

In: Treadmill Exercise and its Effects...
Editors: Nuno Azoia, et al.

ISBN: 978-1-60876-857-8
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Chapter 9

USE OF CARDIOPULMONARY EXERCISE TESTING IN PATIENTS WITH HEART FAILURE

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ABSTRACT

Cardiopulmonary exercise testing (CPET) uses treadmill walking to measure important physiological variables in both healthy and diseased population. This not only measures the efficacy of individual's ability to exercise, to help in diagnosing cardiac and pulmonary conditions, but also be used as a therapeutic measure for those patients with chronic heart failure (CHF). Specific parameters are being used for assessing patients with CHF in CPET. This can be used to optimize therapeutic interventions and also to assess the optimal timing for heart transplantation in these patients. The variables that are helpful in assessment of CHF patients include, VO_2 Max or peak VO_2 , Anaerobic Threshold (AT), VO_2/VCO_2 slope, O_2 pulse and ECG. This commentary will discuss about the different responses of these variables in HF patients. The other important role of CPET is its use in cardiac

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reconditioning, particularly in guiding exercise prescription in individual patients to help reconditioning.

INTRODUCTION

Cardiopulmonary exercise testing (CPET) uses non invasive measurement of physiological variables that characterize the respiratory, cardiac and metabolic responses to the stress of physical exertion. This permits the evaluation of both sub maximal and peak exercise responses, providing the clinician with relevant information for clinical decision making. Modes of CPET usually involve either treadmill walking or cycle ergometry. Each exercise modality has its own strength and weaknesses and the decision to use one method over the other should be made on a case by case basis. Treadmill walking involves a larger muscle mass and more work against gravity. Consequently PVO₂ is, on average, 5-10% higher on the treadmill than a cycle ergometer. The modified Naughton protocol is recommended for treadmill exercise testing in patients with heart failure.[1] This protocol is designed to increase the workload by approximately 1 MET (3.5 ml O₂/kg/min) for each 2 minute stage. This commentary will describe the application of CPET in patients with heart failure.

Table 1. American College of Cardiology/American Heart Association guidelines for cardiopulmonary exercise testing.

Class	Indication
I (indicated)	1 Evaluation of exercise capacity and response to treatment in patients with heart failure who are being considered for heart transplantation 2 Assistance in the differentiation of cardiac versus pulmonary limitations as a cause of exercise-induced dyspnoea or impaired exercise capacity when the cause is uncertain
IIa (good supportive evidence)	Evaluation of exercise capacity when indicated for medical reasons in patients for whom the estimates of exercise capacity from exercise test time or work rate are unreliable
IIb (weak supportive evidence)	1 Evaluation of the patient's response to specific therapeutic interventions in which improvement of exercise tolerance is an important goal or end point 2 Determination of the intensity for exercise training as part of comprehensive cardiac rehabilitation
III (not indicated)	Routine use to evaluate exercise capacity

Adopted from ATS/ACCP statement on Cardiopulmonary Exercise Testing[2]

CPET AND HEART FAILURE

CPET has an important role in heart failure providing important information on patho-physiology of exercise limitation, risk stratification and establishing exercise training protocol. Exercise capacity is reduced even in mild heart failure. The cardiac output may be relatively normal at rest, but usually does not increase adequately with even mild exertion. Peak oxygen uptake ($\dot{V}O_2$ Max) in heart failure is directly related to cardiac output and muscle blood flow at peak exercise. However, the inability to appropriately increase cardiac output results in insufficient increase in perfusion to exercising muscles, which can cause early anaerobic metabolism and muscle fatigue.

