Title: Self-calibrated DCS for Monitoring Absolute Cerebral Blood Flow

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Structured Abstract:

Introduction: Premature infants are believed to be susceptible to neurological impairments, due in part to poor cerebral vascular regulation, which can lead to periods of dangerously low cerebral blood flow (CBF) and ischemic injury if not detected. However, there are currently no established bedside methods of monitoring CBF to alert the intensive care staff of cerebrovascular dysfunction. Diffuse correlation spectroscopy (DCS) is an emerging non-invasive optical technique for monitoring relative CBF, but it does not provide a measure of absolute blood flow, making it difficult to assess if CBF drops to ischemic levels. The DCS signal can be converted into units of CBF by obtaining an estimate of absolute flow using dynamic contrast-enhanced (DCE) near-infrared spectroscopy (NIRS). That is, a single value of CBF obtained using an optical contrast agent can be used to calibrate the blood flow index (BFI) data obtained by DCS. This approach typically requires combining two optical systems: NIRS for measuring CBF and DCS for monitoring BFI. Here, I will present a DCS system capable of obtaining both measurements—thereby removing the need to combine DCS with NIRS.

Methods: The modifications required for the self-calibrated DCS method were to replace a dedicated hardware correlator with a software version in order to access the photon counts, and to record data at multiple source-detector distances. The baseline optical properties were derived from light intensity measurements at different distances using the principle of spatially resolved NIRS and solution to diffusion equation for a semi-infinite homogeneous medium. From the baseline optical properties, the differential pathlength (DP) was calculated, which was used to convert time-varying changes in light intensity caused by the passage of contrast agent indocyanine green (ICG) through the cerebral vasculature into an ICG tissue concentration curve.

Results: Experiments were conducted using newborn piglets in which CBF was increased by changing arterial carbon dioxide tension (PaCO2) from normocapnia to hypercapnia. During the former, baseline intensity and g2 data were acquired to extract baseline optical properties and DP. The DCE protocol required an IV bolus injection of ICG, followed by acquiring serial intensity measurements for 120 s at a temporal resolution of 300 msec. At the same time, the arterial ICG concentration was measured non-invasively by a dye densitometer. CBF was calculated from the tissue and arterial ICG concentration curves. PaCO2 was then increased and multi-distance light intensity and g2 data was recorded to measure changes in light absorption and CBF. A noticeable change in blood flow was observed during this.

Discussion: The study successfully demonstrated that multi-distance DCS can track absorption changes with high contrast to noise and proves that a stand-alone DCS system is capable of calibrating BFI measurements, eliminating the use of two optical system.