UNIVERSITY of HOUSTON | ENGINEERING

Department of Biomedical Engineering

Wednesday, July 29th, 2020

11:00 AM

Defense held online via Zoom

Madeleine Lu

PhD Dissertation Defense

Dr. Sergey Shevkoplyas, Faculty Advisor

"Novel microfluidic technologies for evaluating red blood cell rheology during blood processing and in sickle cell disease"

Abstract

Normal human red blood cells (RBCs) are relatively simple in structure as they contain no major organelles and have no nucleus. Because of this, they typically assume a flat biconcave disk shape at rest. This unique shape grants RBCs the flexibility to deform in response to the varying shear stresses it will experience in circulation as well as squeeze into narrow capillaries smaller than the RBC's major diameter. Therefore, the RBC's ability to deform is crucial in ensuring the efficient delivery of oxygen throughout the entire body. However, under certain conditions or due to certain genetic disorders, the RBC changes in shape and becomes a non-deformable and rigid cell. Additionally, these RBCs have been shown to express surface markers that promote interactions with and adherence to vessel walls. The changes in RBC deformability and adhesiveness, two fundamental hemorheological properties, can impact RBC viability and are associated with a host of adverse clinical outcomes.

This dissertation first investigates how RBC morphology can be affected during blood processing and introduces novel methods for ameliorating such adverse effects. Next, it explores the use of hemorheological biomarkers as quantitative metrics to assess the effectiveness of existing and novel therapeutic options for sickle cell disease (SCD). Many current modalities for analyzing RBC rheology involve the use of large and costly machinery, making it difficult to employ these investigations in a wide variety of settings and impossible to incorporate the studies into the clinical practice. To address these needs, this dissertation further proposes the use of novel microfluidic technologies developed to (1) process stored RBCs to remove harmful residual plasma proteins, (2) investigate the effects of novel storage washing solutions on RBC morphology, and (3) aid in understanding the role both deformability and adhesion play in microvascular perfusion. The contributions of this work build upon our current knowledge on the importance of RBC deformability and adhesion on blood flow and provide low-cost techniques and approaches for processing, evaluating, and monitoring these hemorheological properties.

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