Medical Ultrasonography
2010, Vol. 12, no. 1, 12-16

Application of color Doppler ultrasound in the study of small pleural effusion

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Abstract

Aims: To compare the results of gray scale ultrasound with those of color Doppler ultrasound in order to evaluate the minimal pleural effusion and to differentiate the minimal pleural effusion from pleural thickening. **Patients and methods:** We prospectively analyzed 86 patients who, according to their chest radiographs, were suspected of having minimal pleural effusion. All patients were examined by ultrasonography on gray scale and color Doppler and the presence or absence of pleural effusion was confirmed by thorax CT. Using the color Doppler examination we analyzed the fluid color sign of pleural effusion. **Results:** In our study, the ultrasonography on gray scale in real time detected pleural effusion with 60% specificity, 100% sensitivity and 88,37% accuracy. By applying the color Doppler the specificity of the method is higher (specificity 100%, sensitivity 96.72% and accuracy 97,57%). **Conclusions:** The evidence of pleural effusion on grayscale ultrasound has a greater sensitivity than that of color Doppler ultrasound, but has a smaller specificity. Therefore, color Doppler ultrasound proved to be a useful diagnostic aid in gray-scale ultrasound for the assessment of minimal effusion, having the highest accuracy.

Keywords: pleural effusion, ultrasound on gray scale, color Doppler ultrasound, fluid color sign

Rezumat

Scop: De a compara rezultatele examinării ecografice în scala gri cu cele date de ecografia Doppler color în scopul de a evalua colecția pleurală minimă şi de a o diferenția de îngroşarea pleurală. **Pacienți şi metode:** Am efectuat o analiză prospectivă pe un lot de 86 pacienți cărora, pe baza radiografiei toracice, li s-a pus diagnosticul de suspiciune de colecție pleurală minimă. Toți pacienții au fost examinați prin ultrasonografie în scala gri şi Doppler color, iar prezența sau absența colecției pleurale a fost confirmată prin tomografie computerizată toracică. Folosind examinarea Doppler color am analizat semnul color al fluidului apărut în cadrul colecției pleurale. **Rezultate:** In studiul nostru, ecografia în real time pe scala gri a detectat colecția pleurală cu o specificitate de 60%, sensibilitate de 100% şi acurateţe de 88,37%. Prin aplicarea ecografiei Doppler color specificitatea metodei a fost mai ridicată (specificitate 100%, sensibilitate 96,72% şi acurateţe 97,57%). **Concluzii:** Evidențierea colecției pleurale prin ecografie în scala gri are o sensibilitate mai ridicată decât cea dată de Doppler color, dar o specificitate mai scăzută. Deci, ecografia Doppler color s-a dovedit a fi un instrument diagnostic util ce vine în ajutorul ecografiei în scala gri în aprecierea colecției pleurale minime, având o acurateţe mai ridicată.

Cuvinte cheie: colecție pleurală, ecografie în scala gri, ecografie Doppler color, semnul color al fluidului

Introduction

Pleural effusion, defined as the accumulation of fluid in the pleural space, is a manifestation not only of pulmonary diseases, but of many other diseases. Furthermore, pleural effusion indicates the presence of a pulmonary, pleural or extrapulmonary disease [1,2]. The correct assessment of pleural effusion is beneficial for the management of the respective disease. [3].

Even small amounts of pleural effusion can be detected accurately with US examination. The US image of pleural effusion is characterized by an echo-free space between the visceral and parietal pleura. This space may change in shape with respiration.

Received 29.10.2009 Accepted 15.01.2010
Med Ultrason 2010
Vol. 12, No 1, 12-16
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Although US is very powerful in the evaluation of pleural effusion, differentiating minimal pleural effusion from pleural thickening may sometimes be difficult. Both lesions can appear as anechoic on grayscale US, and thus „free of echoes" does not guarantee the presence of pleural fluid [4,5].

