Original Article

Correlation of pleural effusions' grayscale sonographic parameters with fluid's analysis results

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Background: Quantitative sonographic methods are used to assess pleural fluid's volume but no validated method exists for the measurement of the fluids' density and other qualitative values. We suggest a quantitative method, based on the pixel density of the pleural effusion's image, in order to evaluate the echogenicity of pleural effusion.

Methods: Pleural ultrasound (US) was performed in 62 patients with pleural effusion. Five consequent images of the pleural effusion were retrieved through axial view between the 9th and the 10th rib and one from the 10th rib through coronal view and converted into the high-resolution tagged image file format. The mean echo levels of all pixels of the pleural effusion and of the 10th rib were counted, and the hypoechogenicity index (HI) was calculated according to the following formula: HI = mean echo level of all pixels of the rib/mean echo levels of all pixels of pleural effusion. HI greater than 1 indicates pleural effusion's hypoechogenicity. Diagnostic thoracocentesis was performed and biochemical markers were measured.

Results: LDH, Cell Count, pH and Effusion Pixels (Mean) were both significantly correlated and associated with pixel ratio. Conversely, pixel ratio was not correlated with any other ultrasonography—derived parameter or biomarker.

Conclusions: This study introduced HI as new index, which could demonstrate the inflammation density of pleural effusions. Moreover, when used in combination with classical biomarkers, HI might be a useful adjunct for the discrimination of pleural transudate.

Keywords: Biomarkers; pleural effusion; ultrasonography

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Introduction

Until now, in the sonographic imaging of pleural effusions, the quantitative evaluation of the fluids characteristics was performed indirectly by using other anatomic structures of the thorax as a relative measure of comparison (1). Such quantitative methods are used to assess the fluid's volume but to the best of our knowledge no method exists for the measurement of the fluids' density and other qualitative values. The interpretation of the internal echogenicity of a pleural effusion is based upon the subjective observation and evaluation of each operator. According to the internal echogenicity, effusion can be subclassified as anechoic, complex non-septated, complex septated, and homogenously echogenic (2). Additionally, several visual patterns like swirling (3) or sonographic septations (4,5) have been proven useful as diagnostic predictors for pleural effusions (6). We suggest a quantitative method, based on the pixel density of the pleural effusion's image, in order to evaluate the echogenicity of pleural effusion.

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Table 1 Patient demographics

Characteristics	Value
Age	62.3±18.4
Sex	67.7% male
Race	100% Caucasian
Type of effusion	16.1% transudate
Cause of effusion	
Parapneumonic	27%
Neoplastic	17.5%
CHF	15.9%
Autoimmune	6.3%
TB	4.8%
Traumatic	3.2%
Unknown	25.3%

CHF, Chronic Heart Failure; TB, Tuberculosis.

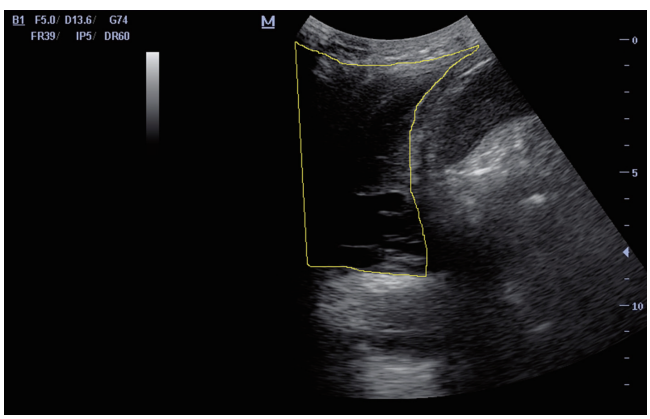

Figure 1 Image cropping technique for analysis using the Image J software.

Methods

Pleural ultrasound (US) was performed prospectively in 62 patients with newly diagnosed pleural effusion. The patient demographics are shown in *Table 1*. All patients signed informed consent. Ethics approval was obtained from our institution (ID: 3648-27/05/14). Five consequent images of the pleural effusion were retrieved through axial view between the 9th and the 10th rib and one from the 10th rib through coronal view and converted into the high-resolution tagged image file format. We used a curvilinear probe (2.5–5 MHz) and the ultrasound settings were: Dynamic range 60 dBs and Depth 8 cm for all the patients. All images were transferred uncompressed to a computer and further processed with a widespread imaging analysis program, available for downloading from the public domain (Image J, 1.42q; National Institutes of Health, Bethesda, MD; http://rsb.info.nih.gov/ij). Pleural effusion echogenicity was measured with histogram analysis. Tissue echo levels were automatically calibrated to the value of 255 for the white pixels and 0 for the black pixels (*Figure 1*). The mean echo levels of all pixels of the pleural effusion and of the 10th rib were counted, and the hypoechogenicity index (HI) was calculated according to the following formula: HI = mean echo level of all pixels of the rib/mean echo levels of all pixels of pleural effusion. HI greater than 1 indicates pleural effusion's hypoechogenicity. The HI calculation required less than a minute for every image taken. Diagnostic thoracocentesis was performed in all patients and biochemical markers were measured.

