Blood Flow in microchannel with stenosis measured by a confocal micro PTV system

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Abstract

Blood in microcircualtion is not a homogenous fluid but the suspension of Red Blood Cells(RBC). So individual RBCs behavior is essential to get good comprehension about the blood flow in microcirculation. In this study we observe the RBCs behavior through the stenosis by using confocal-micro-PTV system. And we can observe the difference of the cell free layer thickness according to Hct.

1. Introduction

Blood is flowing in all over our body for masstransport such as oxygen, hormone, nutrient and so on. The masstransport occurs mainly at microcirculation, because Peclet number in such channels is small enough to generate large molecular diffusion. Thus blood flow in microcirculation is important to better understand physiology and pathology related to malaria, thrombus and so on. Blood flow is very complex in microcirculation. Because blood has two faces ; almost homogenous fluid in large vessel and suspension of Red Blood Cells(RBC) in microcirculation. This means we can not ignore the RBC size comparing with the vessel diameter in microcirculation. So, the blood flow in microcirculation is affected by individual RBCs behavior such as interaction between other cells, deformablity under the high shear rate, the biconcave cell shape and so on. Thus we have to understand the individual RBCs behavior when analyzing the blood flow in microcirculation.

When the Hct is low, it is easy to observe the individual RBCs behavior. But when the Hct is high(over 10%), we can not observe inside of the blood flow because of the less optical transparency of RBCs(Fig. 1) even if the flow speed is low. To overcome this problem, we use confocal-micro-PTV system. This system enables us to visualize the individual RBCs in the high Hct blood over 10%. In Fig. 1 we can find the labeled RBC excited by the laser in this system. In our previous studies, we investigated the RBCs behavior in the straight channel with various Hct[1]. In this study, we investigate RBCs behavior through stenosis and the cell free layer around the stenosis.

2. Methods

2.1. Experimental set-up

Figure 2 illustrates the confocal-micro-PTV system used in this 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), thermo plate(Tokai Hit, Shizuoka, Japan), Objective Lens(Olympus, Tokyo, Japan(magnification:20times, N.A.:0.75, W.D.:0.17[mm])). And we used PDMS microchannel with rectanglar cross section which has 50 μ m width and 50 μ m height. The stenosis has 30 μ m width and 35um height(Fig. 3). And we set the Y-coordinate in vertical direction illusrated as red line in Fig. 3.

2.2. Working fluids

We use 3 kinds of working fluids to compare: (a)pure water with 1% fluorescent particles (FluoSpheres carboxylte 1.0 um orange, Sigma, UK), (b)labeled RBCs by fluorescent dye(C-7000, Molecular Probes, USA) in DEX40 with the Hct of 10% and (c)that with the Hct of 20%. And we track fluorescent particles and labeled blood cells. The blood is taken from 23 years old male and used at the temperature of 37 degree to achieve similar enviroment to the human body. Through this study we did experiment under the Reynolds number 0.2.

3. Results

(a)pure water

First, we track the fluorscent particles in the pure water by the confocal-micro-PTV system. Figure 4 shows that the stream lines are almost symmetric before and after the stenosis. These stream lines meet well with the Stokes flow condition.

(b)Labelled RBCs in high Hct

We do experiment with Hct of 10% and 20%. Figure 5 and 6 show the RBC trajectories in 10% and 20% Hct. And Fig. 7 shows that Y-displacement-Y-location relationship. Y-location 60 μ m 60 μ m upstream of the stenosis means the position in Y-coordinate and Y-displacement means the displacement in Y-direction before and after the stenosis. From these data we can observe that displacement of RBCs in the Y-direction

is larger in 10% Hct than that in the 20% Hct blood flow.

4. Discussion

From the result we can say that the RBCs trajectories are asymmetry before and after the stenosis even under the Stokes flow and observe the Y-displacement is larger in 10% Hct than that in the 20% Hct blood flow. This is because when the Hct increases the channel is full of the RBCs and the RBCs can not move freely. When the RBCs can move freely, they flow asymmetry before and after the stenosis because they are stretched by shear rate on flowing the stenosis. This phenomena is observed in a dilute suspension of RBCs, through the results are omitted in this paper. However, we still do not know the mechanism completely, so we will investigate it as a future work.

Opposite to our result, the earlier study[2] said that as the Hct increases the cell free layer thickness increases. But they did experiment in very low Hct(from 0.1 to 2.6%). Considering their result and our result, we think there must be the peak of increasing cell free layer thickness between the Hct and the cell free layer after the stenosis.

