Quantitative estimation of diffused liver diseases using ultrasonic RF echo signal

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Abstract

For the diagnosis of diffused liver diseases such as liver cirrhosis, a quantitative estimation method using ultrasound is required. In this paper, we present the quantitative estimation results of diffused liver diseases using ultrasonic RF echo signal of clinical data. The probability density function of echo amplitude from normal liver agrees well with the Rayleigh distribution. The probability density function of echo amplitude from cirrhotic liver is different from Rayleigh distribution. Using the statistical characteristics of echo amplitude, we propose quantitative indexes for the estimation of tissue structure. These indexes are applied to the clinical ultrasonic data. The RF echo data of 123 patients were used. Quantitative estimation results of diffused liver diseases using ultrasonic RF echo signal are closely related to fibrosis score of biopsy data. We conclude that the estimation using the statistical characteristics of echo amplitude is effective for the quantitative diagnosis of diffused liver diseases.

1. Introduction

The medical diagnosis using the ultrasonic cross section image has made remarkable result, and the ultrasonic diagnostic equipment is widely used. However, experience and skill of the doctor are required for the diagnosis using the ultrasonic image. We have been measuring acoustic characteristics of tissues[1, 2] and developing a quantitative diagnostic technique of liver diseases which can be applied to the clinical field[3]. In the normal liver, many scatterers are distributed randomly, and the cross-section image obtained using an ultrasonic imaging system has many granular patterns referred to as a speckle pattern. The probability density function of the echo amplitude from the normal livers agrees well with the Rayleigh distribution function. In the cirrhotic liver, there are many fibrotic tissue structures known as nodule structures. The probability density function of echo amplitude from cirrhotic liver is different from Rayleigh distribution. We proposed the quantitative evaluation method considering the inhomogeneous structure in the tissue using ultrasonic RF echo signal. In this paper, we present the quantitative estimation results of diffused liver diseases.

2. Data acquisition

We prepared various kinds of RF echo signals for normal and diseased livers using the digital ultrasonic diagnosis equipment (TOSHIBA Power Vision 6000, Aplio) at Tokyo Medical University hospital. Medical doctors observe B-mode images by operating ultrasonic diagnosis equipment in the same way as in an ordinary diagnosis procedure, and they can send the RF echo signal to a computer. We obtained the RF echo data from 123 volunteers and patients for each liver disease (Table 1). The degree of hepatic fibrosis was assessed by liver biopsy and graded according to the New Inuyama Classification for chronic hepatitis graded F0-4.

<table>
<thead>
<tr>
<th>Stage</th>
<th>Pathological finding</th>
<th>Patients</th>
</tr>
</thead>
<tbody>
<tr>
<td>F0</td>
<td>No fibrosis(normal)</td>
<td>22</td>
</tr>
<tr>
<td>F1</td>
<td>portal fibrosis widening</td>
<td>38</td>
</tr>
<tr>
<td>F2</td>
<td>bridging fibrosis</td>
<td>12</td>
</tr>
<tr>
<td>F3</td>
<td>lobular distortion</td>
<td>21</td>
</tr>
<tr>
<td>F4</td>
<td>Cirrhosis</td>
<td>30</td>
</tr>
</tbody>
</table>

3. Extraction of non-Rayleigh information

In previous studies, it has been shown both theoretically and experimentally that the echo amplitude $x$ for the case with many scatterers per resolution cell, such as the normal liver tissue, has Rayleigh distribution. The Rayleigh distribution function is given by

$$p(x) = \frac{2x}{\sigma^2} e^{-x^2/\sigma^2}$$

where $x$ and $\sigma^2$ represent the envelope amplitude and the variance of the echo amplitude. Using the processing technique that can suppress the signals from the randomly distributed scatterers which correspond to the normal liver, we extracted the quantitative information of the diseased tissue from RF echo signal of liver cirrhosis[3]. Figure 1 shows the RF echo image(a) and extracted result(b). Figure 2 shows the relation between extraction rate and fibrosis score.
4. Slope of Q-Q plot

We also use another parameter to analyze the probability information of echo envelope[6]. It is a slope, which can be calculated using Q-Q probability plot. Q means the quantile of p(x), and the Q-Q plot is realized with the following transformation of equation. If the Rayleigh distribution obey with eq. (1) as shown by the broken line in Fig. 3(a), the cumulative density function can be expressed by eq. (2)

\[ F(x) = \int_{-\infty}^{x} p(x) dx = 1 - e^{-x^2/\sigma^2} \]  

(2)

Using eq.(2), we can get the relation

\[ Y = 2 \{ X - \ln(\sigma) \}, \]  

(3)

where \( X = \ln(x) \) , \( Y = \ln[- \ln(1 - F(x))] \), \( \sigma \) is a deviation. The slope of Q-Q plot is quantitative parameter, which is a value, two in case of the Rayleigh distribution as shown by the broken line in Fig. 3(b). Figure 4 shows the relation between the slope of QQ plot and fibrosis score.

5. Conclusions

In this paper, we presented our quantitative estimation techniques and estimation results. Quantitative estimation results of diffused liver diseases using ultrasonic RF echo signal are closely related to fibrosis score of biopsy data. We conclude that the estimation using the statistical characteristics of echo amplitude is effective for the quantitative diagnosis of diffused liver diseases.

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7. References