A COMBINED FREQUENCY DOMAIN NEAR INFRARED SPECTROSCOPY AND DIFFUSE CORRELATION SPECTROSCOPY SYSTEM FOR MONITORING THE STERNOCLEIDOMASTOID MUSCLE

Carlos A. Gómez, Boston University
cagomez@bu.edu
David Boas, Boston University
W. Darlene Reid, University of Toronto
Darren Roblyer, Boston University

Key Words: Diffuse Optics, Diffuse Correlation Spectroscopy, Respiratory Muscles, Mechanical Ventilation

The process of weaning patients from mechanical ventilation is often difficult, traumatic for the patient, and likely to fail over repeated attempts. Despite the fact that a patient's respiratory muscles must be able to maintain spontaneous breathing in order to achieve successful weaning, the current standard of care does not include monitoring of the respiratory muscles, representing an unmet clinical need. Previous works, including our own, have used near infrared spectroscopy (NIRS) to investigate the sternocleidomastoid muscle (SCM), a secondary muscle of inspiratory respiration, during various exercise protocols [1], [2], helping to establish this as a target muscle for monitoring during weaning. However, prior studies have not measured SCM blood flow or muscle oxygen consumption, which are required to gain a more complete picture of the SCM response to weaning.

In this work a custom frequency domain NIRS (FD-NIRS) [3] and a custom diffuse correlation system (DCS) [4] were combined in order to monitor oxygenated hemoglobin and myoglobin (oxy [Hb + Mb]), deoxygenated hemoglobin and myoglobin (deoxy [Hb + Mb]), blood flow index (BF_i), and relative metabolic muscle rate of oxygenation ($rMMRO_2$) of the SCM. The combined system was characterized via in-vitro measurements and validated in a healthy volunteer study. 20 subjects performed a series of respiratory exercises with a respiratory training device while their SCM was monitored continuously. Each subject performed both a low and high load breathing exercise that consisted of a baseline, perturbation, and recovery period. The low load was defined as 30% of an individual's maximum inspiratory pressure (MIP) and the high load was 90% of their MIP. The MIP was calculated for each subject via a maximum inspiratory pressure breathing exercise.

Both a homogenous single layer Monte Carlo based look up table (LUT) and a subject specific multi layer LUT, which took into account subject's skin tone and adipose thickness, were used to analyze the data. Temporal features, rise and decay time of the perturbation, as well as absolute values of oxy/deoxy [Hb + Mb], BF_i, $rMMRO_2$ were compared between the two loads. The custom combined instrument was able to successfully monitor the SCM at the two loads and was sensitive enough to reveal differences between the loads. Figure 1 shows an example of low and high load responses from a single individual. The rise time was approximately 50 secs faster for tissue saturation and approximately 30 secs faster for BF_i for the high load (Figure 1). Meanwhile, the decay times were approximately 30 sec faster for the high load for both tissue saturation and BF_i (Figure 1). These data suggest our combined system may be beneficial for tracking SCM metabolism.

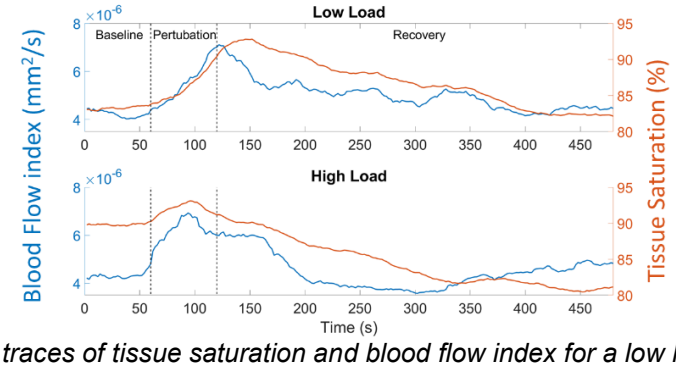

Figure 1 – Example time traces of tissue saturation and blood flow index for a low load (top figure) and high load (bottom figure).

[1] B. Shadgan, J. A. Guenette, A. W. Sheel, and W. D. Reid, “Sternocleidomastoid muscle deoxygenation in response to incremental inspiratory threshold loading measured by near infrared spectroscopy,” *Respir. Physiol. Neurobiol.*, vol. 178, no. 2, pp. 202–209, 2011, doi: 10.1016/j.resp.2011.06.001.
[2] R. Istfan, C. A. Gómez, M. Applegate, D. Rozenberg, W. D. Reid, and D. Roblyer, “Hemodynamics of the sternocleidomastoid measured with frequency domain near-infrared spectroscopy towards non-invasive monitoring during mechanical ventilation,” *Biomed. Opt. Express*, vol. 12, no. 7, p. 4147, 2021, doi: 10.1364/boe.430423.
[3] A. Torjesen, R. Istfan, and D. Roblyer, “ Ultrafast wavelength multiplexed broad bandwidth digital diffuse optical spectroscopy for in vivo extraction of tissue optical properties ,” *J. Biomed. Opt.*, vol. 22, no. 3, p. 036009, 2017, doi: 10.1117/1.jbo.22.3.036009.
[4] P. Farzam *et al.*, “Fast diffuse correlation spectroscopy (DCS) for non-invasive measurement of intracranial pressure (ICP) (Conference Presentation),” in *Proceedings Volume 10050, Clinical and Translational Neurophotonics; 100500U*, 2017, p. 28, doi: 10.1117/12.2252824.