Cardiopulmonary exercise testing

Surgery is associated with a substantial burden of perioperative morbidity and mortality. Patients presenting for surgery at a later age with more comorbidities represent a challenge for anaesthetists and surgeons. The ability to formally assess functional capacity adds an important perspective to the preoperative assessment of patients undergoing surgery.

Cardiopulmonary exercise testing

Cardiopulmonary exercise testing is a non-invasive test providing objective information about the cardiovascular, pulmonary and muscle function under physiological stress and the ability to deliver oxygen to peripheral tissues (Wasserman et al, 2004). Increasingly cardiopulmonary exercise testing is being used for preoperative risk assessment and to enable shared decision-making conversations with patients (Huddart et al, 2013).

Cardiopulmonary exercise testing equipment consists of a cycle ergometer and a metabolic cart containing gas analysers, a computer and screen to display continuous 12-lead electrocardiograph, blood pressure, oxygen saturations and graphical displays of the breath-by-breath measurement of oxygen consumption (VO_2) and carbon dioxide production (VCO_2). Important measurements include the anaerobic threshold, peak oxygen consumption (VO_2 peak), the oxygen pulse (VO_2/heart rate) and the ventilatory equivalents for oxygen and carbon dioxide.

When exercise commences muscle cells increase their oxygen demand. During early exercise, oxygen delivery is able to keep up with the demand so adenine triphosphate (ATP), the body's energy supply, is produced by aerobic metabolism. As exercise length and intensity increases, oxygen demand outstrips supply. The continued production of ATP needs supplementing by anaerobic metabolism. This becomes unsustainable as it results in lactic acid production which eventually produces hydrogen ions. Buffering with bicarbonate results in carbon dioxide production.

$$(H^+) + (HCO_3) \longleftrightarrow (H_2CO_3) \longleftrightarrow (CO_2) + (H_2O)$$

The point at which VCO_2 exceeds VO_2 is known as the anaerobic threshold. The anaerobic threshold is an objective end-point that is unrelated to patient effort. A low anaerobic threshold is an independent predictor of postoperative complications and mortality (Wilson et al, 2010).

> “Cardiopulmonary exercise testing is being used for preoperative risk assessment and to enable shared decision-making conversations with patients.”

VO_2 max represents cardiorespiratory reserve. It is subject to effort so motivation can affect the levels achieved. VO_2 increases linearly at approximately 10 ml/min/watt during exercise before it plateaus (VO_2 max) as either the cardiac system is unable to circulate enough oxygen to the muscles or the respiratory system is unable to take up sufficient oxygen from the lungs to the blood. A lower VO_2 max is associated with a poorer postoperative outcome and earlier death in the general population even if there is no concomitant diagnosed major illness (Moran et al, 2016).

Ventilatory equivalents are important markers of the ventilation/perfusion ratio. Increased ventilatory equivalents suggest increased dead space. The ventilatory equivalent for carbon dioxide is used in preoperative risk assessment. It is increased in lung conditions, heart failure and pulmonary hypertension.

The oxygen pulse is VO_2 divided by the heart rate. It represents the oxygen taken up by the lungs into the blood with each heart beat. It is an indirect indicator of cardiac stroke volume. A low oxygen pulse or one that plateaus early or suddenly in the test implies cardiac output limitations either as a result of cardiac disease or disorders of the pulmonary circulation.

Conclusions

Cardiopulmonary exercise testing is a powerful tool to reliably and objectively assess the functional reserve and look at how patients react physiologically to being put under stress. It is not designed to replace clinical examination or judgement but to supplement information already gathered and identify areas that may need addressing. It provides an individualized estimate of patient risk that can be used to inform collaborative decision making and patient consent. **BJHM**

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Perioperative medicine in a nutshell articles are edited on behalf of Trainees with an interest in perioperative medicine (TRIPOM) (www.tripom.squarespace.com) by Dr S Sothisrihari, ST7 trainee, London North East