EFFECTS OF FLEXIBILITY OF MICROVILLI OF LEUKOCYTES ON ADHESION DYNAMICS

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Abstract. Previous work reported that microvillus deformation has an important influence on dynamics of cell adhesion. However, the existing studies did not consider the effects of microvillus bending deformation on cell adhesion. We present an immersed boundary lattice-Boltzmann lattice-spring method (IBLLM) combined with adhesive dynamics (AD) to simulate a leukocyte rolling along selectin-coated substrate and investigate the effect of microvillus flexural stiffness of leukocyte rolling adhesion.

1 INTRODUCTION

Receptor-mediated adhesion plays an important role in many physiological processes and biotechnology-related applications, such as leukocyte recruitment to sites of inflammation and selective capture of target cells from blood. Experimental and numerical studies have confirmed that a variety of factors, such as cell deformability, association and dissociation rates of adhesion bonds, receptor and ligand densities, and flow rate, affect the dynamics of cell adhesion [1, 2]. Since most of receptors are located at the microvillus tips, deformation of microvilli could potentially affect the adhesion status of cells. Therefore, some simulation work was performed to investigate the influence of microvillus deformation on cell adhesion [3, 4]. However, the existing studies were limited to the extensional deformation of microvilli and did not consider the effects of their bending deformation on cell adhesion, as this study does.

2 METHOD

This study presents an advanced leukocyte model, which consists of a combination of five numerical models: Lattice Boltzmann Method (LBM) for blood flow [5]; Coarse-Grained Cell Model (CGCM) for leukocytes [6]; Lattice Spring Model (LSM) for microvilli [7]; Immersed Boundary Method (IBM) for the blood-cell interactions [8]; and Adhesive Dynamics (AD) for stochastic binding between the leukocyte and selectin-coated substrate [1]. This innovative model introduces the flexural stiffness of microvilli to investigate the influence of bending of microvilli on leukocyte adhesion. These five models are implemented using single-GPU CUDA strategies presented by [9].
3 CONCLUSION

We have demonstrated that the IBLLBM can be accelerated by implementing a single GPU device with CUDA, resulting in a maximum increase in computational power of 80-fold speedup. Also, the simulation results reveal that the flexural stiffness of microvilli and their bending deformation have a profound effect on rolling velocity and adhesive forces. As the flexural stiffness of the microvilli decreases, their bending angles increase, resulting in an increase in the number of receptor-ligand bonds and adhesive bonding force and a decrease in the rolling velocity of leukocytes. This information plays a critical role in the scientific understanding of inflammation as a disease-causing mechanism within the biophysical landscape of the human body and will allow for increased diagnostic efficacy.

REFERENCES


