Cardiopulmonary Exercise Testing in Heart Failure

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Introduction

During cardiopulmonary exercise testing (CPET), peak oxygen uptake (VO_2) is measured, making CPET the "gold standard" measure of maximal functional capacity. During CPET all ventilatory parameters can be measured together with blood pressure, arterial blood gasses, and heart rate (HR), thereby providing insight into mechanisms of functional limitations. Hallmark abnormalities of heart failure (HF) during CPET are decreases in peak VO2, oxygen pulse, and ventilatory efficiency, all reflecting an impaired exercise cardiac output and hampered O2 delivery. Measuring ventilatory patterns and VO_2 update can help determine disease severity and prognosis.

Peak VO_2

VO_2 measured at maximal symptom-limited exercise during CPET provides the best method to assess functional capacity. VO2 is by "Fick" principle equal to HR multiplied by stroke volume and oxygen extraction by peripheral tissues. This value must be adjusted according to age, sex, and body weight. When peak VO_2 is below 14 ml/kg/min, the patient is deemed to be a candidate for transplantation.

Submaximal O_2 Uptake Measurements

Recent studies have identified submaximal exercise gas exchange variables that improve upon the predictive ability of CPET. Oxygen kinetics, oxygen uptake efficiency slope (OUES), VO2 at the ventilatory threshold, and a plateau in the oxygen pulse (VO_2/HR) curve provide detailed data on metabolic and cardiac function. The assessment of aerobic efficiency represented by VO_2 per unit of work predicts patient responses to low-level exercise, activities of daily living, and independence, and relates closely to prognosis in heart failure (HF). Estimation of submaximal gas exchange parameters presented as slopes is particularly helpful when patients do not clearly meet criteria for a maximal volitional exertion as determined by a respiratory exchange ratio <1.0 to 1.1. See Figure 1.

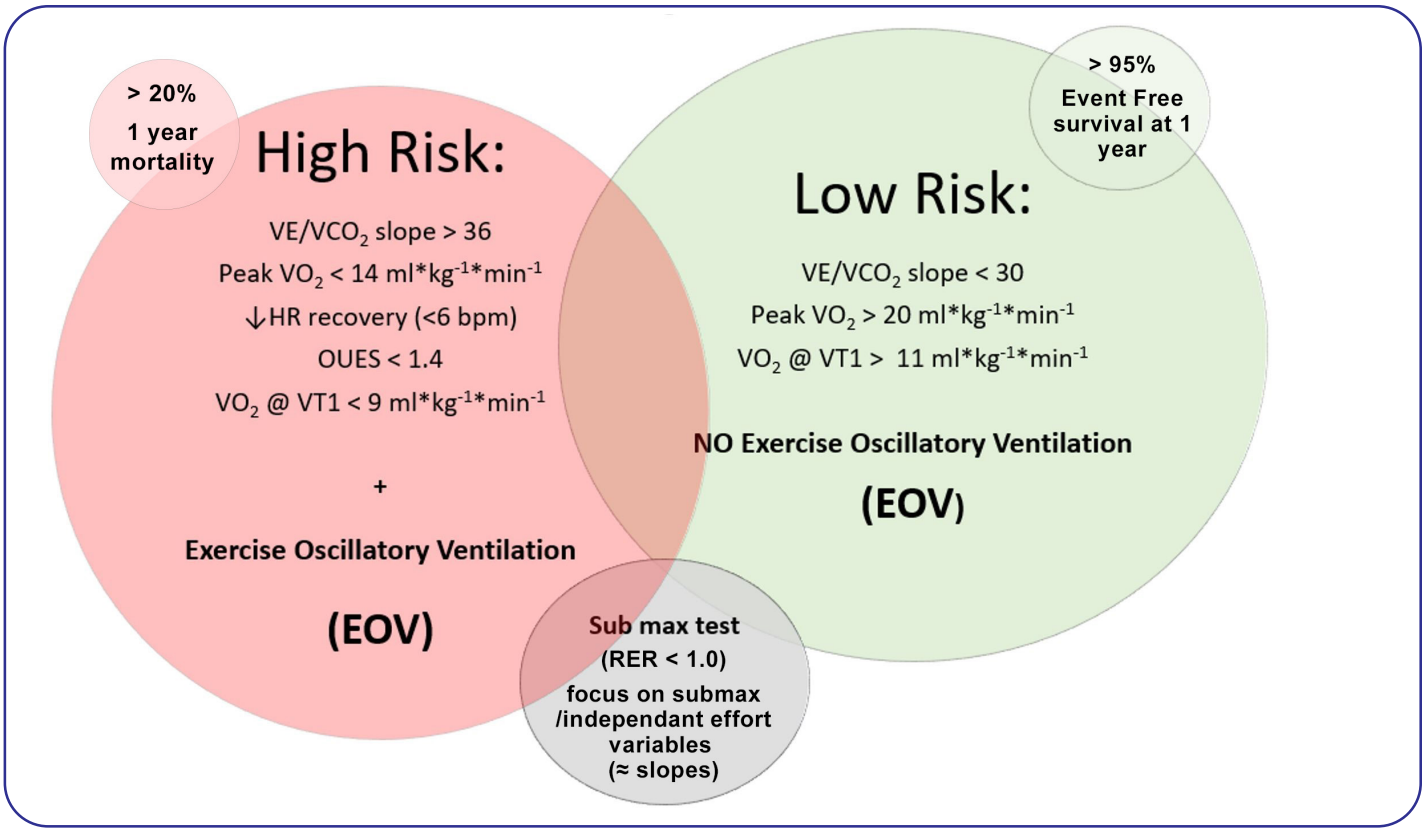

Figure 1 Respiratory exchange ratio (RER)

Figure 2 Vyntus™ CPX

Ventilatory Efficiency and Stability During Exercise in HF

Reduced efficiency of ventilation is shown by a high VE/VCO_2 slope associated with increased pulmonary vascular resistance and decreased right ventricular ejection fraction. The VE/VCO_2 slope is recognized as a powerful predictor of HF events. Periodic breathing during exercise, reported as exercise oscillatory ventilation (EOV), is seen in many patients with advanced HF and is consistently associated with a 1-year mortality >20%.

Synopsis of Practical Approach to CPET Interpretation in Patients with HF

- Peak VO_2 is the current gold standard of cardiorespiratory fitness and functional capacity. Measurement of VO_2 is therefore critical.
- Identification of volitional effort guides the diagnostic focus on gas exchange parameters that are effort independent (OUES, O2-pulse, = oxygen pulse response, and VO_2 at the ventilatory threshold).
- Further investigation then involves identifying the failure to augment systolic blood pressure or slow heart rate recovery.
- While ventilatory efficiency and stability help grade the severity of HF, a steep VE/VCO_2 slope and the presence of EOV indicate increased mortality risk.
- SentrySuite™ provides all important CPET parameters needed for optimal HF diagnosis and clinical management.

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