Title: Optimizing Arteriolar Network Analysis Using an Integrated Hemodynamic Model Derived from Experimental Data

Trainee Name: Zahra Farid

Supervisor(s): Dr. Dwayne Jackson and Dr. Daniel Goldman

Structured Abstract:

Introduction: Diabetes is a chronic disease that has major effects on the vascular system, which leads to conditions such as vision loss and renal failure. The main source of organ failure is the characteristic high blood sugar, which causes damage to the microvasculature leading to abnormal blood flow distribution. Knowing the importance of microvascular structure on blood flow and tissue function, our objective is to develop an analysis technique for studying blood flow in complete microvascular systems. Specifically, we are optimizing our arteriolar network analysis by including variable capillary resistance and venular network geometry, and validating the accuracy of our technique using Murray's law (power-law dependence of flow on diameter) and experimental flow measurements.

Methods: Previously acquired intravital videomicroscopy (IVVM) images of the gluteus maximus muscle of male Sprague-Dawley rats (aged 8-9 weeks; 303±15 g) were used in this study. In our preliminary study, we demonstrated the important role of capillary resistance and venular network geometry on arteriolar blood flow and red blood cell (RBC) distribution in terminal arterioles (TAs). Arteriolar and venular networks were reconstructed from the IVVM data, and total capillary resistance for each network was estimated and applied based on the arteriolar network resistance and relative pressure drop between arteriolar and capillary sections of the network. The capillary resistance in our preliminary study was distributed equally between each TA segment. In our current, optimized approach, the capillary resistance is distributed to each TA segment according to its diameter, and therefore, variable. We acquired fluorescent streaks for experimental blood flow data in an arteriolar network, which we used to validate flow values predicted by our steady-state, two-phase model.

Results: Using the newly acquired experimental flow data and the corresponding reconstructed network, we found an improved match between predicted and measured arteriolar flows using the variable capillary resistance. In addition, the new data gave a Murray's law exponent of approximately 2.8, to which we compared predicted values from blood flow simulations. Using n=3 reconstructed networks, we found a Murray's law exponent of 2.78±0.30 using variable capillary resistance vs. 1.95±0.17 using constant capillary resistance.

Discussion: Our results, using improved theoretical methods and newly acquired flow data, show that our network-oriented approach is moving towards more accurately predicting hemodynamic properties of arteriolar networks under normal baseline conditions. We are currently working to extend this approach and apply it to networks under different experimental conditions.