Heart, Lung and Circulation (2014) **23,** 1036–1040
1443-9506/04/$36.00
http://dx.doi.org/10.1016/j.hlc.2014.05.003

ORIGINAL ARTICLE

Differences in Exercise Capacity in Patients with Chronic Left Heart Failure and Chronic Right Heart Failure

Wei-Hua Liu, MD, Qin Luo, MD PhD, Zhi-Hong Liu, MD PhD *, Qing Zhao, MD PhD, Qun-Ying Xi, MD, Zhi-Hui Zhao, MD PhD

State Key Laboratory of Cardiovascular Disease, Fuwai Hospital, National Center for Cardiovascular Diseases, Chinese Academy of Medical Sciences, Peking Union Medical College, Beijing, 100037, China

Received 7 January 2014; received in revised form 21 April 2014; accepted 4 May 2014; online published-ahead-of-print 27 May 2014

Background Exercise impairment is common in chronic left heart failure and pulmonary arterial hypertension (PAH). Exercise impairment degree is a strong predictor of clinical outcome. Our purpose was to evaluate differences in exercise capacity using cardiopulmonary exercise testing (CPX) in patients with chronic left and right heart failure, and determine which factors were related to exercise impairment.

Methods 102 patients with class II/III New York Heart Association were involved in the study (41 with chronic left heart failure, 61 with chronic right heart failure secondary to PAH). All patients underwent CPX to evaluate exercise capacity.

Results Patients with right heart failure had significantly lower peak oxygen uptake (VO_2), peak VO_2/kg ratio, peak oxygen uptake/heart rate (VO_2/HR) ratio and increases in oxygen uptake/increase in work rate ($\Delta VO_2/\Delta WR$) slope, and had higher minute ventilation/CO_2 production ratio and peak dead space volume/tidal volume during exercise. In patients with left heart failure, peak VO_2/HR ratio was positively correlated with $\Delta VO_2/\Delta WR$ slope. However, VO_2 and VO_2/HR ratio were positively correlated with $\Delta VO_2/\Delta WR$ slope in patients with right heart failure.

Conclusions Compared with left heart failure, patients with right heart failure showed worse exercise capacity resulting from worse pulmonary and cardiovascular adaptation to exercise.

Keywords Chronic heart failure • Pulmonary arterial hypertension • Cardiopulmonary exercise testing • Exercise testing • Rehabilitation

Introduction

Exercise impairment is a common symptom in both chronic left heart failure and pulmonary arterial hypertension (PAH). Heart, lung, kidney and muscles are involved in exercise impairment in left heart failure and right heart failure caused by PAH. Cardiopulmonary exercise testing (CPX) is considered a ''gold standard'' for studying cardiovascular, pulmonary and metabolic adaptations to exercise in heart diseases. Oxygen uptake (VO_2) and increases in oxygen uptake/increase in work rate ($\Delta VO_2/\Delta WR$) slope had been considered as important measures in evaluating exercise capacity in patients with heart failure and a strong predictor of clinical outcome [1,2]. Patients with the same level of heart function have demonstrated different degrees of exercise impairment [3–5]. We designed this study to observe differences in exercise capacity in patients with chronic left heart failure and chronic right heart failure

*Corresponding author. Fuwai Hospital, No. 167 Beilishi Road, Beijing, 100037 China. Tel.: +86 01088398196; fax: +86 01088396589.,
Email: fuwailiu@hotmail.com

secondary to PAH, and determine which factors were related to exercise impairment.

Methods

Patients

One hundred and two stable patients with New York Heart Association (NYHA) functional class II/III were enrolled in this study between October 2010 and December 2012 in Fuwai Hospital. Forty-one patients had chronic left heart failure and 61 patients with chronic right heart failure secondary to PAH. Left heart failure was diagnosed according to the American College of Cardiology Foundation (ACCF)/American Heart Association (AHA) guidelines for heart failure [6]. PAH was defined as type 1, or 4, according to the ACCF/AHA expert consensus document on pulmonary hypertension [7]. Right heart failure was defined as PAH with cardiac index (CI) <2.2 L/(min × m^2) measured by right heart catheterisation. All patients with type 2, 3 or 5 PAH, pulmonary veno-occlusive disease, pulmonary capillary haemanglomatosis, congenital heart disease, forced expiratory volume in 1 s/forced vital capacity (FEV1/FVC) ratio <65% at rest, or having a contraindication for CPX were excluded. All testing was performed before treatment.