Traditionally, color Doppler ultrasound is used for the assessment of cardiovascular diseases, but its application has been extended in other situations by the fluid principle. For example, it has been observed that true fluid in cases of minimal effusion may generate a color flow pattern during respiratory or cardiac cycles, and thus may display a turbulent color signal on color Doppler imaging. This is termed the fluid color sign of pleural effusion [6,7].

We compared the results of the ultrasound examination in real-time, on gray scale with those of color Doppler ultrasound in order to evaluate the minimal pleural effusion, and to differentiate the minimal pleural effusion from pleural thickening.

Patients and methods

From June 2008 to September 2009, we prospectively analyzed 86 patients who were suspected of having minimal pleural effusion on the basis of their chest radiographs. All patients were examined by ultrasonography on gray scale and color Doppler and the presence or absence of pleural effusion was confirmed by thorax CT.

The group of 86 patients comprised 35 women and 51 men, aged between 27-84 years old, with the average age estimated at 57.8 years (table I).

The first radiological diagnosis of pleural effusion was made on plain chest radiographies (fig 1). The most common radiologic appearance was blunting of the costophrenic angle and/or sulci (sharp angle between the diaphragm and rib cage). As fluid accumulates, blunting becomes more pronounced, and an upwardly concave meniscus seems to ascend the lateral chest wall which is called the meniscus sign. Upright posteroanterior radiographs may show lateral costophrenic angle blunting and lateral radiographs show blunting of the posterior costophrenic angle [8,9].

Table I. The demographic dates

Variable	The lot of study (n = 86)
Men	51 (59,30 %)
Women	35 (40,69 %)
Medium age	57.8

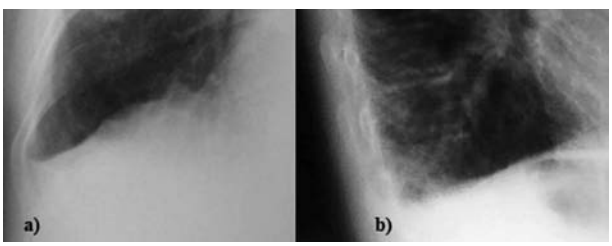


Fig 1. Small right pleural effusion: a) Chest radiography PA. Blunting of the lateral costofrenic angle; b) Chest radiography LL. Blunting of the posterior costofrenic angle

Examination of the pleural space with ultrasonography was made by a convex array 3.5- to 5 MHz probe and a high-frequency linear 4.0 to 12 MHz probe, using the intercostals space as an acoustic window. During chest US examination, patients were scanned in a sitting or supine position with the arm rising above the patient's head, so, the rib space distance was increased and facilitated the scanning.

Less than 1 mm of space is usually present between the parietal and visceral pleura. A thin echogenic line represents parietal pleura. The visceral pleura may be slightly blurred due to reflection artifacts from the US beam as it encounters a lung surface. Both pleural surfaces may rarely be visualized on standard US pictures. However, the parietal pleura does not move, whereas the visceral pleura moves with respiration [10].

On ultrasound gray scale, the typical appearance of the pleural effusion is an anechoic layer between the visceral pleura and the parietal pleura. We analyzed the internal echogenicity of the effusion, the modification of shape during respiration, the presence of the mobile septs and the echogenic densities in the pleural space.

When color Doppler is used, the sensitivity of the Doppler should be set to low flow or the low-velocity scale (typically 0.25 m/sec). The wall filter is set to minimize rejection of small frequency shifts and to avoid interference from respiratory or cardiac movements. The color Doppler gain is increased until a uniform background colored „snowstorm" is obtained and then decreased until just a few random colored speckles remain [11].

Color Doppler ultrasonography can help in differentiating small effusions from pleural thickening by demonstrating the fluid-color sign. The sign refers to the presence of color signal within the fluid collection that is believed to arise from transmitted respiratory and cardiac movements. Any movement of body fluid may be translated into colored images. The „fluid color" sign is demonstrable on color Doppler scans in pleural effusions but is absent in pleural thickening [11]. Pleural thickening appears as a hypoechoic broadening of the pleura, has no movable parts, and colored signals may not be detected [10].