Statistical analysis

Data were expressed as mean ± standard deviation (SD) for continuous variables and percentages when reporting categorical variables. Normality was assessed via the one-sample Kolmogorov-Smirnov Test. Relationships were assessed via Pearson's R or Spearman's ρ correlation coefficients, where appropriate. Associations were assessed via simple linear regression; Curve estimation/Nonlinear regression was subsequently employed to determine the model that best fits the data. For all tests, a P value ≤0.05 was considered statistically significant. IBM SPSS 20.0 (IBM Corporation, San Diego, CA, USA).

Results

Pixel ratio's correlations are presented on *Table 2*. As LDH, Cell Count and pH were not normally distributed, Spearman's ρ was used to assess their relationship with pixel ratio. As displayed in *Table 2*, LDH, Cell Count, pH and Effusion Pixels (Mean) were significantly correlated with pixel ratio. As displayed in *Table 3*, LDH, Cell Count, pH and Effusion Pixels (Mean) were also significantly associated with pixel ratio. Specific nonlinear regression models are displayed in *Table 3*, as selected by a P value ≤0.05 and maximum R2 compared to the linear level. Conversely, pixel ratio was not correlated with any other thoracocentesis—derived parameter or biomarker.

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Table 2 Pixel ratio's correlations

Variable	Coefficient	P value
LDH	−0.815	<0.0001
Cell count	−0.559	<0.0001
pH	0.499	<0.0001
Effusion pixels (mean)	−0.813	<0.0001

Coefficient is Spearman's ρ for LDH, Cell Count and pH; Pearson's R for Effusion Pixels (mean). LDH, cell count, pH and effusion pixels (mean) were significantly correlated with pixel ratio.

Table 3 Pixel ratio's associations

Variable	Model	R^2	P value
LDH	S	0.690	<0.0001
Cell count	Inverse	0.294	<0.0001
pH	S	0.427	<0.0001
Effusion pixels (mean)	Inverse	0.800	<0.0001

LDH, cell count, pH and effusion pixels (mean) were significantly associated with pixel ratio.

Discussion

To the best of our knowledge, no quantitative method is being used in lung ultrasound imaging. We introduce an experimental method, based on the pixel density of the pleural effusion's sonographic image. We employed the hypoechogenicity index, which has been widely used in ultrasound studies of the thyroid and its diseases but not in the lung (7). To achieve standardization in our method we used the same ultrasound depth and dynamic range for all our patients. To compensate for the variability of the gain we used the HI, a fraction of two pixel counts. Additionally, none of the patients had a history of osteoporosis, which could have affected the density of the rib. For better standardization of our method we used the same anatomic viewpoints for all our ultrasound images and 5 consequent images were taken to depict the dynamic movement of the fluid during the breathing cycle.

This method has also limitations regarding the margin of error in calculating the pixels near the solid surfaces due the low resolution. Additionally, obesity is another matter we have to take into consideration, since adipose tissue causes sound attenuation and can influence the depth and limit the observing ultrasound window. In our study, all of our patients had a body mass index below 30, nevertheless the HI index is a fraction and the needed adjustments of the ultrasound's gain affect equally both parts of this fraction. This minimizes errors in measurement due to excess adipose tissue or pleural thickening (8).

This study demonstrated HI as new index, which could indicate the inflammation density of pleural effusions. Moreover, when used in combination with classical biomarkers, such as fluid LDH and cell counts, HI might be a useful adjunct for the discrimination of pleural transudate. This objective quantitative method could be integrated in the ultrasound's software for more accurate measurements. More studies are needed in order to further investigate this quantitative method.

Acknowledgements

None.

Footnote

Conflicts of Interest: The authors have no conflicts of interest to declare.

Ethical Statements: All patients signed informed consent. Ethics approval was obtained from our institution (ID: 3648-27/05/14).

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