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Using Bedside Ultrasound for Diagnosis of Pneumothoraxes

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ABSTRACT

BACKGROUND: In recent years, acute respiratory failure conditions have been evaluated using ultrasonography (US) in emergency and critical care settings. It is helpful for determining the cause of a number of problems involving the pleura and lung, including pneumothorax, alveolar interstitial syndrome, and pleural effusion (PTX). The US has good sensitivity and specificity for the diagnosis of various disorders in addition to being reproducible and timely. Chest X-rays are the method for bedside evaluation of PTX that is most frequently employed (CXR). However, CXR has a limited ability to diagnose PTX, particularly in cases with occult PTX and when the patient is supine. The gold standard for PT evaluation is computed tomography (CT), although it has limitations because to excessive radiation exposure and issues with patient safety during transit.

AIM: The aim of this study was to assess the ability of emergency department clinicians to perform bedside Ultrasonography to detect and assess the size of the pneumothorax in patients.

MATERIAL AND METHOD: The Department of Radiology has carried out this prospective study. Patients with multiple injuries were recruited, whether they were in the emergency intensive care unit (EICU) or the resuscitation room. All of the patients who were analyzed in this study underwent CT scans in addition to CXR and US tests. Only patients who had CT scans were included in studies that had patients with differential verifications. Only individuals who had been assessed for pneumothorax were included in a study if they were also screened for other conditions in addition to pneumothorax. 136 patients who had experienced numerous traumas underwent ultrasonography. Patients who agreed to participate in the trial with their guardians' permission provided signed informed consent.

RESULTS: 136 patients who had experienced numerous traumas underwent ultrasonography. Twenty of them were disqualified due to a lack of a chest CT or a three-hour gap between the US and CT scan. There were 106 patients total, 20 in the resuscitation room, 86 in the intensive care unit, and 90 men and 16 women. The age distribution was 40±12 years. The majority of patients (51.5%), followed by falls (17.7%), crush injuries (8.6%), and other causes (6.2%), all experienced blunt trauma. 51.5% of the patient received mechanical ventilation. Nine patients had minor pneumothoraxes, six had medium-sized pneumothoraxes, and three had big pneumothoraxes in 18 true positive patients whose diagnoses were made by the US and confirmed by CT. One of the three false-positive patients experienced severe late acute respiratory distress syndrome, while the other two experienced pleural adhesion.

CONCLUSION: US is a fresh method for assessing PTX, with benefits including quickness, high accuracy, and high reliability. The usual training programs for doctors working in emergency and critical care settings should include the US abilities. There are numerous areas of current research because lung ultrasonography is a relatively young technology. For instance, new indications are still being recorded and described. The method for quantifying PTX size is still being researched. Moreover, cases of PTX diagnosis in patients undergoing mechanical ventilation or who have significant lung bullae are being recorded. For the diagnosis of pneumothorax and measurement of its size in patients with repeated trauma, clinician-performed US is a reliable tool.

KEYWORDS: Ultrasonography (US); Pneumothorax (PTX); Lung Point Computed Tomography (CT), Lung Sliding, Lung Point.

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INTRODUCTION:

Pneumothorax (PTX) is a medical emergency that needs to be managed quickly to prevent serious complications. In the emergency room, PTX is a significant contributor to respiratory failure, with an annual incidence rate of 22.7 cases per 100,000 people.[1] In emergency and critical care settings, prompt and accurate confirmation or exclusion of PTX is of the utmost importance. The plain chest X-ray (CXR) is a common technique for assessing PTX. However, it has been demonstrated that CXR, particularly when the patient is supine, has low sensitivity in detecting intrapleural air in trauma patients.[2,3] The presence of air in the pleura space is known as pneumothorax (PTX), which is a frequent issue in the intensive care unit. It can occur spontaneously, frequently as a result of trauma, or as a result of pathogenic factors like a central venous catheter, mechanical ventilation, thoracocentesis, and pulmonary biopsy.[4,5] Pneumothorax following trauma critical care unit admission and pneumothorax following intervention are two clinical situations that have been the subject of numerous research, and there have also been infrequent instances of spontaneous pneumothorax.[6] Portable chest radiography (CXR), which can miss more than half of all post-traumatic pneumothorax, has been shown to be an insensitive test for the identification of pneumothorax.[7,8] The most reliable method for finding pneumothoraxes is computed tomography, or CT. Nevertheless, it takes a long time and frequently involves moving seriously injured patients to the CT room, delaying diagnosis. At the bedside, ultrasonography (US) is simple to use. Ultrasound equipment has improved in image quality while shrinking in size, weight, and price because to technological advancements. Clinicians in the US have the option to evaluate seriously injured patients quickly. It has been demonstrated that its detection of pneumothorax has a greater sensitivity and specificity than CXR.[9,10] PTX is linked to a higher risk of intraventricular hemorrhage, chronic pulmonary illness, and passing away during respiratory distress. Successful emergency treatment and the ability to save neonatal lives depend on early diagnosis, precision, and quick discovery.[11] Clinical signs of pneumothorax include decreased auscultation airflow and hypolucent lung fields on chest ultrasonography. Regrettably, the first method of diagnosis has questionable accuracy, particularly for premature infants.[12] Historically, the chest X-ray was the primary tool used to diagnose pneumothorax. According to Wilson-Costello et al., when an LBW newborn is admitted to the hospital, an average of 31 radiographs are taken. The safety of radiation exposure at this dosage is still up for debate. The way different specialists interpret chest ultrasounds differs widely as well.[13] Also, it has been reported that detecting a tiny pneumothorax during the review of chest X-rays can be challenging, particularly in the case of preterm and low birth weight (LBW) infants.[14] According to numerous studies, pulmonary ultrasonography done on a patient's bedhead is just as effective as or even more effective than a traditional X-ray taken when the patient is lying flat.[15] The creation of diagnostic images is virtually impossible because the gas molecules formed in the lung scatter the sound waves emitted by the transducer in endless directions. Yet, they produce a number of artifacts whose examination we can employ to determine whether pneumothorax actually occurred. In actuality, assessing a pneumothorax using ultrasonography is only a study of artifacts. Modern technology has enabled point-of-care testing and inpatient ultrasound, while also making ultrasound machines smaller and more portable.[16]

Our goal is to describe the main ultrasound signs of pneumothorax, consider its practical clinical applications and recognize the possible limitations of this modality.

MATERIAL AND METHODS

The Department of Radiology has carried out this prospective investigation. Patients with multiple injuries were recruited, whether they were in the emergency intensive care unit (EICU) or the resuscitation room. All of the patients who were analyzed in this study underwent CT scans in addition to CXR and US tests. Only patients who had CT scans were included in studies that had patients with differential verifications. Only individuals who had been assessed for pneumothorax were included in a study if they were also screened for other conditions in addition to pneumothorax. 136 patients who had experienced numerous traumas underwent ultrasonography. Twenty of them were disqualified due to a lack of a chest CT or a three-hour gap between the US and CT scan. There were 106 patients total, 20 in the resuscitation room, 86 in the intensive care unit, and 90 men and 16 women. Patients who agreed to participate in the trial with their guardians' permission provided signed informed consent.

Inclusion criteria

- original, blinded trials examining the effectiveness of ultrasound in the detection of pneumothorax;
- studies involving sick populations (populations with known pneumothorax) were avoided;
- clarified in fully the diagnostic standards for pneumothorax on US
- met the criteria for quality as determined by the 14-item QUADAS-2 tool (Quality Assessment of Diagnostic Accuracy Studies).

Exclusion Criteria:

Those with subcutaneous emphysema and/or cardiac arrest following probable tension pneumothorax were excluded from the study.

Diagnosis of PTX

The presence of the following ultrasonographic features is often required to diagnose PTX: a stratospheric sign, abrogated lung sliding or lung pulsing, absence of B lines, and lung point. Lung point is a distinctive symptom of PTX that can be detected at the location where normal lung sliding and PTX coexist (see more descriptions and videos below). According to its pathophysiology, PTX is caused by trapped air in the pleural space detaching the visceral and parietal pleura. All ultrasonographic symptoms should be understood in the context of this PTX pathogenic process.

Diagnosis of pneumothorax by lung ultrasonography

At our department, a portable ultrasound machine is frequently utilized and always available. A 3.5 MHz convex probe and a 7.5 MHz linear probe were occasionally employed. The anterior, lateral, and posterior thoraces were examined while the patients were still lying on their backs.

Pleural line

The position of the ribs allowed for the precise delineation of the pleural line, an approximately horizontal hyper-echoic line between the upper and lower ribs, when the transducer was placed across the ribs longitudinally. With a higher frequency probe, even the parietal and visceral pleura could be recognized clearly.