We compared the results of the ultrasound examination in real-time, on gray scale with those of color Doppler ultra-

sound in order to evaluate the minimal pleural effusion, and to differentiate the minimal pleural effusion from pleural thickening. A 2x2 table and χ^2 test were used for the evaluation of the results. The sensitivity, specificity, and accuracy were determinate. The confidence interval was of 95%.

Results

86 patients,35 women and 51 men, aged between 27-84 years old, with the average age estimated at 57.8 years (between 27-84 years old), were assessed for pleural effusion (table II).

The chest computed tomography confirmed the pleural effusion in 61 patients as a sickle-shaped opacity in the most dependent portion of the thorax, in the posterior pleural recesses and confirmed the absence of pleural effusion in the other 25 patients showing pleural thickening (fig 2).

Table II. Assessment of the pleural effusion on different imaging methods applied on our study

Examination	Presence of PE (TP+FP)	Absence of PE (TN+FN)
Radiography	86	-
Gray scale US	71	15
Color Doppler US	59	27
Thorax CT	61	25

PE=pleural effusion, *TP=number of true positive results, FP=number of false positive results, FN=number of false negative results*

The application of ultrasound on gray scale identified an anechoic or hypoechoic layer between the visceral pleura and the parietal pleura in 71 of the patients. The shape of the effusion varied with respiration and position (fig 3).

When it is affirmed that pleural effusion is absent all dynamic findings of the fluid have to be demonstrated to be absent. In our study there were 15 cases without pleural effusion on ultrasound on gray scale (fig 4).

The ultrasonography on gray scale in real time detected pleural effusion in 61 patients from a total of 61 patients with confirmed pleural effusion, but also in 10 patients whose pleural effusion had not been confirmed. The absence of pleural effusion in 15 patients from a total of 25 patients without pleural effusion was evidenced. Therefore, there were 10 false positive results, but there were no false negative results. Thus, ultrasonography on gray scale had 60% specificity, 100% sensibility and 88.37% accuracy.

The chest color Doppler ultrasonography evidenced the color fluid sign in 59 patients from the total of 61 patients with pleural effusion, although it could not be traced in two cases with real pleural effusion. The sign was not shown in patients without pleural effusion. Therefore, as there were not false positive results, it results in the higher specificity of the method (specificity 100%, sensitivity 96.72% and accuracy 97.57%).

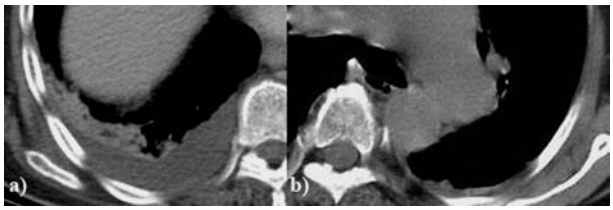


Fig 2. Computed tomography chest scan (mediastinal window): a) Right pleural effusion; b) - left pleural thickening

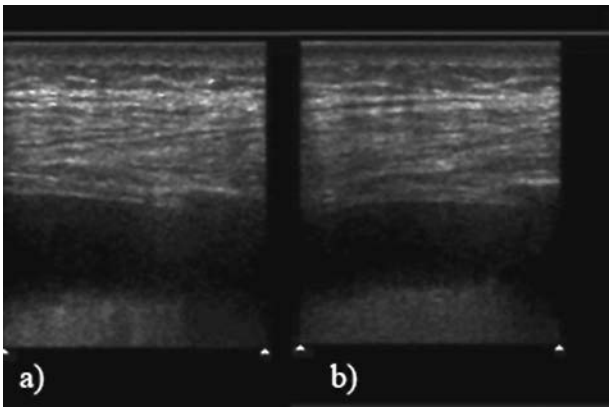


Fig 3. Chest ultrasonography on gray scale in real-time, using a linear 8 MHz probe, intercostal abord, showing an anechoic layer. In the fig 3b we can see that the shape of the pleural space differs from fig 3a, because it changes with the respiration motions. This aspect suggests a pleural effusion.

