Discrimination between pleural thickening and minimal pleural effusion using color Doppler chest ultrasonography

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Abstract  Background: The discrimination of pleural thickening from minimal pleural effusion may be difficult as both lesions appear as anechoic on grayscale ultrasound, hence, free of “echoes” does not confirm the presence of pleural fluid.

Aim of this study: To evaluate the value of color Doppler ultrasound in differentiating minimal pleural effusion that could be aspirated from pleural thickening and to compare it with grayscale ultrasound.

Patients and methods: This analytic cross-sectional study was done prospectively on 40 patients who presented with pleural based opacity in their chest radiographs compatible with minimal pleural effusion. Gray scale ultrasound was done for all patients then color Doppler ultrasound examination was applied to detect the presence or absence of fluid color sign. The presence or absence of pleural effusion was confirmed by aspiration of pleural fluid.

Results: The sensitivity of real time gray scale ultrasound in detecting minimal pleural effusion and differentiating it from pleural thickening was 95.5% while, specificity was 33%, and accuracy was 67%. The ability of ultrasound in discrimination of minimal pleural effusion from pleural thickening improved greatly by application of the color Doppler examination where the specificity of the method reached 100% while the sensitivity was 91% and accuracy was 95%.

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Introduction

Pleural thickening and fibrosis may resemble pleural effusion in plain chest X-ray or even in CT chest and this may lead to invaluable trial for needle aspiration. Small amounts of pleural effusion can be detected with ultrasound. Using chest ultrasound, pleural effusion appears as an echo-free space between both parietal and visceral pleura and shape of this may be changed with respiration [1].

The discrimination of pleural thickening from minimal pleural effusion may be difficult as both lesions can appear as anechoic on grayscale ultrasound, therefore, free of “echoes” does not guarantee the presence of pleural fluid [2,3]. As any movement of body fluid may be translated into colored images, color Doppler imaging was recently used to solve this problem. It was observed that color signal may appear within the fluid collection in the pleural space during respiratory and cardiac cycles (“fluid color sign”) [4]. In case of pleural thickening no colored signals are detected as pleural thickening has no movable part [5]. This study was to evaluate the accuracy of color Doppler ultrasound in differentiating minimal pleural effusion that could be aspirated from pleural thickening and to compare it with grayscale ultrasound.

Patients and methods

This analytic cross-sectional study was carried out on 40 patients suspected to have minimal pleural effusion based on their chest X-ray. They were selected from those attended to the Chest Department, Assiut University Hospitals, Egypt.

Informed consent was obtained from each participant and the study was approved by the Faculty of Medicine Ethical Committee.

Method

The followings were done for the enrolled patients: After medical history and physical examination pleural effusion was suspected firstly by the presence of blunting of lateral costophrenic angle on upright posteroanterior radiographs and blunting of the posterior costophrenic angle on lateral radiographs [1]. Gray scale ultrasound was done by an ultrasound scanner (Aloka Echo Camera SSD-3500; Aloka Prosound; Japan) equipped with a 3.5-MHz convex probe to detect the presence of pleural effusion. The scanning was done using the intercostals space as an acoustic window with the patient in a sitting or supine position rising his arms above his head to widen the intercostal space and facilitate scanning. On ultrasound gray scale pleural effusion appeared as an anechoic layer between the visceral pleura and the parietal pleura [1]. Split pleural signs, the internal echogenicity of the effusion, the change of shape during respiration, the presence of the mobile septa, and thickening of the pleura and the presence of organized fluid in the pleural space were analyzed.

Before the start of the Color Doppler ultrasound examination, the Doppler filter is usually set at 50–100 Hz to eliminate low-frequency signals from vessel wall motion and avoid interference from respiratory and cardiac movement. Color Doppler gain is also adjusted until only a few noise specks are visible in the background [6–8]. During scanning the patients with color Doppler, the sensitivity of the Doppler should be set to low flow or the low-velocity scale (typically 0.25 m/sec) [1]. As pleural thickening has no movable part, the colored signals will not be detected in cases of pleural thickening [5]. Finally the diagnosis of aspirable pleural effusion was followed by needle aspiration to confirm the presence of pleural fluid [4].

Statistical analysis

Statistical analysis was performed using Statistical Package for the Social Sciences (SPSS-version 17) software. The results were expressed as mean ± standard deviation or frequencies. Proportions were compared with chi-square tests. The sensitivity, specificity, accuracy positive predictive value and negative predictive value were calculated as follows:

Sensitivity = true positive / true positive + false negative
Specificity = true negative / true negative + false positive
Accuracy = true positive + true negative / true positive + false positive + true negative + false negative
Positive predictive value = true positive / true positive + false positive
Negative predictive value = true negative / true negative + false negative

Results

Forty patients, 27 men and 13 women with mean age 43.77 ± 16.47 were evaluated for the presence of minimal pleural effusion (Table 1).

