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Evaluation of fatty liver based on frequency characteristic of echo attenuation

エコー減衰の周波数特性に着目した脂肪肝評価法

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1. Introduction

In fatty infiltration of the liver, high attenuation is a typical characteristic of RF singles. It is well known that larger fatty infiltration gives larger attenuation. However, the quantitative estimation method of attenuation in fatty liver has not established. In this study, we analyzed the frequency-dependent attenuation ratio from echo signal using ultrasonic diagnostic equipment to calculate attenuation ratio from echo signal in multiple frequencies. The result of our analysis of echo signal and the quantity of fatty tissue which calculated from pathological specimens was agreed well.

2. Phantom experiment

In order to estimate attenuation ratio in depth direction from backscattered echoes, we have to divide two things. One of them is the profile of the sound field of ultrasonic diagnostic equipment (including probe characteristics). The other one is the specific attenuation characteristic to each living tissue. Therefore, we measured the profile of the sound field in various conditions using the commercially produced target phantom whose attenuation ratio is known. The nonlinearity of diagnostic equipment can be disregarded by using these sound field profiles.

As a basic study, we made two agar-graphite phantoms which have nearly acoustic characteristics from human liver. A normal liver model is an usual used phantom. In a fatty liver model, many minute beef tallows are intermingled inside a normal model.

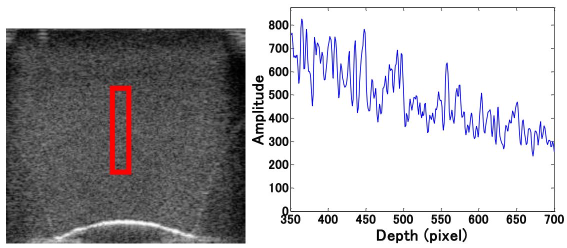
The RF echo signal was accumulated by ultrasonic diagnostic equipment (Aplio™, Toshiba Medical Systems Co.) and a convex probe (PVM-375AT, Toshiba Medical Systems Co.).

The transmitting and the receiving frequency was same, and 1.9, 2.8, 4.0, 5.0, 6.0 MHz were used for each phantom. **Figure 1** and **2** show the echo image and average amplitude of central 50 scan lines of both phantoms, respectively. The influence of sound field is canceled before showing amplitude.

The attenuation ratio α_0[1] was calculated by eq. 1. A_{max} and A_{min} are the maximum and minimum value of echo envelope amplitude, d is the distance between the depth position of A_{max} and A_{min}, and f is the frequency of the transmitting ultrasound.

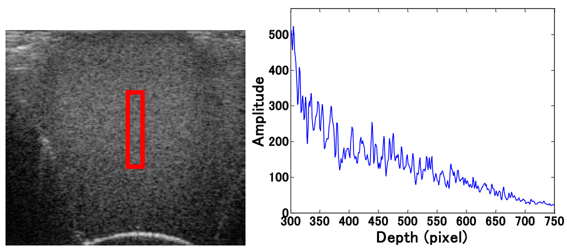
$$\alpha_0 = \frac{20\log_{10}\left(\frac{A_{max}}{A_{min}}\right)}{2df} \qquad (1)$$

Figure 3 is the relationship between the frequency and the attenuation ratio. In the normal liver model, the attenuation ratio is not dependent on the frequency. On the other hand, the change of attenuation ratio depends on the frequency in fatty liver model. This is considered to have received influence in the heterogeneity of a phantom.



(a) RF echo signal (b) Amplitude

Fig. 1 Normal liver phantom (6.0 MHz)



(a) RF echo signal (b) Amplitude

Fig. 2 Fatty liver phantom (6.0 MHz)

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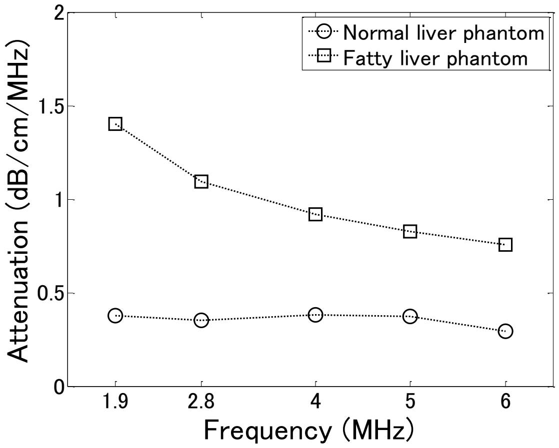

Fig. 3 Relationship between Frequency and Attenuation (phantom experiment)

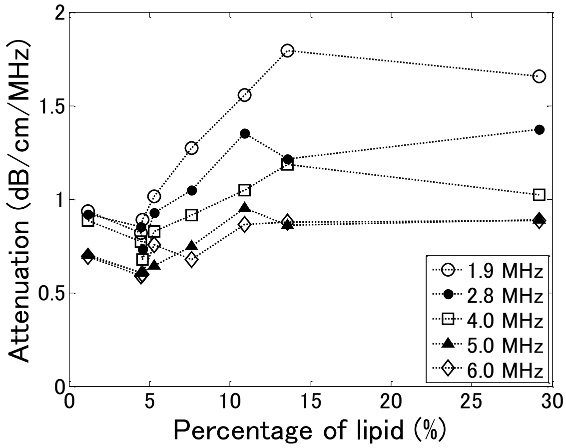

Fig. 5 Relationship between percentages of lipid and Attenuation (clinical data experiment)

3. Estimation of attenuation ratio in clinical data

We obtained 8 cases of clinical echo date sets with different level of fatty infiltration in Chiba University hospital. The setting of ultrasonic diagnostic equipment, frequencies and calculation method of the attenuation are same as phantom experiment.

We also calculate the fatty ratio from pathological images. **Figure 4** is the example of fatty tissues (lipids) which were extracted from an H-E stained pathological image.

Figure 5 shows the relationship between the frequency, the attenuation ratio and the percentage of fatty tissue in each liver. It is confirmed the difference of attenuation ratio is small if the amount of fatty tissue is small. As the amount of fatty tissue increase, the differences of attenuation ratio tend to increase in multiple frequencies as same as phantom experiment.

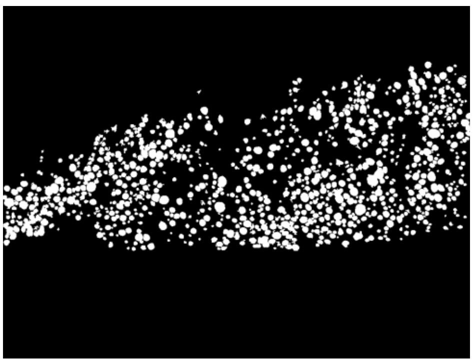

Fig. 4 Fatty tissues in the pathological image

4. Conclusion

Canceling the influence of sound field is advantageous in the characteristic analysis of an echo signal to calculate the attenuation ratio of an echo signal. It is considered that the heterogeneity of the tissue structure in liver is reflected to the frequency dependency of attenuation ratio. It is expected that calculation of the fat amount contained in liver on the basis of the difference of the attenuation factor in two or more frequency will be attained in the future.

Acknowledgment

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References

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