Features of Lung Ultrasound and Chest Radiology in Diagnosing of Pleural Effusion in Critical Care Patients: A Systematic Review

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Abstract

Introduction: Pleural effusion (PLEFF) is mainly caused by volume overload, heart failure, trauma, and pleuro-pulmonary infection, it is common in emergency and ICU patients. Although the function of ultrasonography in detecting PLEFF has long been noted, controversial results have been reported. This study aimed to review the literature on ultrasound and radiography in detecting PLEFF.

Methods: A search was done in Medline, ISI Web of Knowledge, EMBASE, and Scopus databases. Two reviewers independently searched, screened, and included the data and a third author resolved any conflict.

Results: The findings proved that as a screening tool, chest ultrasound has greater diagnostic accuracy in identifying multiple pleural effusions than radiography. Chest ultrasound enables clinicians visualize pleural effusions and also helps differentiate between various types. In addition, chest ultrasound is crucial for thoracentesis and thoracostomy drainage as it enhances safeness and reduces life-threatening complications. This is important not only when inserting a needle or tube drain, but also when monitoring the amount of her PLEFF deflated. In addition, chest ultrasound is often more specific and sensitive than chest radiography, helping to diagnose coexisting lung disease without X-ray exposure.

Conclusion: Thoracic Ultrasound (TUS) is a simple, non-invasive, bedside procedure for diagnosing PLEFF with greater sensitivity and specificity than a chest X-ray. This is crucial for visualizing exudate and helps differentiate various forms of her PLEFF. More recently, ultrasound has been used to guide thoracentesis and insert chest tubes to raise the safeness of this invasive method, especially if an ICU patient is on a ventilator or has a small localized pleural effusion. Additionally, TUS can monitor the PLEFF drainage and determine when to extract the drainage.

Keywords: Ultrasonography, CT scan, radiology, Pleural Effusion.

Introduction

Several situations can cause PLEFF, but the most common causes in the ICU and emergency department are volume overload, heart failure, trauma, and pleuro-pulmonary infections1-3. Fluid accumulation can happen because of hydrostatic and osmotic imbalances within pulmonary capillaries, raised pleural capillary permeability, and lymphatic obstruction4-7. In addition, characteristics known to promote the formation of pulmonary edema in clinical practice (fluid overload, myocardial depression, hypoalbuminemia) are usually coexisting, and the usually high absorptive capacity of the lungs and parietal pleural lymphatics. Beyond this may lead to the worsening of PLEFF-leading symptoms8-10.

PLEFF can be detected by physical assessment. The absence of breath sounds on auscultation, flatness in beats, and decreased tactile nodule muscles in patients who can speak all indicate the existence of PLEFF. Nevertheless, the physical examination of critically ill patients can be complex because several factors can alter intrathoracic sound transmission11-14. As a result, several studies have shown that physical examination
has lower specificity and sensitivity for diagnosing pleural effusion than imaging. Ultrasound is not yet considered the primary diagnostic instrument for detecting PLEFF, and most physicians utilize radiography to detect PLEFF\textsuperscript{15}. X-ray images taken horizontally in the lateral position have high sensitivity and specificity in detecting PLEFF. Still, not all patients, especially those with severe illness or trauma, can obtain them. PLEFF occurs often in emergency and ICU cases with an incidence that varies according to the diagnostic procedure\textsuperscript{16-18}. Also, it is associated with an increased mortality rate. PLEFF can impair gas exchange, hemodynamic stability, and respiratory dynamics. Drainage improves ventilation, thereby improving oxygenation, respiratory mechanics, and compliance. Perfusion rate and re-expansion of collapsed lung parenchyma. Percutaneous pleural drain insertion is often performed in intensive care units, but incorrect tube insertion can have tragic outcomes. Complications from chest tube placement have been reported in up to 20-30% of cases. Some of these complications can be lethal\textsuperscript{19-21}. Although the function of ultrasonography in detecting PLEFF has long been noted, controversial results have been reported. This study aimed to review the literature on ultrasound and radiography detecting PLEFF.

