Summary Sheet

Cardiopulmonary Exercise Testing

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Cardiopulmonary exercise testing involves a patient undergoing exercise of increasing intensity. It is usually performed on a static bike with flywheel to which increasing resistance is applied. During the test oxygen uptake and carbon dioxide production are measured using a metabolic monitoring cart. A 12-lead ECG is recorded simultaneously. Cardio-respiratory performance during exercise is usually defined by the measurement of oxygen uptake by the tissues (oxygen consumption, VO_2), either as the maximum oxygen uptake measurable (VO_{2max}), or as the oxygen uptake at the onset of lactate production, commonly known as the anaerobic threshold (AT). Other useful parameters obtained include measures of ventilatory efficiency and the ability to diagnose myocardial dysfunction from heart failure or ischaemic heart disease.

Anaerobic threshold (AT)
AT is identified as the point at which there is onset of lactate production through the activation of anaerobic pathways. The lactate produced is buffered by bicarbonate to produce water and carbon dioxide. The net effect is an increase in the slope of the graph of carbon dioxide production relative to oxygen uptake Those patients whose AT occurs at oxygen uptake values less than 11 $ml.kg^{-1}.min^{-1}$ are at increased risk of mortality after surgery compared with those who have a higher oxygen uptake at AT.

AT usually occurs at 50-60% of VO_{2max}, and is independent of patient motivation. If the AT is the prime objective of the CPET the test can be stopped after it has been reached, and this may be advantageous in the frail or elderly surgical patient. This variant of CPET is known as a *submaximal* test, as the intention is not to test the patient to their maximum effort. Otherwise the test is continued to maximum effort, at which point the oxygen uptake is known as "$VO_{2\ Peak}$".

Ventilatory efficiency (VE/VCO2)
This is estimated from the ventilatory equivalent of carbon dioxide, which is the ratio of minute ventilation to carbon dioxide production, VE/VCO_2.
A normal value is around 25-30, and increases in the ratio reflect impairment of V/Q mismatch, either from respiratory causes or from impaired cardiac function.
In heart failure patients a value for VE/VCO_2 greater than 34 is associated with a poor prognosis, particularly when combined with an AT less than 11 $ml.kg^{-1}.min^{-1}$.
The same holds true for surgical patients, as the implication is that this combination reflects a patient with more severe underlying cardiac dysfunction. These patients are often asymptomatic at rest, but the mortality rate after surgery in this group is elevated, reflecting abnormal cardiac function response to the stress of surgery.

In a typical UK population of elderly surgical patients approximately 30% will have reduced AT combined with reduced ventilatory efficiency, and hence will be in a high risk group for s urgical intervention. This group of patients should be medically optimised prior to surgery where appropriate, and managed on high dependency care after surgery.

Oxygen pulse and workrate

Two parameters derived from gas exchange data can be used to identify patients with underlying myocardial dysfunction.

- Oxygen uptake per heart beat (VO_2/HR, also known as the "oxygen pulse"). This should increase steadily during exercise as a reflection of increases in underlying stroke volume initially, followed by increases in oxygen extraction. If the slope of the graph flattens during exercise this may reflect underlying myocardial wall motion abnormalities.
- Oxygen uptake to workrate relationship. For each 1 Watt increase in workrate the oxygen uptake should increase by 10 $ml.min^{-1}$. If this relationship is significantly less than 10 $ml.kg^{-1}.min^{-1}.Watt^{-1}$ this may indicate underlying heart failure. If the VO_2 / workrate relationship changes suddenly during exercise this may indicate the onset of myocardial ischaemia with consequent myocardial wall motion abnormalities.

Changes in either oxygen pulse or the VO_2 / workrate relationship usually occur 2-3 minutes before changes in the ST segment of the exercise ECG are observed. If a patient develops these abnormalities they may benefit from referral for cardiological assessment if symptomatic and other parameters such as AT are particularly impaired, or from cardiac protection from cardio-selective beta-blockade if asymptomatic.

Patient Stratification

At York Teaching Hospital, AT, VE/VCO2 and oxygen pulse or workrate are used to stratify patients to the enhanced protocol post-operatively (arterial line and cardiac monitoring).