Effects of RBC aggregation and deformability on blood flow in stenosed microvessels

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Background

The presence of stenosis is often related with the narrowing of blood vessels. Recently, the stenosis has been found in smaller arteries with internal diameters ranging up to a few hundred micrometers [1]. The blood flow characteristics in such microvascular stenosis contain important information related to circulatory disorders or microvascular diseases, such as lacunar infarct [2] and coronary microvascular disease[3]. Because of the complexity of blood flow and biophysical properties, the hemodynamic and hemorheological features have not yet been clearly explored. Due to discrete nature of red blood cell (RBC) motion, the blood flow exhibits non-Newtonian behavior in the stenosed microvessels.

Methodology

Dissipative particle dynamics was employed to simulate the flows of RBC suspension in stenosed microvessls and investigate the effects of RBC deformability and aggregability. A spring-based network membrane model was used to characterize cell deformation, and a Morse potential function to represent the intercellular interaction energy.

Results and Conclusion

The results revealed that the cell distribution is asymmetric before and after the stenosis though the microvascular stenosis is symmetric in geometry. It can be observed cell crowding occurs upstream the stenosis, causing a thinner CFL (cell free layer) than the downstream one. With the decrease in the size of the stenosis, the cell largely deforms itself to squeeze into the narrowing zone, leading to the reduced blood flow velocity and consequently resulting in elevated relative blood apparent viscosity. Also, owing to the interaction between the RBCs and constricted geometry, the augmentation of the Fahraeus-Lindqvist effect can be found in the stenosed microvessels. Furthermore, vascular diseases are often accompanied with reduced deformability or strong aggregability of RBCs. If the RBCs are less deformable, more time is spent on the deforming of RBCs to adapt to the stenosis, so the blood velocity obviously decreases with the RBC deformability. The vascular stenosis not only decreases the gap between different RBCs, but also prolongs the residence time, triggering the formation of the RBC rouleaux, which hinders the deformation and motion of the RBC aggregate when passing through the stenosis and then brings about the blockage.

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References

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