An Observational Study of Peripheral Muscle Oxygenation Using NIRS in a Cohort of Nourished and Malnourished Children with Pneumonia

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Introduction: Malnutrition is estimated to contribute to more than one third of all child deaths around the world especially in middle and low-income countries. Children affected by malnutrition are at 15-fold higher risk of mortality from pneumonia [1]. Pneumonia typical clinical signs may not be reliable in severe malnourished child due to an abnormal inflammatory response and severe muscle wasting and weakness [2]. Near Infrared Spectroscopy (NIRS) is a non-invasive optical technology used in clinical settings to measure changes in tissue oxygenation and hemodynamics that has demonstrated good prognostic capability in patients with sepsis [3]. The purpose of this study was to evaluate whether measurements of peripheral oxygen tissue saturation index (TSI) using a NIRS device could provide an objective measure of a child's systemic effects of pneumonia and allow identification of those who are at increased risk of dying from pneumonia.

Methods: With ethics approval and written informed consent from the parents or guardians, 185 children between 3 months and 5 years of age were recruited at two hospitals in Mbarara, Uganda. Children were stratified into four groups based on their nutritional status (a middle-upper arm circumference [MUAC], lower or higher than 12.5 cm) and the diagnosis of pneumonia (pneumonia and control group). Within six hours following admission, peripheral TSI was continuously recorded over the brachioradialis muscle using a portable NIRS device (PortaLite Mini, Artinis Medical Systems) before, during and following a vascular occlusion test (VOT). Demographic characteristics and clinical data including temperature, heart rate, respiratory rate and arterial oxygen saturation (SpO2) were measured. Multiple variables were calculated from the TSI (Fig.1 a). The diagnostic and outcome performance of the NIRS variables were assessed and compared to the other clinical variables using the Area Under the Receiver Operator Characteristic curve (AUROC).

Results: The baseline TSI was positively associated with the nutritional status of the child suggesting a higher oxidative stress of the muscle of malnourished children (Fig. 1 b). The most sensitive NIRS variables to identify children with systemic effects of pneumonia were the TSI Hyperemia Recovery Area which had an AUROC of 0.6799 (95% CI 0.6541 to 0.7452) in nourished children and the TSI Hyperemia Recovery Time which had an AUROC of 0.6966 (95% CI 0.5510 to 0.8036) in malnourished children. The respiratory rate performed best with an AUROC of 0.9609 (95% CI 0.9443 to 0.9833) and 0.9134 (95% CI 0.9107 to 0.9257) for nourished and malnourished children respectively, although confounded by the fact that respiratory rate is a component of pneumonia diagnosis. We also assessed the prediction of mortality among malnourished children with pneumonia, in which 23 children survived and 6 died. The best NIRS-related predictor was the TSI decline after 40s of vascular occlusion

(ΔTSI_{40s}), with an AUROC of 0.7681 (95% CI 0.7453 to 0.8880) while the best clinical predictor was the SpO_2 with an AUROC of 0.7043 (95% CI 0.5797 to 0.9091) (Fig. 1 c).

Conclusion: NIRS is an emerging technology that may allow clinicians to measure tissue level oxygenation and assess end-organ perfusion in a variety of tissues and for different clinical applications. However, it is still a young technology which requires further development and research. We found a weak association between NIRS features evaluated during a VOT on the brachioradialis muscle and the clinical diagnosis of pneumonia. Our results suggest that TSI baseline in a peripheral muscle is lower in a malnourished child but frequently preserved in the presence of pneumonia. The TSI decline after 40s of the arterial occlusion provided the best prediction of mortality from pneumonia but the small sample size precludes broader conclusions.

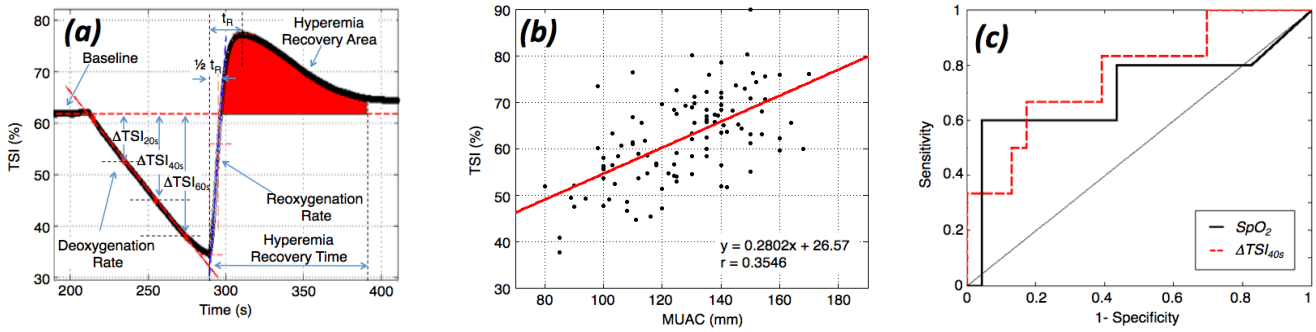

Figure1: (a) TSI before, during and after VOT and graphical representation of calculated variables (b) TSI baseline vs. MUAC (c) Receiver Operator Characteristic for mortality prediction in malnourished children with pneumonia.

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