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Quantitative diagnosis for liver fibrosis using co-occurrence matrix of echo signal

エコー信号の同時生起行列を用いた肝病変定量診断手法

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1. Introduction

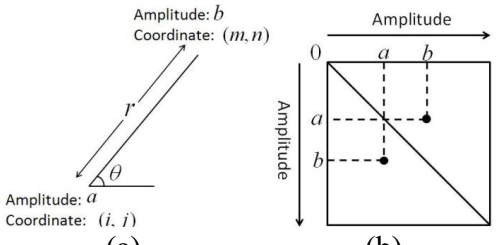
Since the clinical diagnosis depends on the skill of the doctor, quantitative diagnosis method using ultrasonic echo signal is strongly required. Tissue characterization strongly affects amplitude distribution property of the echo because the echo signal is affected by scatterer distribution in the medium[1)]. In hepatitis and cirrhosis images, distribution of co-occurrence matrix was found to change characteristically as disease progresses. This change is analyzed using texture feature[2)]. In this report, we study quantitative diagnostic method using co-occurrence matrices calculated from simulated B-mode images. The images are generated with scatterer distribution model of fibrotic liver[3)].

2. Co-occurrence matrix and contrast

Co-ccurrence matrix is one of the texture analysis methods. On an image f, a pair of pixel coordinates (i, j) and (m, n), whose distance and direction are r and θ, is given, as illustrated in Fig. 1(a). The probability, that amplitudes of (i, j) and (m, n) are a and b, is shown as eq. (1).

$$P(a,b;r,\theta) = P\{f(i,j) = a, f(m,n) = b\} \quad (1)$$

Given fixed positional parameters θ and r, element of the matrix has probability $P(a,b)$ provided that amplitudes of a pixel pair equal to a and b. Therefore this symmetric matrix expresses a relationship between amplitudes of two pixels in 2D surface as shown in Fig. 1(b). Distribution aggregates on diagonal line if amplitudes of B-mode data are uniform. On the other hand, the distribution spreads over the whole matrix if range of the amplitudes is wider.



(a) (b)

Fig.1 How to make co-occurrence matrix; (a): Relative position of two pixels, (b): Display method.

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In order to quantify the shape of co-occurrence matrix, texture feature contrast, as indicated in Eq. (2) is calculated from the matrices.

$$C(r,\theta) = \sum_{a=0}^{n-1}\sum_{b=0}^{n-1}(a-b)^2 P(a,b;r,\theta) \quad (2)$$

The value increases when the distributioin spreads over the matrix.

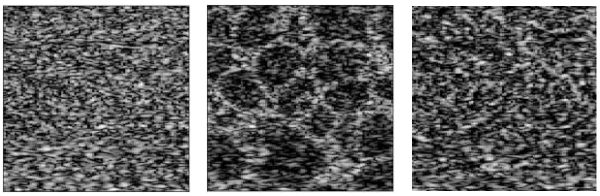
3. Estimation of Contrast using simulation data

In this research, we discuss quantitatively by calculating co-occurrence matrices from ultrasonic simulation images generated with scatterer distribution model of fibrotic liver. If the disease progresses, scatterers in the liver increase as fibrotic tissue is formed. For this scatterer model, fibrolization is expressed as the rate of the volume where scatterers are set, while the ratio of scatterer density between normal region and fibrotic region is set to 1:7. Fibrotic rate of normal liver shown in Fig. 2(a) equals to 0%. The rate increases as the disease progresses. As progression show different feature between Type B hepatitis (Fig. 2(b)) and non-B non-C hepatitis (Fig. 2(c)), these two different types of simulation images are generated from normal to serious cirrhosis (fibrotic rate 30%). On the images, one region of interest (280pixel×80 pixels) is set as one of the pixel pair to calculate co-occurrence matrix. In order to make 2D contrast display shown in Fig. 3(a-c), the other pixel region to be calculated is moved from distance 0 to larger, to all the directions.

Ellipsoidal low contrast region on the origin shows shape of resolution as shown as dark blue region on the origin in Fig. 3(a). The contrast value increases as the distance r increases, gradually converge in one convergent value. Compared with normal liver, convergent value increases as disease progresses.

Also, it is found that distance of convergence increases and the ellipsoidal region spreads as disease progresses, which is remarkable especially for Type B hepatitis. This is resulted from the structural size of liver such as fibrous tissue, nodules and liver lobules.

2D contrast display of type B clinical data is shown in Fig. 3(d-f). Similar tendency to simulation can be seen from these results. As discussed, progress of disease and size of tissue structure are visible.



