, D-dimer, and IL-6, were detected in virtually all patients who experienced a spontaneous pneumothorax in another research of covid 19 individuals [29].

The results of this research showed that the BMI was considerably lower in individuals who had an X-ray-detected pneumothorax than it was in those who had no pneumothorax. And this is supported by another study, which found 43 instances with asymptomatic PSP (0.042 percent) among 101,709 chest X-rays. Asymptomatic PSP has many of the same characteristics as conventional PSP [30]. PSP patients were more likely to be younger, taller, and thinner than the general population of male students. They were also likely to have a higher rate of increase in height each year [15].

Lower BMI has also been linked to an increased incidence of bilateral and contralateral pneumothorax, according to certain studies [31]. For taller men and women, the recurrence was more prevalent [32].

Different inclusion criteria and limited sample sizes may be to blame for the discrepancies in previous studies on whether BMI is connected with the likelihood of primary spontaneous pneumothorax (PSP) recurrence [33]. Low BMI was shown to be a risk factor for recurrence of PSP in 273 individuals, with appropriate follow-up [22].

In addition, the prevalence of COPD was lower in individuals who had an X-ray-detected pneumothorax than in those who did not. a finding that was at odds with the findings of a large cohort research showing that secondary spontaneous pneumothorax was more common in people with COPD or emphysema than in healthy controls [34].

In addition, the BMI of individuals who had a pneumothorax diagnosed by the US was considerably lower than that of those who did not. PSP patients' BMI was found to be lower than that of healthy individuals in another study, and this was cited as a structural risk factor for the development of PSP [35]. As lung elasticity reduces as a consequence of poor nutrition in patients with a low body mass index (BMI), case studies show that PSP occurs as a result of an increase in intra-alveolar pressure caused by vomiting [36].

Patients with cystic fibrosis, on the other hand, did not exhibit any symptoms on ultrasound that mimicked a pneumothorax, despite the fact that those with a pneumothorax having been found by US had lower COPD than those without a pneumothorax being detected. Ultrasonography may be used to rule out pneumothorax in patients with COPD, but it cannot be used to make a diagnosis of pneumothorax with confidence without the assistance of additional imaging modalities [37].

5. Conclusion

Ultrasound imaging of the lungs may identify pneumothorax in ICU patients with more sensitivity than chest computed tomography (CT) or computed tomography (CXR). It is the best bedside test with the least amount of ionising radiation exposure among these two diagnostic methods.

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