**Method**

We followed recommended reporting methods for systematic reviews and guidelines for meta-analyses. For suitable studies, we searched PUBMED, SCOPUS, Web of Science, and Google Scholar databases (1997-2023).

Studies using radiography as a reference test were excluded, and only studies in which the definitive diagnosis of pleural effusion was confirmed by CT or surgery were included. Articles from keywords such as “Ultrasonography” OR “Ultrasound” OR “Sonography” OR Pocket-size ultrasound OR “Chest Film” OR CT scan” OR X-ray OR “Chest Radiograph” combined with “Pleural Effusion” OR “Effusion” OR “Pleural Free Fluid” were used. The online databases searched Terms and words using the ‘And’ and ‘Or’.

Two reviewers independently filtered documents for title, abstract, and methodological validity using a data extraction format before inclusion in the final review. Conversations with senior faculty were used to resolve judge disagreements during the judging stage.

**Result**

Search process and the number of articles obtained in each step are presented in Table 1. Twenty-one studies met the inclusion criteria. One survey was also found through manual search. After detailed evaluation of these surveys 12 studies were included.

The characteristics of included studies are presented in Table 1. The mean age ranging from 4 to 74 years old. The results showed that ultrasonography has high sensitivity and specificity in detecting PLEFF. However, the diagnostic value of radiography has been reported to be lower than ultrasonography. Radiographic sensitivity increased slightly when the analysis was restricted to studies in which the cause of pleural effusion was trauma, surgery, or heart failure. The finding proved that ultrasound is a better detection instrument for PLEFF than radiography.

To prove a suspected diagnosis of PLEFF, utilizing the following imaging tests in studies was suggested:

Plain chest x-ray, ultrasonography, chest computed tomography. CT is assumed to be the gold standard but is expensive and challenging to accomplish in emergency and ICU patients. Cardiophrenic angle blunting, costophrenic angle blunting, and lung opacification can demonstrate pleural effusion.

Nevertheless, technological limitations such as the prone position, posterior-anterior view, and comorbid pulmonary parenchymal disease may donate to substandard radiographic imaging and underdiagnoses of pleural effusion. Exudates as small as 50 mL may be visual on upright lateral X-ray images. However, conventional posterior-anterior imaging requires a volume of at least 200 ml; a volume of around 500 ml destroys the hemidiaphragm. Due to the deep posterior costophrenic angle, his lateral PU radiograph may show less fluid than the poster anterior radiograph. However, an upright or lateral recumbent position is unbelievable in intensive care cases.

Ultrasound measures exudate size more accurately than X-rays of lateral pressure ulcers. A study performed analogizing research ultrasound with lateral PU radiography to detect pleural effusion. They followed that ultrasonography could see pleural effusions less than 15 mm\textsuperscript{13}. As a result, several studies have concentrated on introducing ultrasound in the intensive care to reduce the number of chest radiography studies.
to decrease X-ray exposure and acquire more precise data\textsuperscript{22-38}.

Table 1: Studies’ characteristics.

