11th. World Congress on Computational Mechanics (WCCM XI)
5th. European Conference on Computational Mechanics (ECCM V)
6th. European Conference on Computational Fluid Dynamics (ECFD VI)
July 20 - 25, 2014, Barcelona, Spain

Optical measurement of biomechanical properties of human red blood cells

Hyunjoo Park[1] and YongKeun Park[2]

[1] Department of Physics, KAIST, Republic of Korea 305-701, hyunjoo.park@gmail.com
and http://bmokaist.wordpress.com
[2] Department of Physics, KAIST, Republic of Korea 305-701, yk.park@kaist.ac.kr
and http://bmokaist.wordpress.com

Key Words: *Cell mechanics, Red blood cell, Imaging, Experimental Methods.*

1. Introduction

The dynamic membrane fluctuation in red blood cells (RBCs), consisting of submicron displacements, can be altered by changing the pathophysiological conditions of the cells. Since dynamic fluctuations in the RBC membrane are strongly correlated with the structures of the cell membrane and can be altered by biochemical alterations, we analyzed the membrane fluctuations using a composite membrane model [1] in order to simultaneously retrieve the complete mechanical properties of RBCs. The key mechanical properties of RBCs (bending modulus, shear modulus, area expansion modulus, and cytoplasmic viscosity) were simultaneously measured with minimum perturbation [2]. We have systemically dynamic membrane fluctuations in the cell membrane, which can be altered by various pathophysiological conditions: morphological transition of red blood cell [1]; parasitization by the *P. falciparum* parasites [3-5]; metabolic remodeling of the membrane driven by Adenosine-5'-triphosphate (ATP) [6]; varying osmotic pressure of medium[7]; and sickle cell disease [2].

2. Methods and Results

To quantitatively measure the morphology and dynamic membrane fluctuations of RBCs, we use diffraction phase microscopy (DPM) [8, 9]. By measuring the optical phase shift images of the cell, DPM precisely measures the cell thickness map without using exogenous labeling agent. The blood samples were obtained from healthy individuals and patients with various pathophysiological conditions, including parasitization by the *P. falciparum* parasites [3-5]; metabolic remodeling of the membrane driven by Adenosine-5'-triphosphate (ATP) [6]; varying osmotic pressure of medium[7]; and sickle cell disease [2]. The spatio-temporal information of dynamic membrane fluctuation of individual RBCs was quantitatively measured.

To investigate the biomechanical properties of RBCs, we analyzed the measured membrane fluctuations using our previously developed viscoelastic continuum model of the composite spectrin-network/lipid membrane [1, 7]. By fitting the two-point correlation function of the measured membrane fluctuation to the model, we can quantitatively determine the mechanical parameters. From these fits we determined the four important biomechanical properties of RBCs in SCD: bending modulus, shear modulus, area expansion modulus, and cytoplasmic viscosity.

3. Conclusion

We will present the results on the complete characterization of the relevant biomechanical properties of individual RBCs with various pathophysiological conditions using non-invasive optical measurements. The present optical approach may provide unique advantages for better understanding the cell mechanics by probing the mechanical properties of RBCs without external perturbation. Furthermore, the present method may have potentials to provide further understanding of pathogenesis and pathophysiology of RBC-related diseases which will lead to the development of new tools to manage diseases as well as the stimulation of other related fields such as computational or theoretical cell mechanics.

REERENCES

[1] Y. K. Park, C. A. Best, K. Badizadegan et al., Measurement of red blood cell mechanics during morphological changes, *Proc. Natl. Acad. Sci. USA.*, 107(15), 6731 (2010).
[2] H. S. Byun, T. R. Hillman, J. M. Higgins et al., Optical measurement of biomechanical properties of individual erythrocytes from a sickle cell patient, *Acta Biomat.*, (2012).
[3] Y. Park, M. Diez-Silva, G. Popescu et al., Refractive index maps and membrane dynamics of human red blood cells parasitized by Plasmodium falciparum, *Proc. Natl. Acad. Sci. USA*, 105(37), 13730-5 (2008).
[4] R. Chandramohanadas, Y. Park, L. Lui et al., Biophysics of malarial parasite exit from infected erythrocytes, *PLoS One*, 6(6), e20869 (2011).
[5] M. Diez-Silva, Y. Park, S. Huang et al., Pf155/RESA protein influences the dynamic microcirculatory behavior of ring-stage Plasmodium falciparum infected red blood cells, *Sci. Rep.*, (2012).
[6] Y. Park, C. A. Best, T. Auth et al., Metabolic remodeling of the human red blood cell membrane, *Proc Natl Acad Sci U S A*, 107(4), 1289-94 (2010).
[7] Y. Park, C. A. Best, T. Kuriabova et al., Measurement of the nonlinear elasticity of red blood cell membranes, *Phys. Rev. E*, 83(5), (2011).
[8] G. Popescu, T. Ikeda, R. R. Dasari et al., Diffraction phase microscopy for quantifying cell structure and dynamics, *Opt. Lett.*, 31(6), 775-777 (2006).
[9] Y. Park, G. Popescu, K. Badizadegan et al., Diffraction phase and fluorescence microscopy, *Opt Express*, 14(18), 8263-8 (2006).