5. Conclusion

In this study we investigate the RBCs behavior through the stenosis and the cell free layer. Conventionally it is difficult to visualize the RBCs behavior in the high Hct blood flow. With confocal-micro-PTV system, we could visualize the RBCs behavior in the blood flow in 20% Hct. As a result we observe that higher Hct blood makes thinner cell free layer after the stenosis over 10% Hct. But comparing our results with earlier results[2], we can predict there must be peak between Hct and cell free layer after the stenosis. And not only Hct but stenosis geometry affects the thickness of the cell free layer after the stenosis. In the future we are going to quantify the displacement before and after stenosis according to Hct and stenosis geometry and so on.

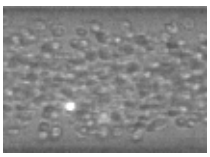

Fig. 1 : Center plane of 10% Hct blood flow in 50 μ m diameter microchannel with excited RBC illustrated by white

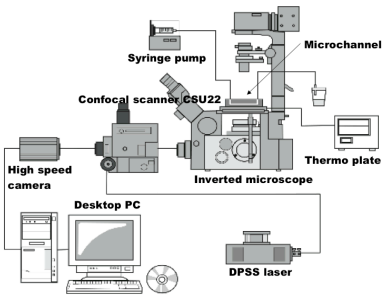

Fig. 2 : Experimental set-up

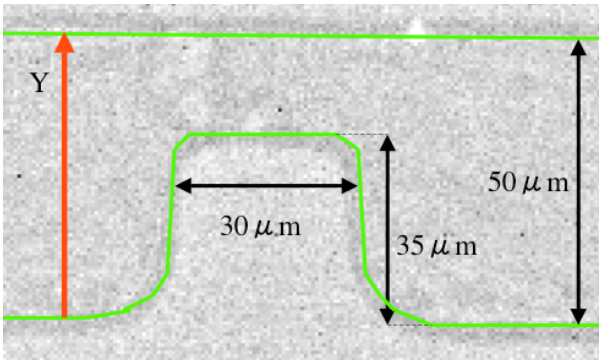

Fig. 3: Stenosis geometry

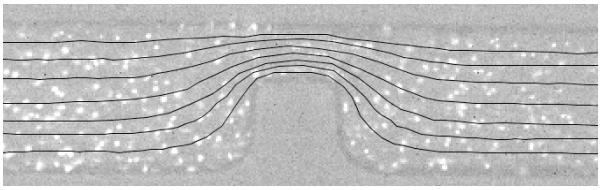

Fig. 4 : Stream Lines of pure water with fluorescent particles tracked by confocal-micro-PTV system

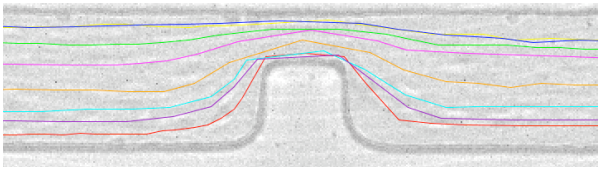

Fig. 5 : Trajectories of RBCs in 10% Hct by confocal-micro-PTV systems

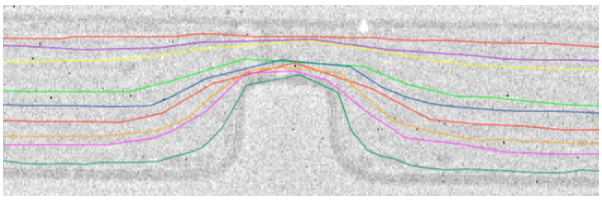

Fig. 6 : Trajectories of RBCs in 20% Hct by confocal-micro-PTV systems

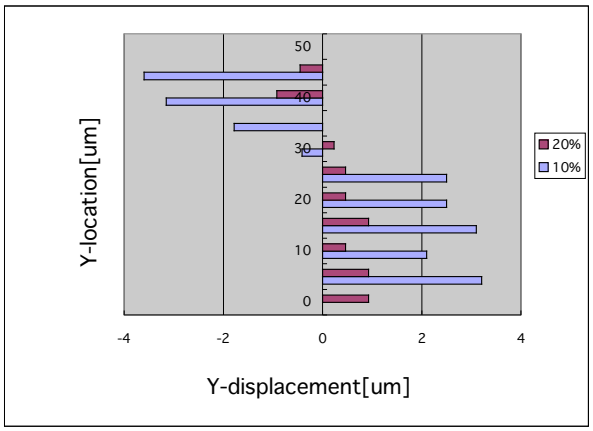

Fig. 7 : Correlation between Y-location and Y-displacement

References

[1]Rui Lima, Tohoku University Ph.D thesis, 2007
[2]Magalie Faivre et al., *Biorheology*.**43**, 147-159, 2006