<table>
<thead>
<tr>
<th>Authors’ name</th>
<th>patients</th>
<th>Number</th>
<th>Age</th>
<th>Groups</th>
<th>outcomes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jacobson et al. (2022) \textsuperscript{21}</td>
<td>thoracic surgical patients</td>
<td>80</td>
<td>55.29</td>
<td>Ultrasonography/chest X-ray</td>
<td>60% of pleural effusions were missed by chest X-ray and detected by ultrasonography, and only 2.4% were missed by ultrason.</td>
</tr>
<tr>
<td>Phung et al. (2020) \textsuperscript{22}</td>
<td>Acute Dyspnea</td>
<td>81</td>
<td></td>
<td>Ultrasonography/chest X-ray</td>
<td>100% vs 73.3%</td>
</tr>
<tr>
<td>Tasci et al. (2016) \textsuperscript{23}</td>
<td>Critically ill patients</td>
<td>55</td>
<td>&lt;5</td>
<td>Portable Ultrasonography/sector Ultrasonography/chest radiography/Auscultation</td>
<td>98% vs. 95% vs 89% vs 87%</td>
</tr>
<tr>
<td>Inglis et al. (2016) \textsuperscript{24}</td>
<td>critically ill patients</td>
<td>145</td>
<td>62</td>
<td>Ultrasonography, chest X-ray/physical examination</td>
<td>fair-to-moderate agreement to detection PLEFP</td>
</tr>
<tr>
<td>Lichtenstein et al. (2004) \textsuperscript{25}</td>
<td>Acute Respiratory Distress Syndrome</td>
<td>32 patients and 10 healthy volunteers</td>
<td>58</td>
<td>Ultrasonography/chest X-ray</td>
<td>93 %accuracy vs 47 %</td>
</tr>
<tr>
<td>Ma et al. (1997) \textsuperscript{26}</td>
<td>hemothorax in trauma patients</td>
<td>245</td>
<td>18</td>
<td>Ultrasonography/chest X-ray</td>
<td>96%</td>
</tr>
<tr>
<td>Kitazono et al. (2010) \textsuperscript{27}</td>
<td>Critically ill in ICU</td>
<td>117 vs 83</td>
<td>54</td>
<td>chest X-ray</td>
<td>66%</td>
</tr>
<tr>
<td>Rocco et al. (2008) \textsuperscript{28}</td>
<td>Thoracic trauma</td>
<td>15</td>
<td>42</td>
<td>Ultrasonography/chest X-ray</td>
<td>94% vs 42%</td>
</tr>
<tr>
<td>Zanobetti et al. (2011) \textsuperscript{29}</td>
<td>dyspnea</td>
<td>404</td>
<td>73</td>
<td>Ultrasonography/chest X-ray</td>
<td>63% vs 40%</td>
</tr>
<tr>
<td>Xirouchaki et al. (2011) \textsuperscript{30}</td>
<td>Critically ill patients</td>
<td>84</td>
<td>57</td>
<td>Ultrasonography/chest X-ray</td>
<td>100% vs 69%</td>
</tr>
<tr>
<td>Schleder et al. (2012) \textsuperscript{31}</td>
<td>hemithoraces</td>
<td>48</td>
<td>65</td>
<td>hand-carried ultrasound/ chest radiography</td>
<td>91% vs 74%</td>
</tr>
<tr>
<td>Kasraei et al. (2016) \textsuperscript{32}</td>
<td>Critically ill patients in ICU</td>
<td>39</td>
<td>54</td>
<td>portable ultrasound/chest radiography</td>
<td>100% vs 33%</td>
</tr>
<tr>
<td>Gazon et al. (2011) \textsuperscript{33}</td>
<td>Critically ill patients in ICU</td>
<td>50</td>
<td>62.4</td>
<td>Ultrasonography/chest X-ray</td>
<td>Moderate agreement</td>
</tr>
<tr>
<td>Graven et al. (2015) \textsuperscript{34}</td>
<td>cardiac surgery</td>
<td>59</td>
<td>67</td>
<td>Pocket-size ultrasound/chest X-ray</td>
<td>Sensitivity 98% vs 40%</td>
</tr>
<tr>
<td>Sachdev et al. (2021) \textsuperscript{35}</td>
<td>Critically ill patients in ICU</td>
<td>413</td>
<td>4</td>
<td>Ultrasonography/chest X-ray</td>
<td>89% vs 47.6%</td>
</tr>
<tr>
<td>Dalen et al. (2015) \textsuperscript{36}</td>
<td>heart failure patients</td>
<td>62</td>
<td>74</td>
<td>Pocket-size ultrasound/chest X-ray</td>
<td>all diagnosis criteria≥ 92%</td>
</tr>
<tr>
<td>Stock et al. (2015) \textsuperscript{37}</td>
<td>internal-medicine</td>
<td>28</td>
<td>68</td>
<td>high-end ultrasound/Ultrasonography</td>
<td>concordantly 73%, ascites, fatty liver, and identification of severe parenchymal liver damage, sensitivity 80%</td>
</tr>
<tr>
<td>Kataoka et al. (2000) \textsuperscript{38}</td>
<td>Chronic heart failure</td>
<td>60 patients and 22 free from disease</td>
<td>76</td>
<td>Ultrasonography/chest X-ray</td>
<td>93 %accuracy vs 43 %</td>
</tr>
</tbody>
</table>
Discussion