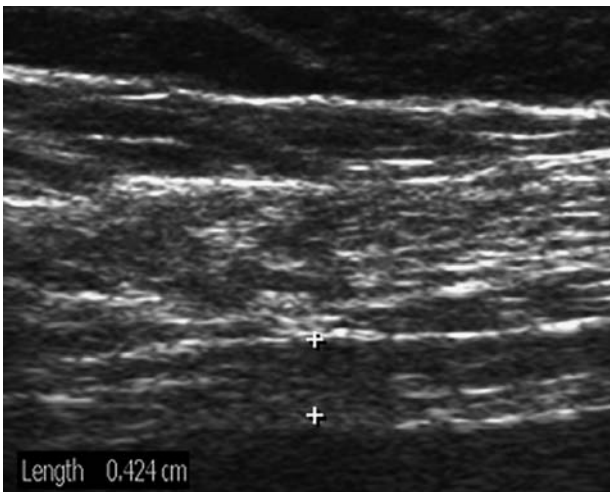


Fig 4. Chest ultrasonography with linear probe showing pleural thickening as an hypoechoic layer, width 0.42 cm.

Table III. Summary table –comparative value of ultrasound on gray scale and color Doppler ultrasound in assessement of pleural effusion

	Gray scale	Color Doppler
TP	61	59
FP	10	0
TN	15	25
FN	0	2
Sensibility	100%	96,72%
Specificity	60%	100%
Accuracy	88,37%	97,67%

TP=number of true positive results, FP=number of false positive results, FN=number of false negative results, TN=number of true negative results, Sensitivity = TP/TP+FN, Specificity = TN/TN+FP, Accuracy = TP+TN/TP+FP+TN+FN

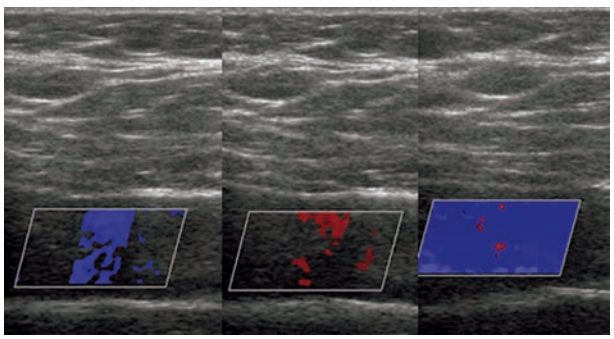


Fig 5. Chest color Doppler ultrasonography with linear probe. Fluid color sign is shown on the consecutive images, which means a pleural effusion.

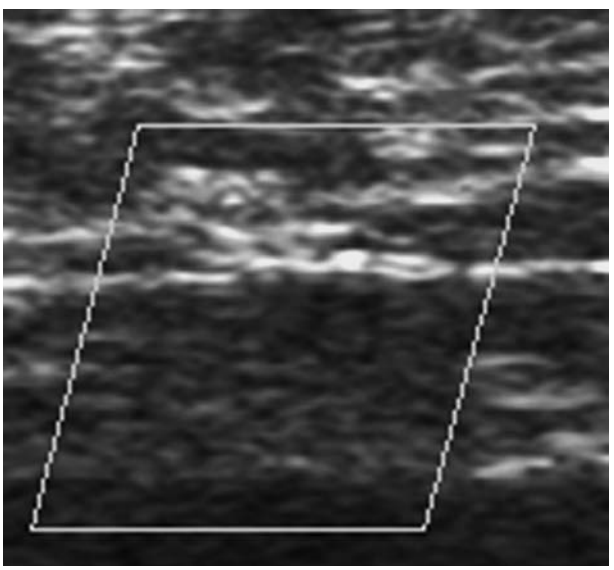


Fig 6. Chest color Doppler ultrasonography with linear probe. The absence of the color fluid sign proves the absence of pleural effusion. Therefore, the anechoic layer is pleural thickening.

Discusion

Imaging plays a major role in the diagnosis and management of pleural disease. Common imaging studies used to confirm pleural effusion are chest radiography, ultrasonography and CT scan. Chest radiography is the primary diagnostic tool because of its availability, accuracy and low cost [8]. On average, more than 150 ml must be present for a pleural effusion to be detected on an upright chest X-ray [9].

