OBSERVATION OF THE BLOOD FLOW IN MICROCHANNEL WITH STENOSIS BY CONFOCAL-MICRO-PIV

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Introduction

Mass transport in human cardiovascular system takes place mainly in microcirculation, so it is important to understand blood flow in microvessels. In such small microchannels, behaviors of red blood cells(RBCs) strongly affect the flow field.

Recently many researcher developed various systems to visualize blood flow in microchannels. But it is very difficult to visualize the center plane of the blood flow when the concentration of RBCs(HCT) is over 10%. In our study, we used confocal-micro-PIV and PTV systems to overcome this problem, and investigate blood flow through stenosis.

Materials and Methods

Figure 1 illustrates the confocal-micro-PIV system used in the study. It is consisted of inverted microscope(IX71;Olympus, Tokyo, Japan), confocal scanning system(CSU22;Yokogawa, Tokyo, Japan), high speed camera(Phantom v7.1;Vision Research, NJ, USA), DPSS laser(Laser Quantum, Cheshire, UK), syringe pump(KD Scientific, Holliston, MA, USA). And we used PDMS microchannel with rectanglar cross section which has 100um width and 80um height. The stenosis has 50um width.

We used 3 kinds of working fluid to measure the flow field: (a)pure water with 0.1% fluorescent particles(FluoSpheres carboxylte 1.0 um orange, Sigma, UK), (b)RBCs with DEX40(Ohtsuka-seiyaku Corporation, Japan) and 0.1% fluorescent particles, (c)10% labeled RBCs by fluorescent dye(C-7000, Molecular Probes, USA) with DEX40. We used objective lens with 20 times magnification. The blood was taken from 23 years old male and used in room temperature. The Reynolds number based on the channel width is about 0.05 throughout this study.

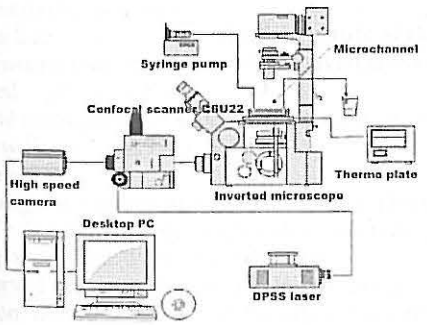

Figure 1 Experimental set-up

Results

(1) Pure water

First, we measure the flow of pure water by the confocal-micro-PIV systems with the frame rate of 1[ms]. The results show that the flow field is similar to the Poiseuille flow before and after the stenosis, and the velocity field is almost symmetric before and after the stenosis (though the result is omitted in this paper).

(2)Red Blood Cells with fluorescent particles

The velocity field of sample(b) measured by the PIV system is shown in Fig.2. We see that there is no big difference in the flow field between sample(a) and (b).

(3)Labelled Blood Cells

The trajectories of RBCs(sample(c)) measured by the PTV system are shown in Fig.3. In the Stokes flow field of Newtonian fluid, the stream lines should be symmetric before and after the stenosis. But we found that the trajectories are no longer symmetric because of the hydrodynamic interaction between RBCs.

Discussions

From the result of the sample(a) and (b), there seems no big difference in the time averaged flow field between the pure water and 10% RBCs. This result is consistent with our prior study[1] which shows RBCs don't affect plasma flow severely when HCT is under 10%.

In Fig.3 the trajectories are not symmetric before and after the stenosis. Therefore, we can conclude that RBC behaviour shows strong unsteadiness. This is because the RBCs interact hydrodynamically, which changes RBCs positions and orientations from when they are alone.

Conclusions

There is no big difference in the time averaged flow field between pure water and 10% RBCs suspension. But the trajectories of individual RBCs are not symmetric before and after the stenosis. Therefore we have to consider the unsteady motion of RBCs and treat Blood as a RBCs suspension diluted with plasma.

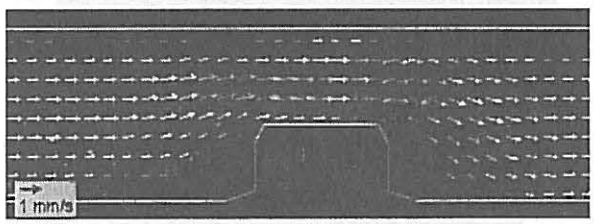

Figure 2 Velocity profile of 10% hematocrit RBCs with fluorescent particles measured by PIV(Re=0.05)

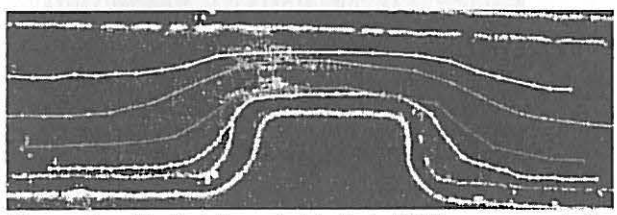

Figure 3 Trajectries of labelled RBCs measured by PTV(Re=0.05)

References

[1]Rui Lima et al., *Meas.Sci.Technol.*17, 797-808,2006