Title: A bedside optical neuromonitor for real-time measurement of cerebral perfusion and metabolism to prevent preterm brain injury

Trainee Name: Ajay Rajaram

Supervisor(s): Keith St. Lawrence and Mamadou Diop

Structured Abstract:

Introduction: In Canada, 8% of births occur prematurely. Preterm infants born with very low birth weights (<1500g) are at a high risk of neurodevelopmental impairment. The premature brain is believed to be vulnerable to periods of low cerebral blood flow (CBF), which can impair energy metabolism and lead to irreversible tissue damage. Today’s neonatal intensive care unit (NICU) is not equipped to track these parameters. There is, therefore, a need for an efficient neuromonitoring method that could alert the neonatal intensive care team to reductions in CBF and cerebral metabolism before injury occurs. The objective of this study is to develop a bedside optical system for simultaneous monitoring of CBF and the oxidation state of cytochrome c oxidase (CCO) – a key component of oxidative phosphorylation and a marker of tissue metabolism.

Methods: Near-infrared spectroscopy (NIRS) is an optical technique that exploits light absorption properties to determine the concentration of chromophores in tissue. Hemoglobin concentration can be used to determine cerebral oxygen saturation (ScO2), and metabolism can be inferred from concentrations of oxidized CCO. Diffuse correlation spectroscopy (DCS) is a technique which analyzes light scatter off of red blood cells to provide a measure of CBF. A custom shutter-based multiplexing method was implemented to combine NIRS and DCS while preventing crosstalk between the two systems. A series of optical elements were employed to maintain an adequate signal-to-noise ratio (SNR). The ability of the hybrid unit to monitor dynamic changes in cerebral perfusion and metabolism was demonstrated in a piglet model of hypoxic-ischemia (HI).

Results: ScO2, CBF, and CCO were measured concurrently throughout HI insult. An immediate response in all parameters was observed upon inducing HI; however, an uncoupling was found between the perfusion and metabolic responses. CCO exhibited a delayed response relative to CBF and continued to drop even after CBF and ScO2 had reached their nadir.

Discussion: This novel hybrid NIRS/DCS system allows for the first ever simultaneous acquisition of CBF and CCO. We believe this system could provide clinicians with greater insight into clinically significant hemodynamic events that precede brain injury. The information provided by this device could enable clinicians to make adjustments to patient management to avoid brain injury, and ultimately improve long-term outcome associated with preterm infants.