Pleural effusion was confirmed by aspiration in 22 (55%) out of 40 cases. The remaining 18 (45%) cases had pleural thickening. Real time gray scale ultrasound showed anechoic area between the visceral and parietal pleura compatible with pleural effusion in 33 (85.5%) patients from a total of 40 patients while the remaining 7 cases (15.5%) were diagnosed as pleural thickening. However, by color Doppler ultrasound pleural effusion was detected in 20 (50%) patients and pleural thickening was diagnosed in 20 (50%) patients (Table 2).

Real time gray scale ultrasound detected pleural effusion in 21 patients from a total of 22 patients with confirmed pleural effusion by aspiration with a sensitivity 95.5%. However, in another 12 patients whose pleural effusion had not been confirmed; gray scale US showed pictures compatible with pleural effusion (12 false positive cases). From 18 patients without pleural effusion, gray scale ultrasound showed pleural
thickening with organization in the pleural space in only 6 patients. Therefore, real time gray scale ultrasound has a low specificity in discrimination of minimal pleural effusion from pleural thickening (33.3%) with accuracy, PPV and NPV being 67.5%, 63.6% and 85.7%, respectively (Table 3).

Color Doppler chest ultrasound detected the fluid color sign in 20 patients from the total of 22 patients with confirmed pleural effusion by aspiration, with a sensitivity of 90.9%.

The fluid color sign was absent in all patients with pleural thickening (no false positive results), and hence it results in a higher specificity of color Doppler ultrasound (specificity 100%) in discrimination of minimal pleural effusion from pleural thickening. The accuracy, PPV, NPV of color Doppler ultrasound in this situation were 95%, 100% and 90%, respectively (Table 3).

Figure 1A shows plain chest X-ray of right pleural based opacity following drainage of right empyema and Figure 1B shows gray scale ultrasound which shows anechoic lesion compatible with pleural effusion. Figure 1C shows color Doppler US of the same patient which shows absence of fluid color sign which means pleural thickening. In Figure 2A plain chest X-ray shows left pleural based opacity. In Figure 2B gray scale ultrasound shows anechoic lesion compatible with pleural effusion while, in Figure 2C color Doppler US of the same patient shows presence of fluid color sign which confirms the presence of pleural effusion.

**Discussion**

Pleural diseases are common clinical conditions and imaging studies are the cornerstone in its management. Although chest X-ray is the initial diagnostic tool because of its availability, accuracy and low cost, it is less sensitive as at least 150 ml must be present for a pleural effusion to be detected on an upright chest X-ray [9]. In addition many pleural lesions as pleural thickening and fibrosis may mimic minimal pleural effusion in plain radiograph. Chest ultrasonography has a well documented role in diagnosis of pleural effusion as it is primarily used to confirm the presence of effusion in a patient with abnormal chest radiographs being able to detect as little as 5–50 ml of pleural fluid, with 100% sensitivity for effusions of 100 ml or more [10,11].

Ultrasonography has the advantage of being portable, low cost, lack of radiation exposure, and ability to perform dynamic and real-time procedural guidance at the bedside [12].

In the current study, real time gray scale ultrasound has high sensitivity (95.5%) but low specificity in discrimination of minimal pleural effusion from pleural thickening (33.3%).

On gray scale US, pleural fluid appears as an anechoic lesion in the pleural space and characterized by changing its shape with respiratory movement. The presence of movable septae also confirms the presence of effusion which could be aspirated. However, loculated and minimal fluid collections lack these criteria [13–15]. Moreover, some pleural lesions other than fluid may appear as focal echogenic lesions on gray scale US arising from the visceral or parietal pleura. Pleural thickening is an example of these lesions. So, it is important to differentiate these lesions from each other before thoracentesis and this differentiation may be difficult with gray scale US [16].

<table>
<thead>
<tr>
<th>Table 1</th>
<th>Demographic data of the study group.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Variable</td>
<td>Study group (n = 40)</td>
</tr>
<tr>
<td>Age (years)</td>
<td>43.77 ± 16.47</td>
</tr>
<tr>
<td>Gender</td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>27 (67.5%)</td>
</tr>
<tr>
<td>Female</td>
<td>13 (33.5%)</td>
</tr>
</tbody>
</table>

Data are expressed as mean ± SD or number (%)

<table>
<thead>
<tr>
<th>Table 2</th>
<th>Evaluation of the pleural effusion and pleural thickening using different modalities.</th>
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</thead>
<tbody>
<tr>
<td>Variable</td>
<td>Pleural effusion (True positive + false positive)</td>
</tr>
<tr>
<td>Chest X-ray</td>
<td>40 (100%)</td>
</tr>
<tr>
<td>Gray scale US</td>
<td>33 (82.5%)</td>
</tr>
<tr>
<td>Color Doppler US</td>
<td>20 (50%)</td>
</tr>
<tr>
<td>Pleural fluid aspiration</td>
<td>22 (55%)</td>
</tr>
</tbody>
</table>

US = ultrasound.

