Biomechanics of Erythrocytes in Sickle Cell Anemia

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Biomedical Background

Sickle Cell Disease (SCD), also known as sickle cell anemia, is a genetic blood disorder resulted from a single point mutation in the β-globin gene. The mutation in sickle hemoglobin (HbS) causes binding between the β1 and β2 chains of two HbS molecules when deoxygenated, and this crystallization produces a polymer nucleus, which grows inside the red blood cell (RBC) (1). The HbS polymerization is believed to damage RBC membrane, decrease the RBC deformability, promote cellular dehydration, and trigger RBC sickling, which leads to vaso-occlusion and impaired blood flow in post capillaries and small vessels, see Fig. 1. However, there is only limited understanding of the link between the hemoglobin HbS polymerization and the life-threatening painful crises of SCD.

There are different types of sickle cells playing critical roles in the vaso-occlusion process, where the relatively soft sickle cells first adhere to the endothelial walls and the sickled and dense RBCs are more likely to be trapped among the adherent RBCs. With significant heterogeneity of the shape and stiffness evolution of sickle RBCs, the vaso-occlusion appears to be a time-delayed/coordinated event among different factors including RBC stiffness, shape and size. These observations point to a fundamental need, in addition to understanding the adhesion process, to characterize the dynamically changing heterogeneous shape and mechanical properties of the sickling RBCs individually and population-wise.

Biophotonic Contributions

Quantitative Phase Imaging (QPI) in the transmission mode provides high precision measurement of the optical path length. Optical path length contains information on both morphology and optical properties of the biological sample where decoupling these two properties have been one of the major challenges in QPI. However, if the biological sample is optically homogenous such as the case of the red blood cell, one can measure the cell morphology with nanometer accuracy in a single shot of the camera. Through high-speed measurement of the morphology, dynamics of the membrane thermal fluctuation can be measured. This dynamic may then be used to monitor erythrocytes mechanics through various stages of the SCD. In our most recent study, we have studied the morphology and mechanics of different types of erythrocytes in a sickle patient and compared the membrane elasticity and cytoplasmic viscosity to that of a normal erythrocyte (2).
**Figure 1** Pathophysiology of sickle-cell disease

**Figure 2** Membrane fluctuation of the RBC in sickle-cell disease

**Figure 1** Topographies of individual RBCs from a sickle-cell patient
Background Publications


Representative Collaborative Publications


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