Backscatter coefficient analysis of fatty liver considering of micro tissue structure

微小組織構造を考慮した脂肪肝の後方散乱係数解析

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1. Introduction

Research on ultrasonic backscattering coefficient (BSC) has been conducted with the aim of establishing quantitative diagnostic technique by ultrasound. It is known that the amplitude of BSC increases with the degree of deposition of fat [1], but its detailed factors has not been elucidated. Therefore, the investigation of the relationship between the progress of lesion and the change of BSC via the histological features is requiring.

The main aim of this study is the understanding of the ultrasonic scattering from each liver tissue (whole cell, nucleus, whole cell and nucleus, lipid droplet etc.). For this purpose, some of BSC analysis methods were performed utilizing the fact that BSC is linked to the Fourier transform of the two-dimensional (2D) acoustic impedance map (2DZM). 2DZM was created by extraction of each tissue from the pathological image, its Fourier transform was performed, and BSC calculated from 2DZM. The scattering phenomena of each liver tissue was examined from BSC.

2. Method

2.1 Construction of 2D impedance map (2DZM)

In this study, four pathological images of rat normal liver obtained from the same individual of 2048 pixels × 1536 pixels (140 μm × 105 μm, 1 pixel = 68.3 nm) were used. Each pathological image was made from paraffin embedding rat liver as thickness of 4 μm and performing H & E staining.

Each kind of tissue (whole cell and nucleus) was manually extracted from the pathological image of rat liver, and acoustic 2DZM was constructed. The values of acoustic impedance were assigned to each extracted tissue. Three kinds of sets of the acoustic impedance values [2] shown in **Table 1** were used. In set of (A), each nucleus was defined as scatterer, and the whole cell was not scatterers. In set (B), each whole cell was defined as scatterer, and the nucleus was not scatterers. In set (C), both of nucleus and the whole cell were defined as scatterers that have different impedances.

Extracellular matrix means an area located outside the whole cell on a pathological image.

For BSC calculation, the acoustic impedance contrast (γ_z) of the scatterers and its surrounding material was used. Assuming that the whole cell is a scatterer, the surrounding material is an extracellular matrix. If the nucleus is assumed to be a scatterer, the surrounding material is considered to be the whole cell. **Table 2** shows the values of the set of γ_z that calculated from acoustic impedance of each tissue shown in **Table 1**.

Table 1 : Impedance values Z (MRayl)

Set of impedance	(A)	(B)	(C)
Extracellular matrix	1.55	1.55	1.55
Whole cell	1.55	1.58	1.58
Nucleus	1.60	1.58	1.60

Table 2 : Normalized Impedance contrast γ_z

Set of γ_z	(A)	(B)	(C)
Extracellular matrix	0	0	0
Whole cell	0	0.019	0.019
Nucleus	0.013	0.019	0.013

2.2 Calculate BSC from 2 DZM

Assuming the plane wave propagation and the weak-scattering, the BSC in 2D space can be computed by averaging 2D Fourier transforms of several 2DZMs as Eq. 1

$$BSC_{2DZM}(k) = \frac{k^3}{4\pi^2} E[|FT(2DZM)|^2] \frac{1}{L^2} \left(\frac{L}{N_p}\right)^4 \quad (1)$$

where E denotes the expected values, L^2 is the surface of a 2D region-of-interest divided in N_p pixels to obtain the 2DZMs, and $FT(2DZM)$ represents a line of the 2D Fourier transform of a 2DZM matrix (with the line being in the direction of the incident wave) [3].

For each 2DZM image, two ROIs of 1024 pixels × 1024 pixels (approximately 70 μm × 70 μm) were prepared to BSC analysis. BSC calculation was performed on a total of four pathological images and the average value of eight ROIs was evaluated. The examples of a ROI of created γ_z maps are shown in **Figure 1**.

3. Results and Discussion

Figure 2 shows the calculated average BSC for each set of impedance values. If the scatterer extracted on the pathological image is regarded as a circle, when only the nuclei were the scatterers (set (A)), the average radius of the scatterer was 3.33 μm, the dispersion of the radius was small (gamma width factor = 70, which means the width of the radius distribution). The surface fraction was as low as 9.93%. On the BSC curve that shows the frequency characteristics, concavities and convexities of at around 140 -160 MHz was able to be confirmed. It was caused from that the radius variation of the scatterer was small.

On the other hand, when the whole cells were scatterers (set (B)), the average radius of the scatterer was 7.80 μm, the variation of the radius was large (gamma width factor = 26). The surface fraction was as high as 73.28%. The BSC curve was smooth in this case, because of the scattering radius dispersion was large.

In the case considering both whole cells and nuclei as the scatterers (set (C)), the shape of BSC curve was very similar to the shape of set (B). From these results, it was confirmed that whole cells with large γ_z were the main scatterers, and the influence of scattering from the nucleus was small.

4. Preparation for examination of fatty liver

From the results of examination in normal liver, it is considered that accuracy of BSC analysis can be evaluated by assuming lipid droplet alone or lipid droplet and whole cell as scattering sources in fatty liver. **Figure 3** shows an example of γ_z map when assuming lipid droplets were scatterers when the acoustic impedances of lipid droplet and whole cell which determined from the analysis results of actual tissue by a scanning acoustic microscopy were set as 1.66 and 1.77 MRayl, respectively. The

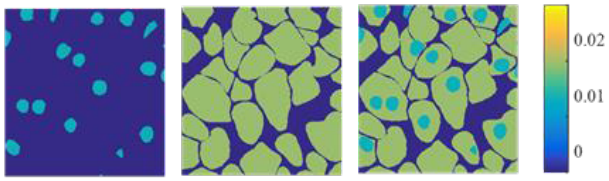

Fig.1 Example of γ_z map. The scatterers were assumed to be (A) nucleus, (B) whole cell, (C) both nucleus and whole cell, respectively.

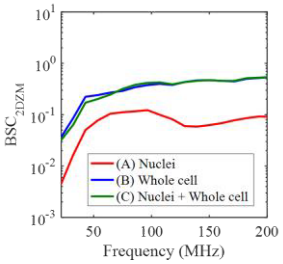

Fig.2 BSC calculated from 2 DZM.

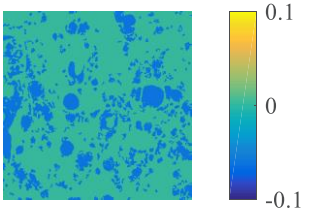

Fig. 3 Example of γ_z map of fatty liver.

relationship between lipid droplet deposition degree (scatterer surface fraction) and BSC will be evaluated with these maps of fatty livers in next step.

5. Conclusion

Acoustic impedances were assigned to each tissue of normal liver, and BSC was evaluated from the echo signal from 2DZM created with these impedance contrasts. It is assumed that the main source of scattering in normal liver is whole cell from the evaluation results of BSC frequency characteristics. Construction of 2DZM and γ_z map and, BSC analysis in multiple fatty liver with different fat deposition degree are underway.

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