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A method of liver fibrosis estimation based on combination of Rayleigh distributions

レイリー分布の組み合わせによるびまん性肝疾患の線維化評価手法の検討

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1. Introduction

In the clinical diagnosis of liver fibrosis using ultrasonic B-mode images, there are some differences between individual docter's diagnosis results. Hence, the realization of quantitative diagnosis is strongly required in the clinical field. In order to realize quantitative diagnosis of liver fibrosis, we have been analyzing the probability density function (PDF) of echo amplitude using B-mode images[1-4]. To achieve the quantitative diagnosis of the stage of liver fibrosis, we propose an amplitude distribution model using two Rayleigh distributions. We examined possibility of the quantititive estimation of liver fibrosis by using the model.

2. Amplitude distribution model of liver fibrosis

When scattered points are distributed closely and uniformly, such as the normal liver tissue, interference-induced random fluctuation in brightness in the image called speckle pattern appears. The PDF of echo envelope of speckle pattern can be approximated by Rayleigh distribution. On the other hand, in heterogeneous medium, such as the liver fibrosis, the PDF of echo envelopes deviates from Rayleigh distribution. It is thought that liver fibrosis is composed of normal liver and fibrosis tissues. We propose the amplitude distribution model for liver fibrosis in which the distribution is modeled by combination of Rayleigh distributions with low variance σ_{low}^2 (normal liver) and high variance σ_{high}^2 (fibrosis tissues).

Rayleigh distribution is given by

$$p(x) = \frac{x}{\sigma^2}\exp\left(-\frac{x^2}{2\sigma^2}\right), \quad (1)$$

where σ^2 is the variance of the echo amplitude.

Amplitude distribution model of liver fibrosis is given by

$$p_{mix}(x) = (1-\alpha)p_{low}(x) + \alpha p_{high}(x), \quad (2)$$

where $p_{high}(x)$ is Rayleigh distribution with high variance, $p_{low}(x)$ is Rayleigh distribution with low variance and α $(0 \le \alpha \le 1)$ is the mixture rate of Rayleigh distribution with high variance. Therefore, model parameters (indices of fibrillization) are the variance ratio ($\sigma_{high}^2 / \sigma_{low}^2$) and the mixture rate ($\alpha$). And, $p_{mix}(x)$ is normalized by second moment about the origin. **Figure 1** shows an example of the combination of two Rayleigh distributions (clinical data, amplitude distribution model, Rayleigh distributions with low variance and high variance are displayed).

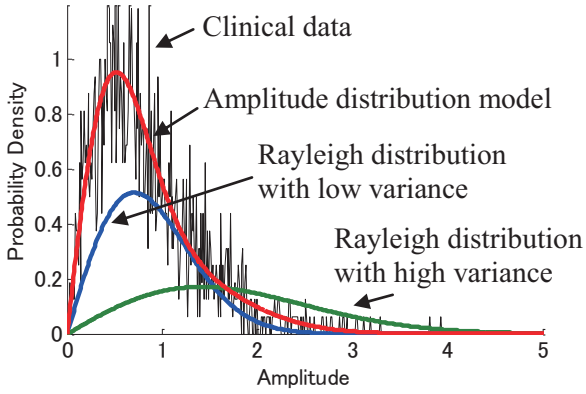

Fig. 1 Combination of two Rayleigh distributions.

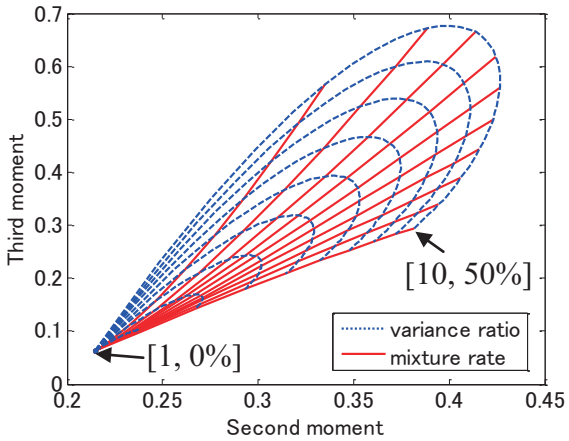

Fig. 2 Evaluation chart using second &third moment.

