Development of a non-Invasive, optical technique for capturing blood flow pulsatility using diffuse correlation spectroscopy

Mahro Khalid

Supervisor: Dr. Keith St. Lawrence

Background: A primary concern in the care of patients with a neurological emergency, such as stroke, traumatic brain injury and subarachnoid hemorrhage, is the incidence of secondary brain injury. These injuries are often a result of complications that impair normal regulation of cerebral blood flow (CBF). However, there are currently no established bedside methods of monitoring CBF that could alert the intensive care staff to cerebrovascular dysfunction before permanent brain damage occurs.

Optical techniques show promise for neuromonitoring as they are non-invasive, extremely safe and hemoglobin is a strong light absorber, which can be used to assess tissue oxygen saturation. An emerging optical method is diffuse correlation spectroscopy (DCS), which uses the temporal correlation of signal fluctuations to characterize the movement of light scatterers. In tissue, signal fluctuations are dominated by the flow of red blood cells through microvasculature; thus, DCS provides a non-invasive means of monitoring CBF. Recent advances in DCS data acquisition schemes have significantly enhanced its temporal resolution, enabling flow pulsatility to be captured and providing a unique means of cerebral perfusion pressure through the calculation of critical closing pressure. So, the purpose of our work is the acquisition of sub-second DCS correlation data, which we believe will provide sufficient temporal resolution to capture flow pulsatility in a microvascular bed.

Materials and Methods: A software-based correlator for DCS was developed to measure changes in CBF due to arterial pulsation. The system consists of a single-photon detector coupled to a high-speed counting board, which feeds the output to a high-level software program to compute autocorrelation functions with sub-second resolution. The advantage of this approach compared to a commercial hardware correlator, which measures correlation times over a wide and fixed range (1µs-1s), is the ability to measure only those correlation times relevant to blood flow (typically between 10 and 100 µs). Targeting the optimal range greatly enhances the signal-to-noise ratio, thereby allowing CBF to be measured with millisecond resolution.

To demonstrate fast acquisition speed of the developed system, we placed an emitter-detector pair on the index finger and collected data at a temporal resolution of 100ms. The measurements were taken over a wide range of time intervals, and data were collected under baseline and reduced blood pressure condition. This was done using an arm cuff occluding device; and then the results were analyzed to see the differences in the pulsatile component of flow.

Results: The results obtained show clearly defined pulsatile waveforms under baseline conditions, which corresponds with the beat-to-beat variability of the heart. Whereas, under arm cuff ischemic condition, the pulsatile component is greatly reduced, affirming our theory that fast blood flow measurements using DCS can provide information about the pulsatility with the changes in flow.

Discussion and Summary: The primary focus of this project was to devise a portable, compact system for fast blood flow measurements. So far we have developed a system capable of acquiring correlations data at 100ms resolution. Initial findings have demonstrated the ability of the system to capture flow waveform associated with arterial pressure. The next step is to translate this technology onto applications that deals with cerebral health. For this, we plan to move onto multiple detectors, so as to increase our depth sensitivity and signal-to-noise ratio. We
also plan to test the device on an animal model and check the pulse variability with the manipulation of vascular compliance and resistance. In short, the final aim of this research is the development of a high-speed DCS system for assessing critical parameters of cerebral microvascular health; such as the correlation between the incidence of secondary brain injury and changes in cerebral perfusion pressure.