(a) (b) (c)

Fig.2 Simulation images. Each sized 84pixel×370pixel (30mm×30mm) ; (a): Normal liver (fibrotic rate 0%), (b): Type B hepatitis (30%), (c): Non-B non-C hepatitis (30%).

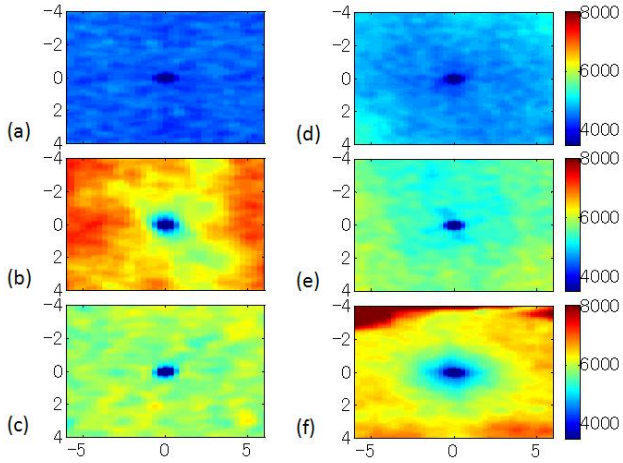


Fig.3 2D display of contrast value calculated from simulation images; (a): normal liver, (b): Type B hepatitis (30%), (c): Non-B non-C hepatitis (30%), calculated from clinical data; (d): normal liver, (e): Type B moderate cirrhosis, (f): Type B serious cirrhosis.

4. Convergent value and convergent distance

In addition to the images shown in Fig. 2, 16 images for 8 levels of progression for two types of hepatitis is used for the analysis. Relationship between fibrotic rate and convergent value is shown in Fig. 4, and fibrotic rate and convergent distance is shown in Fig. 5.

Both in type B hepatitis and non-B non-C hepatitis, contrast convergent values take similar values and show a sharp increase in low fibrotic rate range as shown in Fig. 5. This implies that tissue structure in two types of hepatitis changes in a similar way under certain fibrotic rate. The convergent value increases because of the high brightness signal from fibrotic tissue. Also this implies that in this fibrotic rate range, it is possible to know progress of level from the convergent value. Thereafter over certain fibrotic rate, the plot becomes flat for non-B non-C hepatitis because the tissue structure shows less change. On the other hand for type B hepatitis, convergent value goes on increasing. Fibrotic tissue and nodules can be observed on severe type B hepatitis image because the size of structure becomes larger than resolution. In this case, brightness from fibrotic tissue goes on increasing.

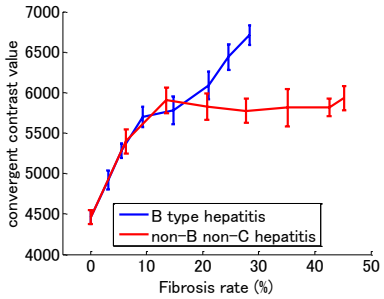


Fig.4 Contrast convergent value with standard deviation error bar.

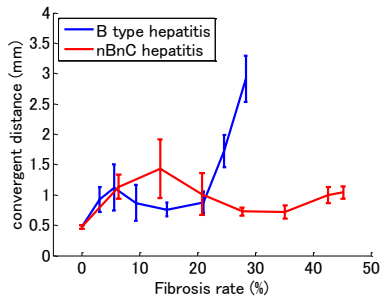


Fig.5 Contrast convergent distance with standard deviation error bar.

Therefore, the increase of convergent value on type B hepatitis is resulted from the change of fibrotic thickness.

Convergent distance of type B hepatitis shows a sharp increase while non-B non-C hepatitis shows flat plot as shown in Fig. 5. As convergent distance is relevant to size of tissue structure, it shows remarkable change on especially progressed type B hepatitis. Therefore, convergent distance is useful to know the structural size of liver, and it is possible to visualize size of liver structure in 2D display of contrast value as shown in Fig. 3(b, f).

5. Conclusion

Texture feature contrast of co-occurrence matrices calculated by type B hepatitis and non-B non-C hepatitis simulation images is analyzed. As a result, contrast as a texture feature was shown to be useful for detecting early-stage disease as it quantifies structural change of liver tissue, and to have the possibility to distinguish structural difference of diseased liver. For further study, we plan to compare simulation results and clinical data in detail, and examine quantitative and robust extract method for structural size of liver.

References

1. T. Yamaguchi, Jpn. J. Appl. Phys., **37** (1998) 3093.
2. Y. Tanaka, *et al*. IEICE technical report US2009-105 (2010) 99.
3. W. Yasuhara, *et al*, *32nd Symposium on Ultrasonic Electronics*, **32** (2011) 163.