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Scatterer distribution model for B-mode image of various fibrotic livers

種々の肝線維化画像を生成する肝組織変化シミュレーション手法

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1. Introduction

We have been developing a quantitative estimation technique for liver deseases using clinical ultrasonic echo data[1)-8)]. For the quantitative diagnosis of diseased liver, it is important to examine a relation between B-mode image and tissue acoustic structure[9)-10)]. But it is difficult to observe continuous stage of liver disease clinically, especially the beginning stage. We have already proposed a scatterer distriubution model of fibrotic livers considering the liver lobule structure to examine the relation between B-mode image and tissue scatterer distribution[11)-13)]. But this model could not generate the various fibrotic livers such as hepatitis B, hepatitis C and alcoholic hepatitis. In this report, we present a new deases progress model with parameters to make various fibrotic livers.

2. Liver tissue

The human liver is composed of small hexagonal structures called liver lobules. They contain central veins at the center and hepatic portal veins at the apex, which are scatter points in a normal liver. Cirrhosis, an irreversible liver disease, destroys a large number of lobules and replaces them with a permanent type of connective tissue called regenerative nodules and regenerative nodules is surrounded by fibrous septa. Fibrous tissues are stronger scattering points than normal liver scattering point. There are some types of diseased liver tissue structures by different causes. For example, in case of alcoholic cirrhosis, nodules are small and fibrous tissue is thick. And, in case of hepatitis B virus-related cirrhosis, nodules are big and fibrous tissue is thin.

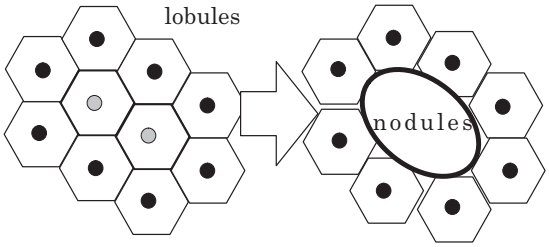

Fig. 1 Replacement of liver tissue by regenerative nodules

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3. Technique of modeling the fibrous livers

To distribute scatterers, we assume the potential distribution defined by circular Gaussian distributions around each central point. The potential distribution is given by

$$P(d) = \exp(\frac{d^2}{2R}) \quad (1)$$

where d is the distance from each center point and R is virtual radius of each lobule or nodule. Scatterers are randomly placed in the local minimum region of the potential distribution.

Liver tissue structural change is simulated as follows.

(1) Central point position of each lobule is defined in three-dimensional space and given R.
(2) Central point inflammatory properties are given at a certain rate, which is called as the inflammatory rate.
(3) Combine the adjoining central points with inflammatory properties.
(4) Central points are relocated considering adjoining center point. Inflammatory properties are cleared.

The procedures (2), (3), (4) to represent the progression of the disease by repeating the procedure. The difference of simulated tissue structure can be expressed by using the inflammatory rate.

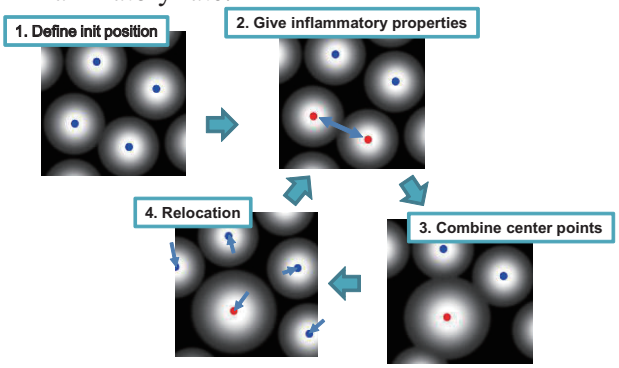

Fig. 2 Expression of disease progression

4. Results

Figure 3(a), (b) show simulated three dimensional tissue structures using our modeling method. The size of each image is 6 mm × 6mm × 6mm. **Figure 3**(a) shows simulated normal liver structures. The size of structures is about 1.0-1.5

mm which is similar to that of a liver lobule. **Figure 3**(b) shows a simulated diseased liver structure. Some lobules replace big nodules, and fibrous tissues surround the nodules.

Figure 4(a)-(c) show simulated cross section images of scatterer distribution in normal and cirrhotic livers using our modeling method. The size of the scatterer distribution image is 20mm × 20mm. **Figure 4**(a) shows simulated normal liver scatterer distribution, shows hexagonal structure which is similar to lobule. **Figure 4**(b) shows simulated hepatitis B virus-related cirrhotic liver. Maximum of the inflammatory rate is 30%. And **Figure 4**(c) shows Alcoholic cirrhotic liver. Maximum of the inflammatory rate is 10%. This method can expresses the difference in the thickness of the fibrous and nodule size variation.

Figure 5(a), (b) show B-mode images calculated using the structures of scatterers in **Fig. 3** (a), (b). The size of each image is 20mm × 20mm.The center frequency is 7.0 MHz. The aperture and the focal length of the transducer are 10mm and 31.3mm. The low echo speckle can be seen in **Fig. 5**(b). It is similar to the features in clinical images.

5. Conclusion

We have presented a modeling technique for various fibrous livers considering the liver lobule structure and the progression of the nodular structure. This technique enables us to obtain various B-mode images of fibrous liver considering tissue acoustic structure. We will examine relationship between tissue structure and simulated B-mode image to develop quantitative diagnosis methods.

Acknowledgment

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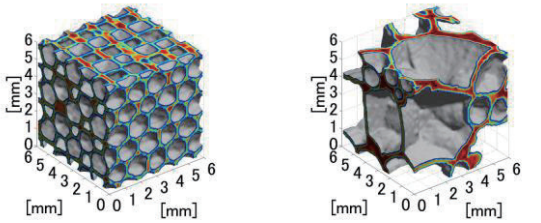
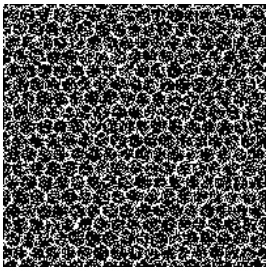
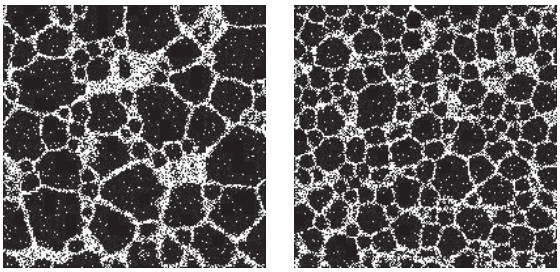


(a) Normal liver (b) Diseased liver

Fig. 3 Simulated diseased liver tissue structure

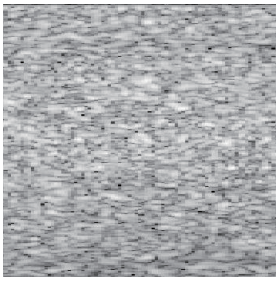


(a) Normal liver

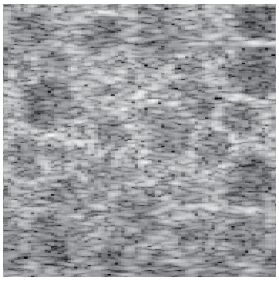


(b) B virus-related (c) Alcoholic

Fig. 4 Simulated scatterer distribution



(a) Normal liver



(b) Diseased liver

Fig. 5 Simulated B-mode image