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Reduction of influence on interference among scatterers in evaluation of red blood cell aggregation by analyzing ultrasonic backscattering characteristics

超音波後方散乱特性解析による赤血球集合度評価時の散乱体間における干渉の影響の低減

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1. Introduction

Since it is known that excessive red blood cells (RBCs) aggregation is closely associated with diseases such as cardiovascular diseases and diabetes, it is suggested that the measurements of RBCs aggregation could be useful in the diagnosis and monitoring of these diseases.[1)] We have proposed a non-invasive and quantitative method to evaluate the degree of RBCs aggregation by estimating the size of RBCs' aggregation by analyzing the backscattered power spectra from them in the vascular lumen.[2)]

In our previous method, the center position of the analysis window to calculate the power spectra for the RF signals obtained from the vascular lumen was fixed at the focal point of the ultrasound probe. However, the dip appears in the calculated power spectrum when the analysis region includes the range where the RF signal is degraded by the interference of scattered waves. The dip deteriorates the reproducibility of the scattering power spectra among beams and affects the shape of the averaged spectrum.

In the present study, we propose an analysis method to obtain the reproducible spectrum from the RF signals for scattered waves from the vascular lumen by suppressing the occurrences of the dips by interference among scattered waves, and investigate the effect on the scatterer size estimation by improving the shape of the scattering spectra.

2. Estimation the size of RBCs aggregation

The scattering power spectrum of the RF signal obtained from the vascular lumen includes the frequency characteristics of the applied signal, transmission and reception properties of the ultrasonic transducer, sound pressure property, and propagation attenuation property as well as the scattering characteristics of the RBCs. By normalizing the power spectrum by that of the RF signal reflected from the vascular wall, the frequency components common to both measurements can be removed, which allows extracting only the scattering properties of RBCs.[2)]

By fitting the slope of extracted scattering spectrum to one of the theoretical spectra of the scattering signal from a single sphere scatterer with different sizes[3)] with the normalized scattering power as a weighting function, we can estimate the size of RBCs aggregation.

3. Measurement method

An aqueous solution of microparticles with a size of 20 μm was used as phantom simulating blood. To disperse the particles, a surfactant was used, and the aqueous solution was stirred in an ultrasonic washing machine. The volume ratio of particles in the aqueous solution was set at 7%. An ultrasound system (Tomey UD-8000) with a sampling frequency of 240 MHz was used for the ultrasound measurements. **Figure 1** shows a schematic diagram of the measurement. An ultrasonic probe with an operating center frequency of 30 MHz (frequency range: 19-40 MHz) was used. The number of beams was 113, and 19 frames were

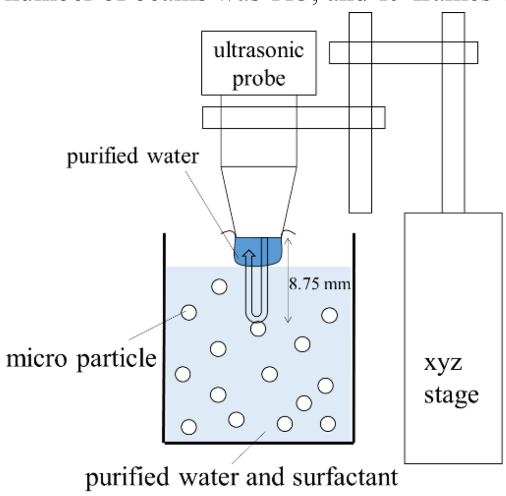

Fig. 1. Schematic diagram of the measurement.

acquired three times.

The Hanning window with a width of 240 μm was used for windowing the RF signal to obtain the scattering power spectrum. In our previous method, the center of the window position was fixed at the focal point of the ultrasonic probe, and the RF signals extracted from a total of three points shifted back and forth by half of the window width were used for each beam. In the present study, alternatively, the position where the amplitude of the RF signal became the maximum in the range of ±250 μm from the focal point was set as the center position of the analysis window.

Moreover, the scattering power spectrum was normalized by the reflection power spectrum obtained from a reflector in water to estimate the size of the particles.