Lung sliding

It was discovered that the respiratory excursion of the lung toward the abdomen was causing a forward-and-back movement of the visceral pleura against the parietal pleura. It had a "seashore sign" that featured immobile parietal tissue over the pleural line and was distinctive in the temporal motion mode.

Comet-tail artifacts

The pleural line produced a well-defined, laser-like hyper-echoic reverberation artifact that extended to the screen's edge. Alveolar and/or interstitial pulmonary edema are typically indicated by the presence of comet-tail artifacts.

The pneumothorax was measured and given the classification of small (70%). The ratio of the pneumothorax to pleural cavity volume, which could be automatically estimated by defining the margin of the pneumothorax and pleural cavity at various CT slices on the CT workstation, was the determining factor for lung CT. For lung US, the size of the pneumothorax was determined as follows: depending on the extent of the pneumothorax, the normal pleuro-pulmonary interface or the edge of the pneumothorax lies in the anterior, lateral, or posterior chest.

STATISTICAL ANALYSIS

Data were examined using the statistical program SPSS13.0 and represented as mean standard deviation (SPSS Inc., Chicago, IL, USA). Using a Kappa agreement test, the effectiveness of US and CXR for the identification of pneumothorax was compared to the gold standard (CT + chest drain). Low agreement is indicated by a Kappa value of less than 0.40, while close agreement with the gold standard is indicated by a value of more than 0.75. A paired Student t-test was used to compare how long it took to acquire US and CXR. Statistical significance was defined as a p-value 0.05.

RESULT: -

136 patients who had experienced numerous traumas underwent ultrasonography. Twenty of them were disqualified due to a lack of a chest CT or a three-hour gap between the US and CT scan. There were 106 patients total, 20 in the resuscitation room, 86 in the intensive care unit, and 90 men and 16 women. The age distribution was 40 ± 12 years. The majority of patients (51.5%), followed by falls (17.7%), crush injuries (8.6%), and other causes (6.2%), all experienced blunt trauma. 51.5% of the patients received mechanical ventilation.

Table 1: Efficacy for diagnosing pneumothorax in multiple trauma patients by clinician-performed ultrasonography and radiography

	Value	95% CI	Value	95% CI
Sensitivity	86.2 (20/25)	73.7–98.8	27.6 (5/25)	11.3–43.9
Specificity	97.2 (83/86)	94.0–100	100 (86/86)	100–100
Positive predictive value	89.3 (22/25)	77.8–100	100 (5/5)	100–100
Negative predictive value	96.3 (83/87)	92.7–99.9	83.5 (76/98)	77.0–89.9
False positive ratio	2.8 (3/86)	0–6.0	0 (0/86)	0–0
False negative ratio	13.8 (4/25)	1.2–26.3	72.4 (20/25)	56.1–88.7
Accuracy	94.8 (88/98)	91.1–98.6	84.4 (84/106)	78.3–90.6

Pneumothorax was present in 25 of the 106 trauma patients (21.5%), of which three had a bilateral pneumothorax, according to the gold standard (86 patients with CT scans and four patients with chest drains). The absence of both lung-sliding (N=25) and comet-tail artifacts (N=35) led the US to diagnose pneumothorax in 22 individuals, two of whom had bilateral pneumothoraxes. In comparison to CXR, the US had much higher diagnostic accuracy, negative predictive value, and sensitivity. According to the Kappa agreement test, US and CT had a better agreement than CXR did.

Table 2: Concordance in size determination of pneumothorax between ultrasonography and computed tomography in 21 true positive patients

		US		Total
Chest CT	**Large**	**Moderate**	**Mild**	**(CT)**
Large	2	0	0	2
Moderate	1	4	1	6
Mild	0	2	8	10
Total (US)	3	6	9	18

Nine patients had minor pneumothoraxes, six had medium-sized pneumothoraxes, and three had big pneumothoraxes in 18 true positive patients whose diagnoses were made by the US and confirmed by CT. One of the three false-positive patients experienced severe late acute respiratory distress syndrome, while the other two experienced pleural adhesion. Three patients had minor pneumothoraxes, and one patient had a locally separated pneumothorax, which caused false-negative results. In eight individuals with medium or large pneumothorax, CXR identified pneumothorax. 14 of the 15 patients with false negative CXR results who later suffered mild and medium pneumothoraxes. Among 25 pneumothorax patients, 16 had at least one chest injury, such as a hemothorax, lung contusion, rib fracture, or contusion of the chest wall. They also had a variety of symptoms and indications, such as dyspnea, chest discomfort, hypoxia, and tachycardia. Because to a significant clinical suspicion of a big or stress pneumothorax, four patients had their chest tubes placed; the US successfully identified all four of these cases. Chest drains were inserted immediately following the CT scan in nine patients with big or medium pneumothorax, resulting in an improvement in symptoms and oxygenation in seven individuals.

