Frederic Fairfield Memorial Award Winner 2017

Chris McKnight

Title:
Shedding new light on diving physiology: Using non-invasive near-infrared light spectroscopy to measure haemodynamics and oxygenation in the brain and blubber of free-swimming seals

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Abstract:

Knowledge of oxygen store management during diving underpins our understanding of energetics and foraging decisions in marine mammals. Minimally invasive measurement of real-time tissue-specific blood flow, oxygenation, and oxygen consumption in diving mammals remains challenging. We developed the first aquatic, non-implanted, near-infrared spectroscopy (NIRS) sensor measuring regional microvascular blood flow (total haemoglobin [tHb]) and oxygenation (oxy-deoxyhaemoglobin [HbO_2 - HHb]) in brain and blubber of four freely-diving harbour seals.

Optical properties (μ_a, μ_s, g, μ_s') were generated for seal tissues using optical-coherence-tomography and spectrophotometry. Optical propagation and Differential-Pathlength-Factor (DPF) were modelled using 3D Monte Carlo radiation transfer codes to develop bespoke, seal- specific optical algorithms extracting tHb, HbO_2 and HHb concentrations from the optical signal.

The sensor was attached to fur on the head, for cerebral measurements, or shoulders, for blubber measurements. Instrumented seals performed voluntary dives (n =120) swimming underwater to a feeding station 60m from a respirometry chamber. Oxygen consumption (VO_2) was measured for each post-dive surfacing.

Blood flow to brain and blubber decreased rapidly at the onset of each dive and was maintained during the dive. Oxygen depletion rate was constant throughout the dive and independent of locomotor activity, suggesting locomotor muscle blood flow decouples from core and peripheral flow. Brain and blubber blood flow increased rapidly 10-15s before surfacing to pre-dive levels, reaching oxygen concentration minima (O_{2min}), suggesting reperfusion in anticipation of surfacing. O_{2min} of brain and blubber tissue for each dive were compared with VO_2. Linear regression models showed a robust relationship (R^2 = 0.98 and 0.96) between O_{2min} and VO_2 in brain and blubber, showing utility of the method to estimate total body oxygen consumption dive-by dive.

Blood shunting from blubber occurred on a dive by dive basis rather than throughout immersion. This approach provides a new perspective on haemodynamic regulation and oxygen management of core (brain) and peripheral (blubber) tissues in phocids.