Title: NNeMo (Neonatal Neuromonitor): A non-invasive optical device for continuous monitoring of cerebral blood flow and energy metabolism in the developing brain

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Structured Abstract:

Introduction: The human brain relies almost exclusively on oxidative metabolism, having very limited energy storage, and is therefore susceptible to injury related to impaired cerebral blood flow (CBF). This is particularly evident in preterm infants as the underdeveloped vascular system in the immature brain can lead to poor CBF control. For example, cerebral autoregulation – the ability to maintain CBF despite changes in blood pressure – is known to be impaired in this age group [1]. However, the impact of cerebrovascular dysfunction on the coupling of CBF to cerebral energy metabolism in the developing brain is unknown due to a lack of adequate technologies for assessing these measures in such a fragile population. This study outlines the development and implementation of a unique neuromonitor for the neonatal intensive care unit (NICU) to measure CBF and energy metabolism. Metabolic measures were the cerebral metabolic rate of oxygen (CMRO2) and the oxidation state of cytochrome c oxidase (oxCCO) – the final electron acceptor in the electron transport chain and a direct marker of oxidative metabolism [2].

Methods: The neonatal neuromonitor (NNeMo) combines hyperspectral near-infrared spectroscopy (H-NIRS) to measure cerebral tissue saturation (StO2) and oxCCO with diffuse correlation spectroscopy (DCS) to provide continuous CBF monitoring. The combination of these systems was achieved using a multiplexing shuttering system capable of continuous quantification of StO2, CBF, oxCCO, and CMRO2 with a temporal resolution of 6 seconds. Infants at a high risk of brain injury (< 32 weeks gestational age and/or weighing less than 1500 grams) were recruited and monitored immediately following birth and resuscitation. Cerebral saturation, perfusion, and metabolism were recorded for 6-hour periods within the first 72 hours of life.

Results: Fluctuations in CBF were found to correlate temporally with changes in cerebral tissue saturation. A temporal delay in oxCCO was observed compared to the CBF and StO2 responses. Large and persistent drops in CBF preceded changes in metabolism, which is in agreement with metabolic change observed within animal models of brain injury. Ongoing studies will determine hemodynamic and metabolic correlation to the onset of brain injury.

Conclusions: Combination of H-NIRS with DCS provides a unique monitoring approach to study the coupling of CBF and metabolism in the developing brain. Preliminary investigation confirms the feasibility of clinical monitoring immediately following birth and shows the value of physiological precursors to structural injuries. Early assessment of perfusion and metabolism could provide clinicians with greater sensitivity to changes preceding preterm brain injury and could aid in patient management to ultimately improve clinical outcomes.