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Effect of various parameters on ultrasonic estimation of red blood cell aggregation degree
赤血球凝集度の超音波推定時における種々のパラメータの影響

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1. Introduction

In our past study, aggregation degree of red blood cell (“RBC” hereafter) has been controled, then, relationship between the aggregation degree and peak frequency of ultrasonic reflection spectrum has been examined. The peak frequency is regaeded as a hopeful index for estimation of the RBC aggregation. However, the volume percentage of the RBC, which is one of important factor of the peak frequency, namely, hematcrit (“Hct” hereafter), varies with subjects and their physial conditions. In addition, the RBC aggregation is directly affected by ambient temperature which would be chengable during an extracorporeal circulation treatment. Therefore, consideration on the effects of the Hct and the temperature on the aggregation degree is required.

In this study, using dextran 70, which has been confirmed to be a control substance of the RBC aggregation, the RBC aggregation degree with five steps of the Hct and three steps of the temperature was researched. And correspondence between the changes in the aggregation degree caused by the Hct and the temperature and the peak frequency was examined.

2. Materials and methods

〈2･1〉 **Outline** A control method of RBC aggregation degree is conducted by dropping a 10 wt% solution of the dextran 70 used as a coagulant into porcine blood sample. The aggregation degree was confirmed with measurement of an index of the aggregation degree, namely, the interface sedimentation velocity.

〈2･2〉 **Sample preparation** The porcine blood was centrifuged and its raw Hct was measured. The Hct of the blood samples were adjusted to desired Hct with removal of the supernatant or with addition of saline.

〈2･3〉 **Measurement by microscope and interface sedimentation velocity** To measure the aggregation diameter, blood smear samples were produced. For accurate microscopic measurement of the aggregation diameter on the blood smear samples, overlapping of the aggregations in the microscope field is required to be avoided. Thus, the blood sample was diluted to the Hct of 5% and the aggregations were separated. The aggregation diameter was defined as the average value of the long and short diameters obtained with the image processing software (ImageJ).

The interface sedimentation velocity was investigated with parameters of concentration of dextran 70 and temperature. The height of the sedimentation interface was captured by a fixed-point camera with a resolution of 0.1 mm every 10 minutes for 180 minutes. The interface sedimentation velocity was derived from the each image, and was represented by the maximum value obtained at each condition. In addition, the sample viscosity was measured with a tuning-fork viblo viscometer.

〈2･4〉 **Peak frequency measurement**

An experimental setup including a 20 MHz non-focused transducer is shown in Fig. 1. Applying Fast Fourier Transform to the acquired signal, the power spectrum was obtained. The blood samples were prepared to the Hct of 30, 35, 40, 45 and 50 %. And at the each Hct condition, the concentrations of the dextran 70 were set as 0, 0.5, 1.0, 1.5, 2.0 and 2.5 %.

In order to investigate the effect of the temperature, the concentrations of the dextran 70 were set at only two typical points, 20 degree centigrade as the room temperature and 37 degree as the body temperature. Under the conditions with the three parameters mentioned here, the peak frequencies were measured.

3. Result

〈3･1〉 **Measurement by microscope and interface sedimentation velocity** Controllability of the aggregation degree was demonstrated in our past articles[1].

The experimental results of the interface sedimentation velocity and the viscosity were shown in Table 1, 2. Contrary to the past article [2], the aggregation degree was considered to be

increased in the case of the temperature of 37 degree, because the both of the interface sedimentation velocity and the viscosity were increased than ones in the case of the temperature of 20 degree regardless of the concentration of the dextran 70.

〈 3・2 〉 **Peak frequency measurement**

The experimental results of the peak frequency with the distance between the transducer and the reflection board equal to 10 mm is drawn in Fig. 2. A decline trend of the peak frequency with the increase of the concentration of the dextran 70 was observed in every case of the Hct. This result is consistent with our past result [3]. In all cases of the concentration of the dextran 70, the peak frequency was declined with the increase of the Hct. Under the experimental conditions of this study, the Rayleigh scattering which can be described by equation 3.1 is the dominant factor of the ultrasonic attenuation.

$$k_s = \frac{2\pi^5}{3} n \left(\frac{m^2-1}{m^2+2}\right)^2 \frac{d^6}{\lambda^4} \qquad \cdots\cdots (3.1)$$

where, n is number of particle, d is diameter, m is reflection coefficient, λ is wavelength.

Because the number of particle is proportional to the Hct, the eq. 3.1 suggests that the larger the Hct, the larger the attenuation in the higher frequency component. This explanation agrees with the experimental results shown in Fig. 3. The experimental result of the peak frequency with two temperatures was shown in Table. 3.

4. Conclusion

Quantitative relationships among the peak frequency, the Hct and temperature, aggregation degree, and the blood viscosity should be clarified in future studies.

References

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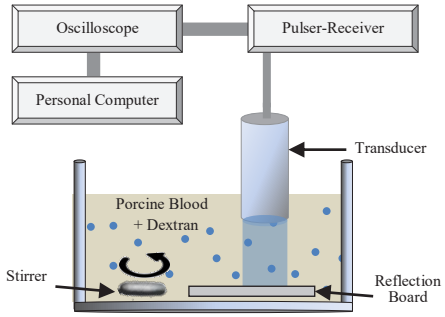

Fig. 1 Experimental setup for detecting peak frequency of ultrasonic reflection spectrum in porcine blood.

Table.1 Changes in interface sedimentation velocity by temperature

		temperature	
		20℃	37℃
dextran 70	0%	0.43	1.31
	2%	2.85	9.80

Table.2 Changes in viscosity by temperature

		temperature	
		20℃	37℃
dextran 70	0%	4.82	5.11
	2%	7.71	11.5

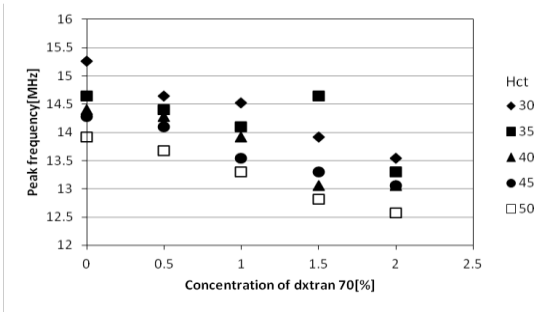

Fig. 2 Changes in peak frequency by Hct and concentration of the dextran 70.

Table.3 Changes in peak frequency by temperature and concentration of the dextran 70.

		temperature	
		20℃	37℃
dextran 70	0%	14.04	14.16
	2%	12.21	13.18