Cardiopulmonary Exercise Testing in Heart Failure

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Abstract: A growing body of literature has underscored the value of ventilatory gas exchange techniques during exercise testing (commonly termed cardiopulmonary exercise testing, or CPX) and their applications in the management of patients with heart failure (HF). The added precision provided by this technology is useful in terms of understanding the physiology and mechanisms underlying exercise intolerance in HF, quantifying the response to therapy, evaluating disability, making activity recommendations, and quantifying the response to exercise training. Importantly, a wealth of data has been published in recent years on the prognostic utility of CPX in patients with HF. These studies have highlighted the concept that indices of ventilatory inefficiency, such as the VE/VCO_2 slope and oscillatory breathing, are particularly powerful in stratifying risk in HF. This article provides an overview of the clinical utility of CPX in patients with HF, including the applications of ventilatory inefficiency during exercise, the role of the pulmonary system in HF, respiratory muscle performance (RMP), and the application of CPX as part of a comprehensive clinical and exercise test evaluation. (Curr Probl Cardiol 2015;40:322–372.)

Gerald F. Fletcher, MD, FAHA, FACC: HF continues to be a worldwide health care burden. With this burden, there are often many complicated and

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expensive diagnostic procedures and tests performed. The authors herein describe and discuss in clear detail the use of CPX to evaluate patients with HF. Such testing is noninvasive, relatively inexpensive, and provides, as the authors clearly discuss, much diagnostic and prognostic data to the clinician with the means to improve overall patient care. In addition, the authors provide clear insight into the value of CPX use in concert with the standard electrocardiographic exercise test, as such is not always done as part of the exercise evaluation in subjects with cardiovascular disease or pulmonary disease or both.

Introduction

Recent advances in the treatment of cardiovascular disease (CVD) have led to marked improvements in the survival rate of patients experiencing a cardiac event. However, although these advances in treatment have led to a decline in most CVDs, marked growth in the prevalence of heart failure (HF) has occurred since the 1970s.[1,2] The growing prevalence of HF reflects a combination of increasing incidence, an aging population, and improvements in the treatment of both acute CVD and HF.[1] Given the growing prevalence of HF, a great deal of research has been directed toward optimal strategies to estimate risk for adverse events in these patients. A hallmark symptom of HF is exercise intolerance, typically evidenced by excessive shortness of breath, fatigue, or both with exertion. Quantifying the degree of exercise intolerance in a controlled setting is therefore valuable to assess the degree of cardiac impairment and to optimize therapeutic management in HF. In recent years, the physiological response to progressive exercise using direct measures of ventilation and gas exchange, commonly termed the *cardiopulmonary exercise test* (CPX), has evolved to become an important clinical tool in the management of patients with HF. This technology is useful in terms of quantifying responses to therapy, evaluating disability, assessing the mechanism of exercise intolerance, making activity recommendations, quantifying the response to exercise training, and estimating prognosis. The current article provides an overview of the clinical applications of CPX with a focus on patients with HF.

Evolution of CPX

Historically, exercise capacity was expressed as an estimated value based on maximal work rate (WR) achieved on a treadmill or cycle ergometer. CPX was generally limited to the domain of research physiologists and pulmonary medicine. The concept that estimated