CPET RESPONSES IN HEART FAILURE

Peak oxygen uptake ($\dot{V}O_2$ Max) is the gold standard measure of aerobic fitness. This reflects the maximal ability of a person to take in, transport and use oxygen. This can be used as a measure of severity of heart failure. One study by Mancini et al is considered to be the cornerstone of documentation of the prognostic power of $\dot{V}O_2$ Max in heart failure patients.[3] It divided the patients into 3 groups- patients with $\dot{V}O_2$ of <14 ml/kg/min who had been accepted for transplantation, patients with $\dot{V}O_2$ of ≥ 14 ml/kg/min who were considered too well for transplantation, patients with $\dot{V}O_2$ of <14 ml/kg/min but with significant co morbidity that precluded heart transplantation. The 1-yr survival rates were 48%, 94% and 47% respectively in the 3 groups. Of note, a $\dot{V}O_2$ of <10 ml/kg/min was associated with significantly poorer predicted survival. This result was adopted by the AHA/ACC consensus statement on the selection and treatment of candidates for heart transplantation.[4]

Ventilatory anaerobic threshold (VAT) is the point at which anaerobic production of high energy phosphate compounds supplements aerobic production. This is considered to be a surrogate measure of quality of life in patients with heart failure. The VAT is undetectable in large proportion of patients with CHF, especially in those with reduced exercise tolerance, restricting the prognostic and decisional value of $\dot{V}O_2$. The predictive role of $\dot{V}O_2$ can vary depending on the detection of VAT. This was shown in a study

by Opasich et al.[5] In that, when VAT was detected, patients with PVO_2 of <10 ml/kg/min have a high event rate, whereas those with a PVO_2 of >18 ml/kg/min have a good prognosis. When VAT was undetectable, patients with $PVO_2 <10$ ml/kg/min have a high risk of events and for those with $PVO_2 >10$ ml/kg/min, the risk stratification is considered to be inconclusive and the replication of CPET is recommended.

Ventilatory expired gas parameters (VE/ VCO₂ slope) are abnormally high in CHF. Recently, this has been proposed as an alternative prognostic indicator in patients with CHF. This dimensionless ratio indicates how many litres of air are being breathed to eliminate 1 litre of CO₂. An abnormally high VE/ VCO₂ slope is associated with poor outcome. One study by Chua et al reported that a VE/ VCO₂ slope of >34 was associated with worse prognosis in patients with heart failure.[6]

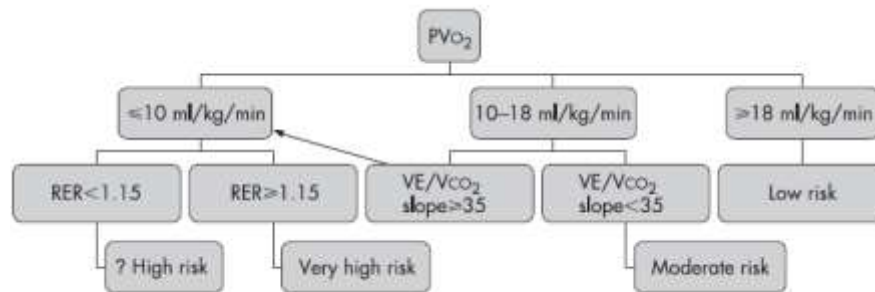
Peak oxygen consumption and the VE/ VCO₂ slope are inversely related to each other.[7] Patients with oxygen consumption under 11 ml/kg/min and VE/ VCO₂ slope of more than 34 are particularly at high risk.[8-9]

Electrocardiographic (ECG) abnormalities is an important tool in treadmill exercise testing. However, if the resting ECG is abnormal, the use of CPET for diagnosing ischaemia is reduced. This is the case in patients with heart failure, as often their ECGs are abnormal with left ventricular hypertrophy pattern, left bundle branch block etc.

Table 2. Cardiopulmonary exercise pattern in heart failure patients.

Measurement	Heart Failure
$\dot{V}O_{2\max}$ or $\dot{V}O_{2\text{peak}}$	Decreased
Anaerobic threshold	Decreased
Peak HR	Variable, usually normal in mild
O ₂ pulse	Decreased
$(\dot{V}_E/\text{MVV}) \times 100$	Normal or decreased
$\dot{V}_E/\dot{V}CO_2$ (at AT)	Increased
V_D/V_T	Increased
Pa_{O_2}	Normal
$P(A-a)O_2$	Usually normal

V_D/V_T - ratio of physiological dead space to tidal volume, MVV- maximal voluntary ventilation, HR- heart rate, $\dot{V}_E$ - minute ventilation, $\dot{V}CO_2$ - carbon dioxide output
Adopted from ATS/ACCP statement on Cardiopulmonary Exercise Testing[1]



RER- respiratory exchange ratio

RISK STRATIFICATION ALGORITHM

Corra and Mezzani proposed a new risk stratification algorithm for patients with CHF, taking into account the above mentioned measures derived from CPET.[10] They divided patients with CHF into three groups depending on PVO_2 , as in the following flowchart.