DISCUSSION

Pneumothorax is often diagnosed based on a combination of symptoms and a physical exam, with chest radiography or a CT scan providing additional confirmation. Due to alterations in the patient's state, the distance, and other circumstances, late radiography makes it challenging to detect pneumothorax. Moreover, 30% of all pneumothorax samples may be misdiagnosed, and the chest radiograph is not always accurate.[17,18]

According to Volpicelli et al.[19], the lung pulse sign has significant relevance since it "rules out pneumothorax even in the absence of lung sliding and B lines." This is crucial because, in a medical emergency, eliminating PTX can point clinicians to other possible causes of a decrease in oxygenation or respiratory distress. Examining the opposing side of the suspicious lung region is a helpful way to diagnose PTX. The identical patient's two lungs were sampled for these two video clips in the third intercostal gap at the mid-clavicular line.

28 studies were included in the Ebrahimi et al.[20] study, which demonstrated that the combined sensitivity and specificity of chest ultrasound were 0.87 and 0.99, respectively. They also conducted meta-regression, and the results demonstrated that an emergency physician had higher diagnostic accuracy when using US to diagnose PTX than a non-emergency physician. In non-trauma circumstances, higher pooled sensitivity was seen, but poorer specificity was noted. Only 13 original research publications were included in the Alrajab et al.[21] investigation, most likely as a result of more stringent selection criteria. Chest ultrasound (US) has been shown by Oveland et al.[22] to accurately measure the course of PTX during mechanical breathing. In a case study that our team published, we discovered a double lung point sign in a baby, and a chest CT scan later confirmed the PTX.[23]

Since the 1990s, at least twice as many minor pneumothoraxes have been diagnosed due to the increased use of CT.[24] Our findings show that US and CT have a good degree of agreement in the detection of minor and medium pneumothoraxes. Regarding the clinical management of patients with minor and medium pneumothoraxes, there is currently minimal information.[25] Kirkpatrick and colleagues[26] reported that two false positive diagnoses of left sided pneumothoraxes in trauma patients with left lung atelectasis resulted from right main-stem endotracheal intubation. In our study, pleural bonding was confirmed by CT was the cause of two out of every three erroneous positive findings. Third, if a pneumothorax is small or geographically separated, it may go unnoticed. A tiny pneumothorax typically develops in the anthropical or antero-basal area when the patient is supine.[27] As a result, a diagnosis cannot be made from a restricted examination of the second intercostal area. Even though the entire thorax was examined in our investigation, we failed to diagnose three minor pneumothoraces. Another explanation is that lung-sliding may be difficult to discern because of chest muscular contraction during spontaneous breathing. Those who are mechanically ventilated and temporarily paralyzed may help with diagnosis.

It is crucial to remember that a diagnostic test's performance is evaluated in part by its test characteristics, and a test's true worth ultimately depends on how it affects the course of the patient's condition. Our study did not address other crucial issues like the potential for harm as a result of the test (in our case, potential exposure to unnecessary procedures to treat a small pneumothorax or exposure to ionizing radiation), physician perception and confidence in test results, as well as the ability to base treatment decisions on test results. Future studies might be planned to evaluate the impact of two distinct testing approaches, one using US and the other using CXR, specifically for pneumothorax. The number of invasive procedures and follow-up exams resulting from the index test, as well as the overall condition-related cost of treatment, are potential outcome metrics. We anticipate that US will perform better than CXR in most respects and be safer, more practical, and more affordable.

CONCLUSION:

US is a brand-new method for assessing PTX, and it offers benefits including quickness, high accuracy, and high reliability. The usual training programs for doctors working in emergency and critical care settings should include the US abilities. There are numerous areas of current research because lung ultrasonography is a relatively young technology. For instance, new indications are still being recorded and described. The method for quantifying PTX size is still being researched. Moreover, cases of PTX diagnosis in patients undergoing mechanical ventilation or who have significant lung bullae are being recorded. For the diagnosis of pneumothorax and measurement of its size in patients with repeated trauma, clinician-performed US is a reliable tool. In comparison to CXR, it has the advantages of portability, simplicity, speed, and superior sensitivity and accuracy. When treating patients with numerous traumas in emergency departments, US is a helpful adjuvant.

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