The study protocol was performed according to the 1975 Declaration of Helsinki, and was approved by the institutional Ethics Committee of Fuwai Hospital, China. Informed consent was obtained from each patient. The project approval number was 2012-401.

Cardiopulmonary Exercise Testing

Symptom-limited exercise was performed on a bicycle ergometer with a breath-by-breath system (COSMED, Italy) according to the ATS/American College of Chest Physicians (ACCP) Statement on CPX [8]. Minute ventilation/CO_2 production (VE/VCO_2) ratio was defined as: $VE/VCO_2 = 863/[PaCO_2 \times (1\text{-}VD/VT)]$, where, VE = minute ventilation, $VCO_2 = CO_2$ production, VD = dead space volume, VT = tidal volume, $PaCO_2$ = arterial CO_2 tension. Change in CPX parameter from rest to peak exercise was defined as: Δmeasure = (peak measure-rest measure)/rest measure × 100%.

Echocardiography

Two-dimensional echocardiography and Doppler ultrasound (Philips IE33, Netherlands) examination was performed on the same day before CPX. Left ventricular end diastolic dimension (LVDD), right ventricular end diastolic dimension (RVDD) and left ventricular ejection fraction (LVEF) were determined according to the recommendations of the European Association of Echocardiography [9].

Right Heart Catheterisation

Right heart catheterisation was performed three days after CPX. Pulmonary capillary wedge pressure (PCWP) and mean pulmonary artery pressure (mPAP) were determined using balloon flotation catheter (Edwards Lifesciences, USA). CI was determined by the Fick method.

Statistical Analyses

Data was analysed using SPSS 13.0 (SPSS Inc; Chicago Illinois). Continuous variables were presented as mean ± SD and categorical variables as a percentage. A *t* test was used to compare continuous variables. A Chi-square test was used to compare categorical variables. The univariate general linear model was used to determine exercise capacity differences between two groups with adjustment of body mass index (BMI), gender, age and smoking groups. Multivariate linear regression was used to determine relationships between VO_2, oxygen uptake/heart rate (VO_2/HR), VE/VCO_2 ratio and $\Delta VO_2/\Delta WR$ slope.

Results

Patients

Table 1 shows the baseline characteristics of the two groups. Patients with left heart failure were older, had a higher BMI, and had a higher proportion of men and smokers. These factors can affect CPX measurements.

Table 2 shows that patients with right heart failure had a higher VE/VCO_2 ratio and a lower end-tidal partial pressure of CO_2 ($PetCO_2$) at rest.

Table 1 Baseline Characteristics.

Measure	Left heart failure (n = 41)	Right heart failure (n = 61)	*p* value
Age (years)	44.90 ± 9.864	31.23 ± 10.26	<0.001
Men (n)	37	13	<0.001
Smokers (n)	23	6	<0.001
BMI (kg/m^2)	24.71 ± 4.11	21.88 ± 2.78	<0.001
Echocardiography			
LVDD (mm)	70.29 ± 11.33	36.74 ± 5.96	<0.001
RVDD (mm)	24.56 ± 4.53	31.64 ± 6.56	<0.001
LVEF (%)	29.41 ± 9.78	65.20 ± 6.99	<0.001
mPAP (mmHg)		53.84 ± 16.54	
PCWP (mmHg)		9.38 ± 3.36	
CI (L/(min × m^2))		1.98 ± 0.22	
ICM (n)	8		
NICM (n)	33		
Type 1 PAH (n)		55	
Type 4 PAH (n)		6	

BMI = body mass index, LVDD = left ventricular end diastolic dimension, RVDD = right ventricular end diastolic dimension, LVEF = left ventricular ejection fraction, PCWP = pulmonary capillary wedge pressure, mPAP = mean pulmonary artery pressure, ICM = ischaemic cardiomyopathy, NICM = non-ischaemic cardiomyopathy, PAH = pulmonary arterial hypertension.