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Detection of RBC Aggregation in Blood Flow Based on Ultrasonic Echo Correlation Method

超音波エコー相関法に基づいた血流中の赤血球凝集体検出方法

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1. Introduction

In recent years, importance of measurement of the blood viscosity has enhanced. The mechanism of increase of the blood viscosity is known as a result of the aggregation of the red blood cells (RBC). The increase of the flow resistance and the further aggregation would be conducted by the viscosity increase. We propose a measurement technique which estimates the blood viscosity with a cross-correlation process between the ultrasonic echoes acquired on a blood vessel model.

In the case of a low viscosity blood, which corresponds to less RBC aggregation as mentioned above, each RBC flows free changing its relative position within the blood flow. On the other hand, in the case of a high viscosity blood in which grown-up aggregations of the RBC can be found, it is assumed that the relative positions of the each RBC would be maintained within an aggregation in the blood flow (Fig. 1). Thus, variations between two ultrasonic echoes obtained at the upstream and the downstream is considered to reflect the degree of the aggregation. According to this concept, a rate of highly correlated region between the echo signals suggests the rate which the aggregations occupy the volume of the blood vessel in the axial direction. In this study, the cross-correlation technique was applied to estimate the degree of the aggregation, and *in vitro* experiments were performed.

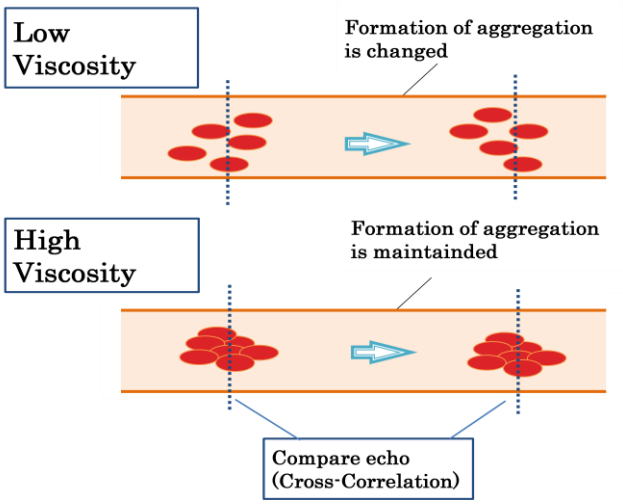

Fig.1　Concept of echo correlation method.

2. Experimental setup

A diagram of the experimental set-up is shown in Fig. 2. A silicone tube with an inside diameter of 10 mm was used to imitate the blood vessel. Blood mimicking sample was consisted of “graphite capsule” and “graphite fluid”, thus graphite powder was used as a substitution of the RBC. The “graphite capsule” was prepared by dispersing 4 wt% graphite powder with the diameter of 150 μm in a soft capsule body, which was made from a sodium alginate and a calcium chloride. The graphite capsules were shaped to a globular form 2 mm in diameter. The “graphite fluid” was a 2% aqueous solution of polyvinyl alcohol (PVA) involving the graphite powder with the same concentration as the graphite capsule.

The blood mimicking sample was flowed inside the silicone tube with an average flow velocity of 3.0cm/s. A 5 MHz ultrasonic transducer (6.0mmϕ, non-focused), which was connected to a pulser-receiver, was placed directly above the silicone tube to acquire the echoes. During the blood mimicking sample was flowed, the first and the second echoes were acquired with the time interval of 10 msec by an oscilloscope. These experimental datasets were forwarded to a personal computer, and off-line cross-correlation processes were performed between them.

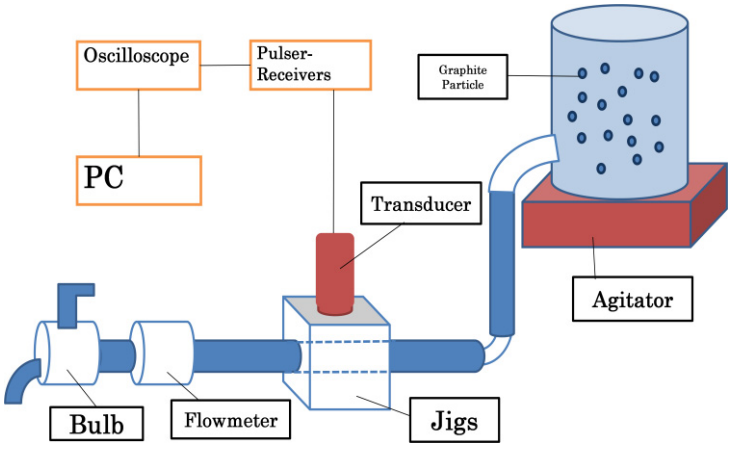

Fig.2　Experimental setup.

