MEASUREMENT OF RED BLOOD CELL DEFORMABILITY WITH COUNTER ROTATING RHEOSCOPE TO DETECT SUBLETHAL DAMAGE

[1]Shigehiro Hashimoto, [1]Masayoshi Omori, [1]Teruyuki Yamanari, [1]Yusuke Morita, [1]Naoki Ogawa, [1]Koichi Imoto, [2]Hajime Otani and [2]Hiroji Imamura
[1]Biomedical Engineering, Osaka Institute of Technology, Osaka, Japan; email: hasimoto@elc.oit.ac.jp
[2]Dept. of Thoracic and Cardiovascular Surgery, Kansai Medical University, Japan

INTRODUCTION

Deformability of red blood cells is an important parameter to maintain blood circulation, because cells have to deform to pass through capillary. Sublethal damage on red blood cells might occur through artificial blood pumps, before hemolysis [1].

METHODS

A parallel-disk type of counter-rotating 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. The rotating speed was regulated with a stepping motor, which is controlled by a computer. The shear rate, which is calculated from the velocity deference between two disks, is constant regardless of the distance from the disk. A red blood cell can be observed under shear without translational movement, when it is suspended at the stationary plane in the middle part of the shear field.

A red blood cell deforms from biconcave to ellipsoid in Couette-type of shear field. Deformation of the red blood cell was quantified with an elongation index (E), which was calculated from dimensions of the major (L) and minor (W) axes 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. Both large C and small R indicate large deformability.

A concavo-convex Couette flow system has been designed to damage red blood cells under shear [2]. In the space between a stationary convex cone and a rotating concave cone, the sample blood was sheared in a uniform shear field, where the shear rate is constant regardless of the distance from the axes of rotation. Variation was made on shear rate with the rotational speed of the convex cone.

Human blood was drawn from volunteers with anticoagulant of ethylene-diaminetetraacetic acid and sheared for one hour at the shear rate of 640 per second at twenty degrees Celsius.

Before measurement of deformation, the cells were classified according to the density by a centrifugation method [3]. The phthalate ester solution with controlled density was used as a separator. After separation, the red blood cells were suspended in a dextran aqueous solution to separate each other and exposed to the high shear stress (<6 Pa) field at low shear rate.

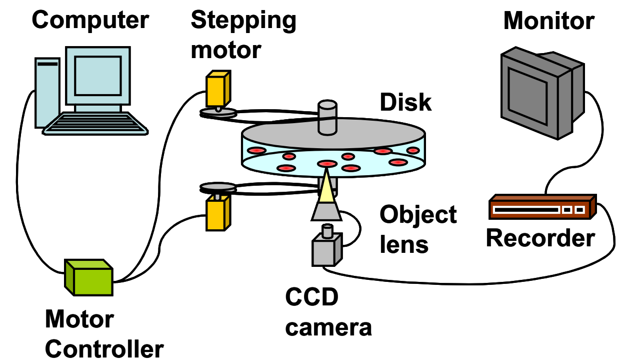

Figure 1: Pattern diagrams of system.

RESULTS AND DISCUSSION

The experimental results shows, that the lighter cells are more compliant than heavier cells and that density of cells increased after exposure to shear fields, although cells of each density level keep their deformability.

One of the advantage of a parallel-disk type of counter-rotating rheoscope system is that a red blood cell deforms in the shear field without contact to the surface of wall, which gives effects to the deformation of the red blood cell.

CONCLUSIONS

The designed system has enough sensitivity to detect sublehtal damage of red blood cells with deformability.

REFERENCES

1. Kameneva MV, et al.. *ASAIO Journal* **41**, M457-460, 1995.
2. Hashimoto S, et al.. *Artificial Organs* **13**, 458-463, 1989.
3. Danon D, Marikovsky Y, *J Lab Clin Med* **64**, 668-674, 1964.

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.