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The use of lung ultrasound in the diagnosis of pneumothorax in trauma patients

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Abstract

Introduction and purpose: Pneumothorax is a condition in which air is present in the pleural cavity and often has a traumatic etiology. It can be a life-threatening condition, making quick and effective diagnosis essential. Chest ultrasound can be a useful study for this purpose.

A brief description of the state of knowledge: The sonographic signs of pneumothorax are absence of lung sliding, absence of B-lines, absence of lung pulse and presence of lung point. When a pneumothorax is suspected, the supine position is the most appropriate position for the patient. The sonographic technique consists of exploration of the least gravitationally dependent areas progressing more laterally. The bedside sonographic diagnosis of pneumothorax can be performed with most ultrasound machines without the need of any sophisticated functions. The average time to perform this examination varies from two to three minutes. In the most recent meta-analysis chest ultrasound sensitivity and specificity were 0.91 (95% CI: 0.85 to 0.94) and 0.99 (95% CI: 0.97 to 1.00), respectively. There was a significant difference in the sensitivity of CUS compared to CXR with an absolute difference in sensitivity of 0.44 (95% CI: 0.27 to 0.61; P<0.001).

Conclusions: Chest ultrasound is a safe, effective and sensitive method of diagnosing pneumothorax. It may be considered as the first study of trauma patients with suspected pneumothorax.

Key words: Pneumothorax; chest ultrasound; ultrasonography

1. Introduction and purpose

Pneumothorax is a condition in which air is present in the pleural cavity. This is the second most common consequence of a blunt chest injury[1]. It can quickly turn into a life-threatening condition that requires a quick response and adequate supply to avoid consequences that are dangerous for the patient[1,2]. Therefore, diagnosis as soon as possible is crucial. Traditionally, the first examination used is chest X-ray, but especially when performed in the supine position, it is characterized by low sensitivity[3–5]. This creates a problem because a large proportion of trauma patients are in the supine position. The gold standard in the detection of pneumothorax is computed tomography, which is able to visualize the occult pneumothorax, i.e. one that is not visible on a chest X-ray[6,7]. However, it also has limitations such as the dose of radiation taken by the patient, the cost, and the fact that some patients are not transportable for examination. Chest ultrasound is a study that has become more and more popular in intensive care units in recent years. It is non-invasive, portable and does not generate radiation. It is performed in a supine position and is accessible at the bedside, therefore it does not require transport and can be safely performed even during resuscitation. It is characterized by high sensitivity and specificity, which allows for an effective rule in and rule out the diagnosis of pneumothorax[4,8–10].

2. Description of the state of knowledge

The sonographic signs of pneumothorax are absence of lung sliding, absence of B-lines, absence of lung pulse and presence of lung point[10]. Lung sliding is the movement of the pleural line synchronous with tidal ventilation visualized in 2D[11]. When present, it means that the parietal and visceral pleura are in touch and regional ventilation is present, thus excluding pneumothorax[11,12]. Absence of lung sliding suggests pneumothorax with context-dependent accuracy[11,13]. However, it does not necessarily indicate a pneumothorax[14].

B-lines are vertical hyperechoic comet-tail artifacts deriving from the pleural line and moving synchronously with it. Their presence makes it possible to rule out pneumothorax[15].

The lung pulse refers to the subtle rhythmic movement of the visceral upon the parietal pleura with cardiac oscillations[10]. Its presence indicates that the parietal and visceral pleura are in touch but regional ventilation is impaired. It confirms absence of regional ventilation and rules out pneumothorax at the same time[16].

The described signs play a greater role in exclusion than in confirming pneumothorax, since their absence is not specific to pneumothorax. The presence of any of them makes it possible to rule out pneumothorax in a particular area of insonation. On the other hand, a symptom specific for pneumothorax is lung point[17]. It is the contact point between the collapsed lung and the pneumothorax air collection and is described as alternation of normal and abolished sliding during tidal ventilation[11]. Its presence confirms pneumothorax with a sensitivity of 66% and a specificity of 100%[18]. A lung point will be absent in complete pneumothorax where the lung is completely retracted to the hilum[5]. The location of the lung point may be used to provide a semi-quantitative estimate of the size of a pneumothorax[19]. In extreme emergency, absence of any movement of the pleural line, either horizontal (sliding) or vertical (pulse), coupled with absence of B-lines allows prompt and safe diagnosis of pneumothorax without the need for searching the lung point[10].