The VE/VCO_2 slope yields an efficient predictive contribution for almost one- quarter of patients with moderate CHF. The attainment of a peak Respiratory Exchange Ratio (RER) of ≥ 1.15 allows the identification of nearly half of patients with severe exercise intolerance with “true” low peak aerobic power, who are thus at high risk. This stepwise process can assist doctors in clinical decision making by describing a reliable risk for the individual patient.

EXERCISE PRESCRIPTION

Many patients with CHF are often concerned or afraid that physical exertion may provoke serious complications and as a result, voluntarily reduce their activities. By successful completion of an exercise test, the patient can only be reassured that exercise training is safe, but may also gain confidence by actually performing the exercise task. Furthermore, the physiologic exercise responses enable the health care provider to select a target heart rate and a target rating for breathlessness for monitoring a specific intensity of prescribed exercise. Finally, non invasive measurement of oxygen saturation with oximetry during incremental or submaximal CPEX can provide an initial

evaluation of desaturation to assess the patient's requirement for supplemental oxygen. In summary, CPET is recommended to establish and to provide an individualized prescription for exercise intensity before a patient starting a cardiac rehabilitation program.

CONCLUSION

The CPET provides unique diagnostic and prognostic information in a non-invasive setting. The use of CPET technology is becoming increasingly prevalent in cardiology services. The information provided by the CPET allows suitable pharmacological or device based adjustments to be considered in the management of CHF, which can be crucial in maintaining a patient's quality of life and longevity.

REFERENCES

- [1] Naughton, J; Sevelius, G; Balke, B. Physiological responses of normal and pathologic subsets to a modified work capacity test. *J Sports Med*, 1963, 31, 201-7.
- [2] ATS/ACCP statement on cardiopulmonary exercise testing. *Am J Respir Care Med*, 2003, 167, 211-77.
- [3] Mancini, DM; Eisen, H; Kussmaul, W; et al. Value of peak oxygen consumption for optimal timing of cardiac transplantation in ambulatory patients with heart failure. *Circulation*, 1991, 83, 778-86.
- [4] Costanzo, MR; Augustine, S; Bourge, R; et al. Selection and treatment of candidates for heart transplantation. *Circulation*, 1995, 92, 3595-612.
- [5] Opasich, C; Pinna, GD; Bobbio, M; et al. Peak oxygen consumption in chronic heart failure: toward efficient use in the individual patient. *J Am Coll Cardiol*, 1998, 31, 766-75.
- [6] Chua, TP; Ponikowski, P; Harrington, D; et al. Clinical correlates and prognostic significance of the ventilatory response to exercise in CHF. *J Am Coll Cardiol*, 1997, 29, 1585-90.
- [7] Witte, KK; Cleland, JG; Clark, AL. Chronic Heart failure, chronotropic incompetence, and the effect of beat blockade. *Heart*, 1992, 4, 481-86.
- [8] Gitt, AK; Wasserman, K; Kilkowski, C; et al. Exercise anaerobic threshold and ventilatory efficiency identify heart failure patients for

- high risk of early death. *Circulation*, 2002, 106, 3079-84.
- [9] Arena, R; Myers, J; Abella, J; et al. Influence of heart failure etiology on the prognostic value of peak oxygen consumption and minute ventilation/carbon dioxide production slope. *Chest*, 2005, 128, 2812-2817.
- [10] Corra, U; Mezzani, A; Bosimini, E; et al. Cardiopulmonary exercise testing and prognosis in heart failure. *Chest*, 2004, 126, 942-50.