Title: Development of near-infrared spectroscopy system to monitor microvascular function: Pilot project in the Intensive Care Unit

Trainee Name: Dr. Asher Mendelson

Supervisor(s): Dr. Christopher Ellis

Structured Abstract:

Introduction: Microvascular dysfunction - particularly maldistribution of oxygen and RBC flow - has been implicated in many acute and chronic diseases that affect countless patients around the world. Yet, current medical diagnostics are generally unable to provide a functional assessment of human microcirculation in vivo. Our lab has developed optical processing and analytics for rodent intravital microscopy that allow real-time dynamic tracking of the oxygen regulatory system during progressive microvascular failure in sepsis (i.e. overwhelming systemic infection). The purpose of this project is to demonstrate translational physiology from rodent to human scale and feasibility of this monitoring system in the clinical environment.

Methods: We use a modified QE65000 continuous-wave spectrometer (650-900nm; Ocean Optics) and broadband light source connected via optical fibres to a 3D-printed probe holder. Patients with sepsis and controls are recruited from the Intensive Care Unit (ICU) at University Hospital. Optical signal is captured at the bedside for up to 4-hrs on the quadriceps and/or biceps muscle. Baseline clinical demographics and physiologic parameters are recorded; administration of vasoactive drugs, intravenous fluids, and clinical events are noted. Tissue hemoglobin and oxygen content are analyzed over a minimum of 10 minutes to generate microvascular functional metrics.

Results: To date, fifteen (15) patients have been studied in the ICU (age 68.8 yrs +/- 10.8; weight 90.0 kg +/- 13.4). The system incorporates well into the physical clinical environment but the probe is vulnerable to motion artifact from patient movement. The increased signal intensity at 15mm vs 20mm probe distance was advantageous for post-processing. Changes in tissue oxygen and hemoglobin content were detectable during intermittent venous occlusion with compression stalkings. We observe oscillations in oxygen and hemoglobin in a patient with severe sepsis that are highly comparable to those in our septic animal models. Preliminary analysis of microvascular functional metrics appears to discriminate between control patients and those with moderate and severe sepsis.

Discussion: Continuous monitoring of microvascular oxygen and hemoglobin content in human skeletal muscle is feasible at the bedside and can provide a functional assessment of the human microcirculation in real-time. Metrics appear concordant with our pre-clinical animal work. Future efforts will be directed towards optimizing data capture and signal stability, as well as establishing the range of observed values over a heterogenous patient population in the ICU.