Title: Developing a Hybrid Optical System for Studying the Dynamic Regulation of Blood Flow/Metabolism in the Human Brain

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Structured Abstract:

Introduction: The brain relies on cerebral blood flow (CBF) for a continuous supply of oxygen and energy substrates. Due to its high metabolic demand – 20% of the body's total energy – and lack of its own energy stores, the brain is vulnerable to injury if CBF is significantly impeded, such as during a stroke. It has also been suggested that subtle changes to CBF regulation could contribute to age-related neurological diseases such as Alzheimer's. However, this link remains speculative because of the lack of non-invasive methods to study dynamic regulation of blood flow and oxidative metabolism in the human brain. Optical techniques are promising as oxy and deoxyhemoglobin concentrations can be measured by near-infrared spectroscopy (NIRS), CBF can be measured by an emerging technology known as diffuse correlation spectroscopy (DCS), and the combination can be used to quantify cerebral oxidative metabolism. The goal of this project is to develop a hybrid NIRS/DCS system with sufficient temporal resolution to study dynamic coupling of CBF, oxygenation and energy metabolism. The first step is to modify existing NIRS and DCS systems in order to provide simultaneous measurements without crosstalk between the two optical measurements. This study presents initial tests that were conducted to assess the suitability of optical filters for isolating DCS and NIRS signals.

Hypothesis: Simultaneous DCS and NIRS measurements can be achieved using optical filters to prevent signal crosstalk between the two systems, which will enable real-time measurement of CBF, oxygenation and energy metabolism.

Methods: Because the hybrid system uses different emission lasers for DCS (855 nm) and NIRS (760 and 830 nm), it should be possible to isolate the signals from the two systems with the appropriate high/low pass optical filters. To test the required isolation, experiments were conducted that involved the acquisition of NIRS and DCS data at varying source-detector distances (SDD) since intensity is inversely proportional to distance. A 3D-printed probe holder held emission and detection fibres of both systems in place above a tissue-like liquid phantom. Trials were conducted by collecting DCS data while varying NIRS signal intensity. Likewise, NIRS detectors were set to acquire data with DCS source on.

Results: DCS emission resulted in an immediate saturation of the NIRS detector, but with appropriate filtering, the NIRS system could work with DCS emission 3 cm away from its detectors. DCS was capable of measuring flow values accurately with NIRS emission 2 cm away from its detectors without modification.

Discussion: Preliminary results show that both systems can work together, collecting data from approximately the same tissue volume. The experiments with the tissue-mimicking phantom indicated filters will not be required on the detector side of the DCS system but is required for NIRS in order for the hybrid system to function.