The findings of this study prove that chest ultrasound is a beneficial and noninvasive technique for detecting PLEFF in emergency and ICU patients. However, chest ultrasound is preferable to decubitus radiography in diagnosing the volume of effusion fluid, so the diagnostic power of sonography is greater than radiography in the same thickness of effusion fluid. Moreover, the superiority of ultrasonography in diagnosing pleural effusions is recognized in a growing body of professional literature. Kataoka et al. (2000) compared chest ultrasonography with physical examination and upright poster anterior chest radiographs to diagnose pleural effusion in patients with chronic heart failure. They reported diagnostic accuracy of 91% for chest ultrasound, compared with 56% for physical examination and 33% for radiography. Lichtenstein et al. conducted a prospective study comparing the accuracy of physical examination, ultrasonography, and chest radiography with chest CT in 32 patients with acute respiratory distress syndrome and ten volunteers. Lung ultrasonography had a sensitivity of 92%, a specificity of 93%, and a diagnostic accuracy of 93%. Bedside chest radiography and physical examination showed low sensitivity, specificity, and diagnostic accuracy of PLEFF. Rocco et al. (2008) compared bedside radiography and ultrasound for diagnosing pleural effusions in trauma patients. They demonstrated that ultrasound is more accurate than X-rays for detecting pleural effusions. Xirouchaki et al. (2011) compared the diagnostic performance of bedside ultrasonography and chest radiography in intensive care cases. For pleural effusion diagnosis, ultrasound demonstrated 100% sensitivity, 100% specificity, and 100% diagnostic accuracy, whereas X-ray was 65%, 81%, and 69%, respectively. Therefore, the International Consensus Conference on Lung Ultrasound states that “pulmonary ultrasound is more precise than supine radiography and as accurate as CT for detecting pleural effusions”. In particular, ultrasound may help determine the character of the pleural effusion while ruling out pre-existing lung pathology.

Compared with the current research results, another study reported similar results. They found that the sensitivity and specificity of ultrasonography were calculated to be 93% and 96%, respectively, whereas the values of radiography were estimated to be 24% and 100%, respectively. Our results were similar to Yousefifard et al. (2016) study, and they showed that the higher sensitivity of the radiography in this study might be due to the inclusion of additional investigations in the analysis. Grimberg’s study lacked subgroup analysis, so no other comparisons were possible. A further meta-analysis considered his ten papers to evaluate the diagnostic value of ultrasonography in diagnosing pneumonia. They discovered a sensitivity of 94% and a specificity of 96% for this tool.

This study showed lung ultrasound is a practical diagnostic modality for detecting pneumonia in critical care patients. Congruent with this study, the current study reported a significant diagnostic value for ultrasonography in detecting PLEFF. One aspect that impacts ultrasonography's accuracy is the ultrasound device's operator and machine, demonstrated by different studies.

Conclusion

Lung ultrasound is a simple, non-invasive, bedside procedure for diagnosing PLEFF with greater sensitivity and specificity than a chest X-ray. This is crucial for visualizing exudate and helps differentiate various forms of her PLEFF. More recently, ultrasound has been utilized to conduct thoracentesis and insert chest tubes to raise the safeness of this invasive method, especially if ICU patients are on a ventilator or have a bit of localized PLEFF. Also, the Lung ultrasound must monitor PLEFF drainage and choose when to pull the drainage.

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Conflict of Interest Disclosures

None.

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Authors’ Contributions

All the authors have contributed to developing the concept and producing the final manuscript.

Ethical Statement

It did not involve data collection at an individual level.
or human subjects.

References