When a pneumothorax is suspected, the most appropriate position for lung ultrasound is supine because pleural air collects in the least dependent part of the thorax, or the anterior chest wall, which is highly accessible to ultrasound imaging[20]. According to the recommendations, in the supine patient, the sonographic technique consists of exploration of the least gravitationally dependent areas progressing more laterally. In most patients without pre-existing pleural diseases, the pneumothorax will be located in the least of the gravitationally dependent areas of the pleurac cavities. The bedside sonographic diagnosis of pneumothorax can be performed with most ultrasound machines without the need of any sophisticated functions[21]. During assessment for pneumothorax in adults, a microconvex probe is preferred. However, other transducer (e.g., linear array, phased array, convex) may be chosen based on physician preference and clinical setting[3,10,22]. High-frequency linear probe allows for higher resolution which translates into better visualization of superficial structures and the pleural line. A microconvex or curvilinear probe may be more suitable for deeper lung imaging as it provides better penetration. In cases where different diagnoses are taken into account and there is a need for a "whole-body" examination, the microconvex probe should be considered as the first choice[21,23]. Ultimately, the choice of transducer depends on the experience and preferences of the examiner.

The probe should be placed on anterior chest wall in sagittal orientation to allow visualisation of at least two ribs and the pleural line in between them. Then, following from medial to lateral, visualize the pleural line in 2nd-4th intercostal spaces, as this is where most of the pneumothoraxes will be visible. When in doubt, comparing images from the opposite site may facilitate diagnosis. M-Mode and Power Doppler also can be used[10,21,23]. The average time to perform this examination varies from two to three minutes[24,25].

In the most recent meta-analysis by Chan et al., which aimed to compare the effectiveness of the diagnosis of chest ultrasonography by frontline non-radiologist physicians versus supine chest x-ray for diagnosis of pneumothorax in trauma patients in the emergency department, ultrasonography had a sensitivity of 0.91 (95% CI: 0.85 to 0.94) and a specificity of 0.99 (95% CI: 0.97 to 1.00). In the same study, chest radiography had a sensitivity of 0.47 (95% CI: 0.31 to 0.63) and a specificity of 1.00 (95% CI: 0.97 to 1.00). This study included 13 prospective, paired comparative accuracy studies in which patients were suspected of having pneumothorax. There was a significant difference in the sensitivity of CUS compared to CXR with an absolute difference in sensitivity of 0.44 (95% CI: 0.27 to 0.61; P<0.001). The results of this meta-analysis show that the diagnostic accuracy of chest ultrasonography performed by frontline non-radiologist physicians was superior to supine CXR for diagnostic traumatic pneumothorax in trauma patients[4].

Staub et al.'s study included 14 studies in the primary analysis. This meta-analysis was designed to evaluate the effectiveness of chest ultrasonography in emergency diagnosis of traumatic pneumothorax in adult patients. Studies included patients with different types of trauma (multiple trauma, blunt or penetrating chest trauma, blunt or penetrating torso trauma). All the studies used chest computed tomography as the reference standard. Reported experience and training differed from study to study. Chest ultrasonography had AUC of 0,979 for the diagnosis of traumatic pneumothorax (sensitivity 95% CI: 0.75-0.90, specificity 95% CI: 0.97-0.99). This study shows that lung ultrasound has good sensitivity in detecting pneumothorax in trauma patients and can be a good diagnostic tool[26].

Another meta-analysis compared the effectiveness of chest ultrasonography with that of a chest radiography. 19 studies were included in the subgroup of trauma patients. The pooled sensitivity and specificity for chest ultrasound in this subgroup were 0.85 (95% CI: 0.78-0.91) and 0.99 (95% CI: 0.99-1.00), respectively. In the same subgroup, the sensitivity and specificity for chest radiography were 0.46 (95% CI: 0.35-0.57) and 0.99 (95% CI: 0.96-0.99), respectively. Additionally, a meta-regression was performed which showed that the sensitivity and specificity of the ultrasound was higher when performed by the emergency physician (0.88 (95% CI: 0.78-0.91) and 0.99 (95% CI: 0.98-1.00) vs 0.81 (95% CI: 0.73-0.90) and 0.98 (95% CI: 0.96-0.99))[9].

3. Conclusions

Chest ultrasound is a sensitive method of diagnosing pneumothorax. It can be successfully used for this purpose in patients with chest injuries. It is a more precise method than chest radiography and should be considered as an initial diagnostic strategy in trauma patients with suspected pneumothorax.

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