3. Detection of the RBC aggregation

Four kinds of the blood mimicking sample were prepared, namely, the graphite fluid without the graphite capsules and the graphite fluid with three kinds of concentration of the graphite capsules. In the each case of the sample, the initial echo signal was acquired.

The correlation coefficient distribution was computed from the two echoes obtained with the time interval of 10 msec. In this study, the sum of the correlation coefficient along the axial direction (550 samples / line) is made into the information on correlativity.

Furthermore, the process of the signal acquisition was performed for 1 sec, thus a hundred datasets were collected.

The results of the sum of the correlation coefficient along the axial direction in the cases of four kinds of the blood mimicking sample were shown in Fig. 3. The dimension of correlation window was equivalent to 0.4 mm. The result that the sum of the correlation coefficient became higher according to the increase of the concentration of the graphite capsule was demonstrated.

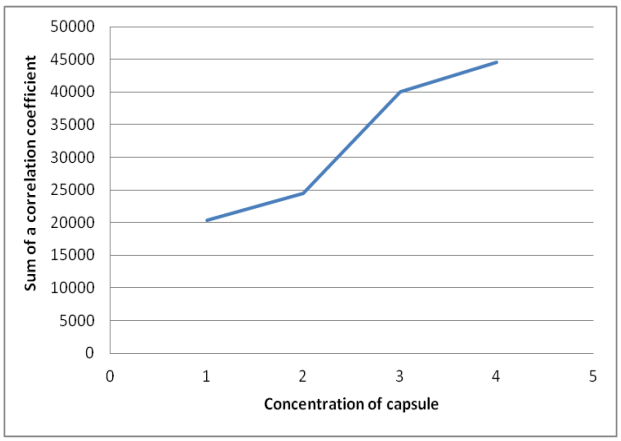

Fig.3 Sum of the correlation coefficient distributions. (1: Graphite fluid without graphite capsules.2: Graphite fluid with low concentration of graphite capsules. 3: Graphite fluid with midle concentration of graphite capsules. 4: Graphite fluid with high concentration of graphite capsules.)

Accumulation process (up to 100 times) of the sum of the correlation coefficient along the axial direction, which was performed for each result of the four kinds of the blood mimicking sample, was plotted in Fig. 4.

The difference in the sum of the correlation coefficient was emphasized, as the data accumulation progressed. A future work is to quantitatively evaluate the size and concentration of the RBC aggregation with the index of the sum of the correlation coefficient along the axial direction.

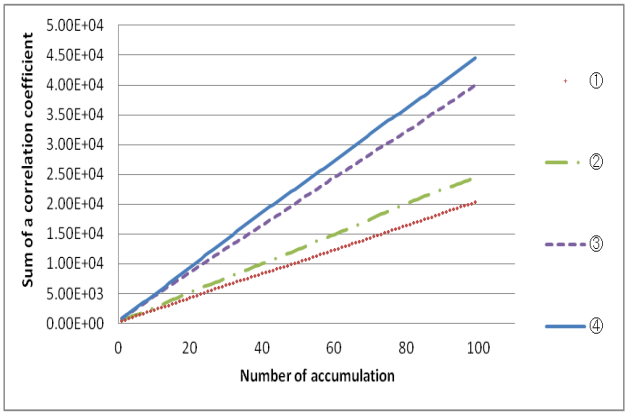

Fig.4 Relationship between the sum of the correlation coefficient and the tne number of data accumulation. (1: Graphite fluid without graphite capsules.2: Graphite fluid with low concentration of graphite capsules. 3: Graphite fluid with midle concentration of graphite capsules. 4: Graphite fluid with high concentration of graphite capsules.)

4. Conclusion

In this study, a relationship between the sum of the correlation coefficient along the axial direction and the concentration of the RBC aggregation in the blood flow was shown.

A future work is to detection of the RBC aggregation quantitatively, from the difference in slope on Fig.4 between without RBC aggregation and with RBC aggregation

5. References

1. S.Maeda: JOURNAL OF THE PHYSIOLOGICAL SOCIETYOF JAPAN 66(9), 287-297, 2004-09-01