8th. World Congress on Computational Mechanics (WCCM8)
5th. European Congress on Computational Methods in Applied Sciences and Engineering (ECCOMAS 2008)
June 30 – July 5, 2008
Venice, Italy

THREE-DIMENSIONAL SIMULATION OF BLOOD FLOW ARISING FROM MALARIA INFECTION

***Hitoshi Kondo[1], Yohsuke Imai[1], Takuji Ishikawa[1], Ken-ichi Tsubota[2], Chwee Teck Lim[3] and Takami Yamaguchi[1]**

[1]Department of Bioengineering and Robotics, Tohoku University
6-6-01 Aramaki Aza Aoba, Aoba-ku, Sendai-shi, Miyagi 980-8579, Japan
hitoshi@pfsl.mech.tohoku.ac.jp

[2]Department of Electronics and Mechanical Engineering, Chiba University
1-33 Yayoi, Inage, Chiba 263-8522, Japan
tsubota@fculty.chiba-u.jp

[3]Division of Bioengineering and Department of Mechanical Engineering, National University of Singapore
9 Engineering Drive 1, Singapore 117576
ctlim@nus.edu.sg

Key Words: *malaria, red blood cell, numerical simulation, particle method.*

ABSTRACT

Malaria is one of the most serious, commonest and widespread infectious diseases of the red blood cells (RBCs). The invasion and occupation of a malaria parasite in a RBC exert mechanical and surface morphology changes. Infected RBC (IRBC) plays a critical role in the microvascular obstruction that leads to severe symptoms in malaria. However, the detailed mechanism of microvascular occlusion due to malaria transmission has not been clarified. In our previous study, we developed a two-dimensional model of blood flow in malaria infection [1]. The two-dimensional model could express some characteristics behaviors of IRBC. In this study, we extend this model to three-dimension to examine more realistic physiological flow conditions. All the components of blood is discretized by particles. In the model, the motion of all particles, which is assumed to be incompressible fluid, is governed by continuity equation and Navier-Stokes equation. These equations are solved by using Moving Particle Semi-implicit (MPS) method [2]. Deformability of RBCs is depicted by spring network model. A membrane particle is connected to their neighboring membrane particles by two kinds of springs, stretch/compression and bending springs. IRBCs lose their deformability because of alteration of membrane structures as well as influence from the rigid parasites. The loss of deformability is expressed by increasing the spring coefficients. These spring coefficients are determined by comparison between numerical results and experimental results [3]. Adhesion of IRBCs to endothelial cells or neighboring RBCs is also modeled by using locally connected springs. Maturation of parasites inside a host RBC develops knobs on the surface that mediate cell-cell interaction. The increase in the adhesive interaction with the progression of infection is represented by increasing the spring coefficient. These spring forces are substituted into the external force term in the Navier-Stokes equation. We will show the numerical results of three dimensional blood flow with IRBC, and discuss the efficiency of the proposed model.

REFERENCES

[1] H. Kondo, Y. Imai, T. Ishikawa, K. Tsubota and T. Yamaguchi, "Modeling of malaria-infected red blood cell mechanics using a particle method", *Proceedings of APCOM'07-EPMESC XI*, CD-ROM, (2007).

[2] S. Koshizuka, Y. Oka, "A particle method for incompressible viscous flow with fluid fragmentation", *Nucl Sci Eng.*, Vol **123**, pp. 421-434, (1996)

[3] S. Suresh, J. Spatz, J.P. Mills, A. Micoulet, M. Dao, C.T. Lim, M. Beil, T. Seufferlein, "Connection between single-cell biomechanics and human disease states: gastrointestinal cancer and malaria", *Acta Biomater.*, Vol. **1**, pp. 15-30, (2005)