MEASUREMENT OF ERYTHROCYTES DEFORMABILITY WITH COUNTER-ROTATING PARALLEL DISK SYSTEM

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INTRODUCTION

Erythrocytes deform to pass through capillary in micro-circulation. Deformability of erythrocytes is an important parameter to maintain blood circulation. To measure erythrocytes deformation, several methodology have been designed in the previous studies. Measurement of erythrocytes deformability is available to detect their sublethal damage and to design micro-capsule like artificial erythrocytes. In this study, erythrocytes deformability was quantitatively evaluated with shear stress responsiveness in the counter-rotating parallel disk system.

METHODS

A parallel-disk-type rheoscope system has been designed and manufactured. In the system, Couette-type shear field is induced in the fluid between two counter-rotating disks, which are made of transparent silica glass (5 mm thickness, 80 mm diameter). The distance was maintained 0.1 mm between two disks supported with ball bearings (100 mm diameter). The rotating speed (<0.4 rad/s) was regulated with a stepping motor, which is controlled by a computer. The shear rate (<200 1/s), which is calculated from the velocity deference (<20 mm/s) between two disks and from the dimension between two disks, is constant regardless of the distance from the disk. An erythrocyte can be observed under shear without translational movement , when it is suspended at the stationary plane in the middle part of the shear field. Deformation of erythrocytes was viewed at a distance of 27 mm from the rotational axis through an optical-phase-contrast microscope with an objective lens of 20 magnifications, which has a long focal length of 6.9 mm. The picture was recorded with a charge coupled device camera at a shutter speed of 0.001 s, with a video tape recorder, and with a computer. Human erythrocytes were suspended in a dextran water solution (hematocrit of 0.5%, viscosity between 0.02 Pa s and 0.06 Pa s) and were sheared between two counter rotating disks at 25 degrees C.

Erythrocytes deform from biconcave to ellipsoid in Couette-type of shear field. Erythrocytes deformation was quantified with an elongation index (E), which was calculated from the length of major axis (L) and that of the minor axis (W) by $E=(L-W)/(L+W)$. E becomes zero in a sphere ($L=W$), and approaches to unity as the deformation advances ($L>>W$). The elongation index (E) was plotted as a function of shear stress (S), and the fitting exponential curve was calculated by $E=C(1-\exp(-S/R))$, Where C is the critical elongation and R is the shear stress responsiveness.

RESULTS AND DISCUSSION

The dextran concentration in medium does not affect on shear stress responsiveness. Erythrocytes deformation is not governed by shear rate, but by shear stress in these shear condition. Couette-type flow has an advantage to quantify the shear, because uniform shear rate is applied to the whole space. The counter rotating rheoscope is a devise to observe sheared cells, which are suspended at the stationary plane in the middle part of Couette-type flow without contact between cells and surfaces. Increase of stiffness of the disks minimizes secondary flow.

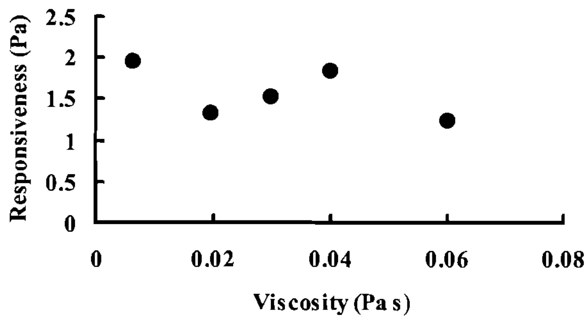

Figure 1: Relation between medium viscosity and shear stress responsiveness.

SUMMARY

The designed experimental system has enough geometrical accuracy to evaluate shear stress responsiveness. The present study shows that erythrocyte deformation is not governed by shear rate, but by shear stress.

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ACKNOWLEDGEMENTS

This work was supported in part by a Grant-in-Aid for Scientific Research from the Japanese Ministry of Education, Culture, Sports, Science and Technology.