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3. Estimation of model parameters

In order to decide model parameters in clinical echo data, we used second and third moment about the mean calculated from the PDF. **Figure 2** shows evaluation chart using second & third moment by amplitude distribution model of liver fibrosis. Solid lines are contour lines on which the mixture rate is constant and dotted lines are contour lines on which the variance ratio is constant. Range of the variance ratio and the mixture rate is 1~10 and 0~50[%], respectively. The PDF with model parameters [1, 0%] (= [the variance ratio, the mixture rate]) is Rayleigh distribution (normal liver). If model parameters increase, the PDF deviates from Rayleigh distribution (that is, liver fibrosis proceeds). When the mixture rate is fixed, both second and third moment increase with increase of the variance ratio. When the variance ratio is fixed and the mixture rate is low, both second and third moment increase with increase of the mixture rate. On the other hand, when the variance ratio is fixed and the mixture rate is high, both second and third moment decrease with increase of the mixture rate.

4. Application to clinical data

Figure 3(a)-(c) shows scatter plot of clinical echo data in evaluation chart. Clinical echo data sets (*in vivo*) of liver fibrosis are classified by New-Inuyama classification using the result of biopsy. Analyzed areas of clinical echo image are decided to exclude the blood vessel. Each ROI size is 40×40 pixels.

It can be confirmed that the parameters move on the evaluation chart along with the stage of liver fibrosis from figure 3. In F0 which corresponds to normal liver, model parameters converge on [1, 0%]. In F2 and F4, as the stage of liver fibrosis proceeds, the variance ratio increase. That is, the stage of liver fibrosis is related to the variance ratio. On the other hand, the clear relationship between the stage of liver fibrosis and the mixture rate was not found. From these results, the possibility of the quantitative diagnosis was shown by using the model parameters.

5. Conclusion

To achieve the quantitative diagnosis of the stage of liver fibrosis, we proposed amplitude distribution model using two Rayleigh distributions and analyzed the PDF of the echo envelope amplitude using actual clinical data.

As a result, it shows the correlation of the stage of liver fibrosis with the variance ratio. It is thought that the stage of liver fibrosis can be quantified by estimating model parameters by using proposed amplitude distribution model of liver fibrosis. We will examine much clinical echo data from F0 to F4 by using the model parameters.

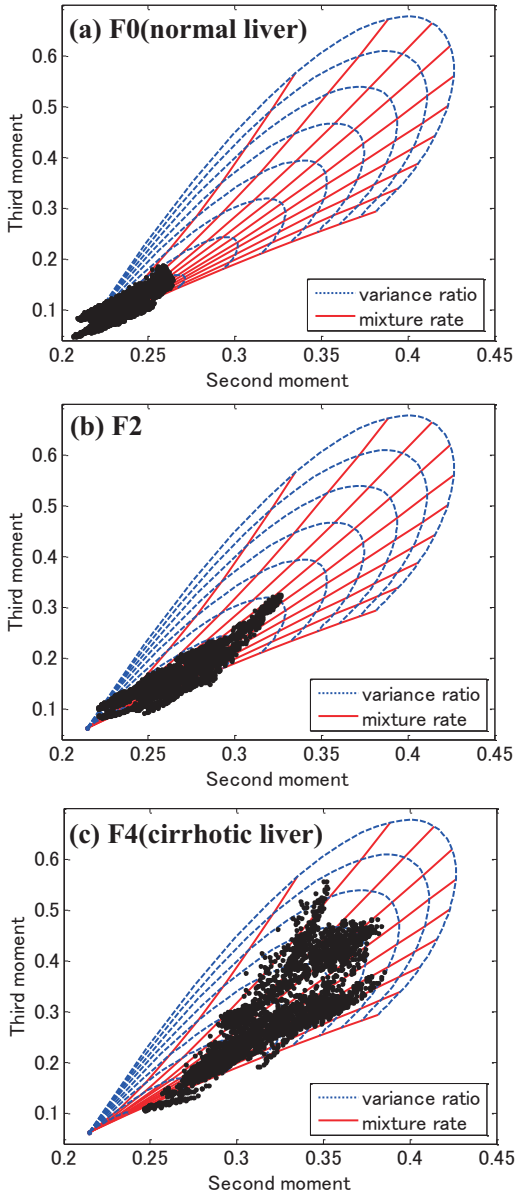

Fig. 3 Scatter plot of clinical echo data in evaluation chart (F0, F2, F4).

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