<table>
<thead>
<tr>
<th>Table 3</th>
<th>Sensitivity, specificity, accuracy, PPV and NPPV of Gray scale and Color Doppler US in the studied patients.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Variable</td>
<td>Gray scale US</td>
</tr>
<tr>
<td>TP</td>
<td>21</td>
</tr>
<tr>
<td>FP</td>
<td>12</td>
</tr>
<tr>
<td>TN</td>
<td>6</td>
</tr>
<tr>
<td>FN</td>
<td>1</td>
</tr>
<tr>
<td>Sensitivity</td>
<td>95.5%</td>
</tr>
<tr>
<td>Specificity</td>
<td>33.3%</td>
</tr>
<tr>
<td>Accuracy</td>
<td>67.5%</td>
</tr>
<tr>
<td>PPV</td>
<td>63.6%</td>
</tr>
<tr>
<td>NPV</td>
<td>85.7%</td>
</tr>
</tbody>
</table>

TP = number of true positive results, FP = number of false positive results, FN = number of false negative results, TN = number of true negative results, PPV = Positive predictive value, NPV = Negative predictive value, US = ultrasound. Sensitivity = TP/TP + FN. Specificity = TN/TN + FP. Accuracy = TP + TN/TP + FP + TN + FN. Positive predictive value = TP/TP + FP. Negative predictive value = TN/TN + FN.
The color Doppler ultrasound is useful in such situations to evidence the presence of fluid color sign which confirms the presence of fluid in the pleural space [4,17–19].

Tsai and Yang [17] found that the presence of an echo-free space between the visceral and parietal pleura that changes shape with respiration or contains movable strands or echo densities on grayscale US, or displays a fluid color sign on color Doppler US, indicates the presence of fluid accumulation [16].

In our study the presence of pleural fluid was confirmed by aspiration in 22 cases and this was considered as the gold standard for the presence of pleural fluid. Moreover, Color

Figure 1  (A) Plain chest X-ray (Posteroanterior view) showed persistent right pleural based opacity following intercostals tube drainage of right empyema (Arrow). (B) Gray scale US showed anechoic lesion compatible with pleural effusion (Arrow). (C) Color Doppler US showed the absence fluid color sign which means pleural thickening (Arrow).

Figure 2  (A) Plain chest X-ray (Posteroanterior view) showed minimal left pleural based opacity (Arrow). (B) Gray scale US of showed anechoic lesion compatible with pleural effusion (Arrow). (C) Color Doppler US showed the absence fluid color sign which means pleural thickening (Arrow).

Figure 3  (A) Plain chest X-ray (Posteroanterior view) showed left pleural based opacity (Arrow). (B) Gray scale US showed anechoic lesion compatible with pleural effusion (Arrow). (C) Color Doppler US showed the presence of fluid color sign which means pleural effusion (Arrow).
Doppler US has higher sensitivity and specificity for detecting minimal pleural effusion (90.9% and 100%, respectively) and accuracy 95% which was in concordance with those of Wu et al. [18] where they studied 51 patients and found sensitivity 94.3% and 100% specificity of color Doppler ultrasound. In our study false negative results were reported in 2 cases which may occur if the color gain was set inappropriately low. There was no false positive result in our study as all cases with positive fluid color sign had pleural effusion which could be aspirated. Also, this agreed with Kalokairinou-Motogna et al. [1] who reported that if the technical method is correct, there are no false-negative results, the fluid color sign having specificity 100%. Wu et al. [4] reported a relatively high sensitivity (89.2%) and specificity (100%) of the fluid color sign in detecting minimal fluid collection that have been shown in a study comprising 76 patients.

In the present study, despite the higher sensitivity of real-time, gray-scale for detecting minimal effusion is less specific as aspiration is failed in many cases fulfilling the criteria of pleural fluid in gray scale scanning. Color Doppler US with its higher specificity can overcome this drawback of gray scale US.

Conclusion

Application of color Doppler examination increases the accuracy of real-time chest ultrasound to discriminate pleural thickening from minimal pleural effusion and hence color Doppler examination proved to be a useful diagnostic tool when added to real-time gray-scale ultrasound for the diagnosis of minimal pleural effusion.

Acknowledgment

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References