4. Results and Discussion

Power spectra were obtained by the previous and proposed methods. **Figure 2** shows an RF signal for a single beam obtained from the solution of 20-μm particles and the analysis ranges by the previous and proposed methods. **Figure 3** shows the calculated scattering power spectra for two analysis ranges in Fig. 2. Although the dip appeared in the scattering power spectra around 33 MHz in the previous method, the dip was suppressed by the proposed method.

Figure 4 shows the average scattering power spectra calculated for a frame. The vertical bar shows the standard deviation at each frequency. The standard deviation was reduced by the proposed method. This is because the power spectra whose dips were suppressed as shown in Fig. 3 were also obtained for other beams by the proposed method.

Moreover, the size of the particles was estimated. **Table 1** shows the average sizes and the standard deviation (SD) of 19 frames. By improving the reproducibility of the shape of the scattering power spectra by the proposed method, the standard deviation of the estimated sizes decreased. Moreover, a closer size to the true value was obtained by the proposed method. This is because the slope of the normalized power became larger due to the increase of the power spectrum around the center frequency of the probe by removal of the dips.

5. Conclusion

The dip appeared around the center frequency of the scattering power spectra was suppressed and more reproducible power spectra could be obtained among beams by the proposed method. From now, we will introduce a method considering the attenuation of ultrasound propagation[2)] to improve the size estimation accuracy.

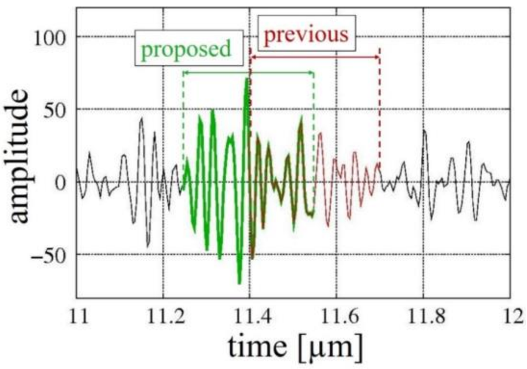

Fig. 2. RF signal and analysis range.

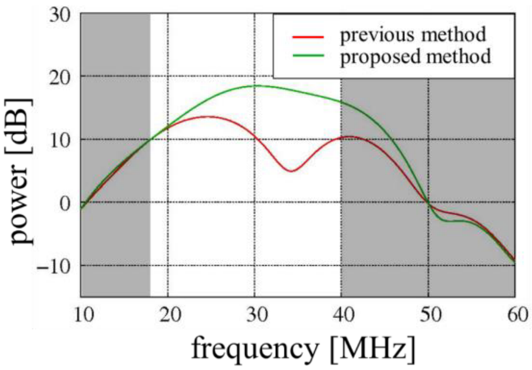

Fig. 3. Scattering power spectra for an RF signal in Fig. 2.

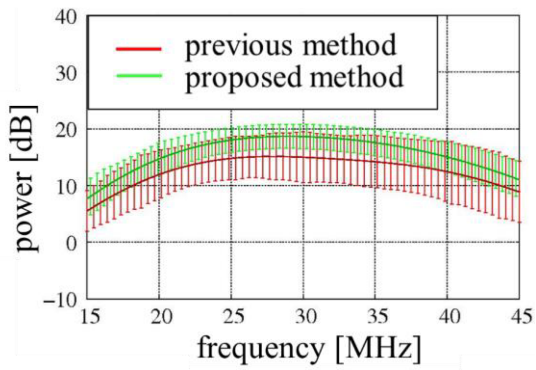

Fig. 4. Average and the standard deviation of the power spectrum calculated for a frame.

Table 1. Estimated sizes (true size: 20 μm). [Unit: μm]

	1st		2nd		3rd	
	Avg.	SD	Avg.	SD	Avg.	SD
Previous	25.6	3.1	24.2	2.4	24.0	2.7
Proposed	22.6	2.2	21.3	2.3	21.4	2.0

References

1. D. G. Paeng, et al., Ultrasound Med. Biol., Vol. 30, pp. 45-55 (2003).
2. K. Nagasawa, et al., J. Med. Ultrasound, to be submitted (2020).
3. P. M. Morse and H. Feshbach: Methods of Theoretical Physics, New York (1953).