The value of US for diagnosis of pleural effusion is well documented. Ultrasonography is primarily used to confirm an effusion in a patient with abnormal chest radiographs [2] being able to detect as little as 5-50 ml of pleural fluid, with 100% sensitivity for effusions of 100 ml or more [3,4,8,12,13]. The benefits of ultrasound, however, include its portability, cost, lack of radiation exposure, and ability to perform dynamic and real-time procedural guidance at the bedside [8,12].

Marks *et al* found that if a lesion changed shape with respiratory excursion and if it contained movable strands or echo densities, the lesion contained fluid and could be aspirated. These could be the best criteria to distinguish effusion from solid pleural lesions with grayscale US. However, these criteria still have limitations for detecting loculated and minimal fluid collections [12,14,15,16,17].

If an anechoic layer, „free of echoes" appears on grey scale ultrasonography, this is not a reliable sign for fluid, because it can not differentiate minimal pleural effusion from pleural thickening, both lesions having the same aspect on gray scale ultrasound [4,5].

Pleural thickenings are defined as focal echogenic lesions arising from the visceral or parietal pleura greater than 3 mm in width with or without irregular margins. There are various echogenicities of thickened pleura. It is important to differentiate minimal or loculated pleural effusion from pleural thickening before thoracentesis because both conditions may have similar US pictures [3,16].

If, on gray scale ultrasound, an anechoic layer appears in pleural space and this image happens not to be indicative of pleural effusion or pleural thickening, then color Doppler ultrasound is useful to evidence color fluid sign [6,17,18,19].

Relatively high sensitivity (89.2%) and specificity (100%) of the fluid color sign in detecting minimal fluid collection have been shown in a study comprising 76 patients. In brief, 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 [3].

False-positive fluid color sign: it is possible to have color signals appear in areas adjacent to an anechoic flu-

id collection, or even potentially in hypoechoic pleural thickening, if the color gain is set inappropriately high or the wall filter is set inappropriately low [20].

False-negative fluid color sign: if the technical method is correct, there are not false-negative results, the fluid color sign having a specificity 100%.

On a prospective analysis made by Wu et al on the ultrasonographic findings in 51 patients, they found a sensitivity 94.3% sensitivity and 100% specificity of color Doppler ultrasound. Although real-time, gray-scale ultrasound is also sensitive for detecting minimal effusion (sensitivity 100%), it is less specific (specificity 68.7%). With relatively high sensitivity and specificity, this method proved to be a useful diagnostic aid to real-time, gray-scale ultrasound for diagnosis of minimal or loculated effusion [18].

Our results are in concordance with those from the literature as this study indicates that color Doppler ultrasound has a lower sensibility, but a greater specificity that those of gray-scale ultrasound. In assessment of minimal pleural effusion color Doppler ultrasound is superior to ultrasound on a gray scale, having a specificity of 100%, comparative with ultrasound on a gray scale that has a specificity of 60%. On the other hand, ultrasound on a gray scale is more sensitive to the detection of pleural effusion compared to color Doppler ultrasound, with a sensitivity of 100%, whereas color Doppler ultrasound has 9a 6.72 % sensitivity.

Conclusion

The minimal pleural effusion is frequently met in many diseases. Its prompt diagnosis is an important factor in the management of the disease that determine the effusion. There are times, however, that an anechoic image in real time gray scale ultrasonography cannot differentiate minimal pleural effusion from pleural thickening.

The moving of the pleural fluid generates a color signal on color Doppler imaging, termed the fluid color sign of pleural effusion. The fluid color sign indicates the presence of pleural effusion with a 100% specificity.

The evidence of pleural effusion on grayscale US has a greater sensitivity than that on color Doppler ultrasound, but a smaller specificity (sensitivity 100% vs. 96,72%, and specificity 60% vs. 100%).

Color Doppler ultrasound proved to be a useful diagnostic aid in gray-scale ultrasound for the assessment of minimal effusion, demonstrating the highest accuracy.

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