

Cardiac Output and NIRS in CPET (Prof. Piergiuseppe Agostoni)

This abstract addresses the essential role of Cardiac Output (CO) and the arteriovenous oxygen difference (a-vO₂diff) in interpreting maximal oxygen uptake (VO₂) using the fundamental Fick Principle: $VO_2 = CO \times (Ca - Cv)$. Measuring CO during Cardiopulmonary Exercise Testing (CPET) is crucial for identifying physiological limitations beyond just VO₂. Methods for measuring CO include the Inert Gas Rebreathing Method (using soluble and insoluble gases like SF₆ or N₂O to measure Pulmonary blood flow) and non-invasive devices such as PhysioFlow. PhysioFlow uses six electrodes on the thorax to continuously monitor heart rate (HR) and stroke volume (SV), deriving CO and cardiac index by stroke waveform morphology analysis. This device provides accurate, reproducible, and sensitive measurements, even in challenging patient populations.

The detailed analysis of VO₂ deficits is highly relevant for understanding functional capacity. For example, in a patient with a measured VO₂max that was 51% of predicted, the deficit was primarily attributed to cardiogenic limitations (74%) and anemia (26%), mainly due to a reduced increase in HR (71% of predicted). Clinical applications are broad, including monitoring patients with severe heart failure treated with CRT-D, Mitra Clip, or a Left Ventricular Assist Device. Increasing LVAD pump flow is associated with an improvement in resting and peak exercise CO and VO₂, and improved ventilation efficiency. However, increasing LVAD speed may also deteriorate alveolar-capillary gas diffusion.

The presentation notes that the Fick Principle can be "deceptive", as it does not explicitly address the distribution of blood flow. The a-vO₂ difference depends on blood distribution towards working muscle. Ideal Cardiac Output is defined as the lowest CO estimated for a given VO₂ that reflects ideal extraction (muscle extraction equals that of the whole organism).

Furthermore, Near Infrared Spectroscopy (NIRS) is introduced as a non-invasive optical technique for evaluating muscle energetics and tissue O₂ saturation. NIRS uses NIR light 700-1000nm to measure changes in oxyhemoglobin and deoxyhemoglobin, thereby determining the Tissue Oxygenation Index or Tissue Saturation Index. NIRS can also provide insights into complex phenomena such as periodic breathing in patients.