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Case report

Ergospirometry in the assessment of functional significance of myocardial ischemia

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Sažetak It has been shown that the ECG exercise stress test (ET) has low sensitivity and this limitation is successfully overcome by combinations with imaging techniques (stress echocardiography (ESE), nuclear medicine, magnetic resonance). Despite improved accuracy in the detection of myocardial ischemia and segmental wall motion analysis, these combinations cannot precisely determine the significance of functional impairment. Thus, the application of ergospirometry significantly improved the sensitivity of ECG ET. In addition to the fact that the most important parameters of CPET are peak myocardial oxygen consumption (PeakVO2) and assessment of ventilatory function, there are specific CPET markers. Significant myocardial ischemia (> 10% of the left ventricular myocardium i.e 3 segments) leads to significant dyssynergia (hypo or akinesia) inducing transient decrease in the ejection fraction. We can detect this point as a plateau (flattening) of the oxygen pulse (VO2/HR) as a consequence of decreased stroke volume and, also, the inadequate increase in VO2 despite the increase of the workload load. These markers appear after echocardiographic changes, and before ECG changes and chest pain on the ischemic cascade of events. We presented a case of a patient with complete left branch block and suspected coronary heart disease who showed typical changes on CPET, and a significant narrowing of LAD on coronary angiography. We used combined stress echocardiography with CPET (ESE-CPET) to confirm ischemia.

Ključne reči Ergospirometry, myocardial ischemia, combined stress echocardiography cardiopulmonary exercise test

Introduction

The application of ergospirometry (CPET) with expiratory gas analysis significantly improved the sensitivity of ECG ET[1,2,3]. The most important features of the CPET are objective determination of the maximal functional capacity - peak myocardial oxygen consumption (PeakVO2) and assessment of ventilatory function. However, significant transient myocardial ischemia (> 10% of the left ventricular myocardium i.e 3 segments) leads to significant dyssynergia (hypo or akinesia) inducing significant decrease in the ejection fraction which can be presented as a plateau or flattening of the oxygen pulse (VO2/HR) and, also, the inadequate increase in VO2 despite the increase of the workload load. These markers appear after echocardiographic changes, and before ECG changes and chest pain on the ischemic cascade of events[1,4] .

Case Report

A 50 years-old male patient, was referred for CPET due to exertional dyspnea. He had well controlled arterial hypertension, and hypercholesterolemia. Physical examination confirmed a normal finding in the heart and lungs and 12 - channel electrocardiogram (ECG) showed sinus rhythm, and image of left bundle branch block (LBBB) (Figure 1).

CPET test (maximal treadmill Bruce with breath-by-breath analysis) lasted 11 minutes and was terminated in the presence of CPET sigs of ischemia accompanied by severe dyspnea. Working efficacy reached the plateau and was decreased (8 ml/kg/min) accompanied by the oxygen pulse flattening followed by increase after the end of the test. (Figure 2). Ventilatory parameters were normal. As we are referral ESE center this test was combined with the ESE with echocardiograpic assessment before and after the test (wall motion analyses and examination of the diastolic function because of unexplained dyspnea. We detected the exercise induced hypokinesia of the distal segments of septum nad inferior left ventricular wall. Diastolic functin was preserved as mitral E to mitral anular è ratio was 9.

Coronary angiography showed 90% diameter stenosis of mid LAD and RCA minor luminal narrowing and was treated by percutaneous coronary intervention with the stent implantation.

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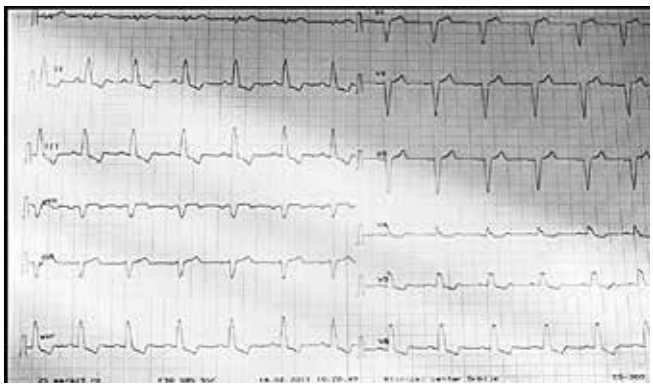

Figure 1. The resting ECG with the left bundle branch block in patient with unexplained dyspnea and chest pain

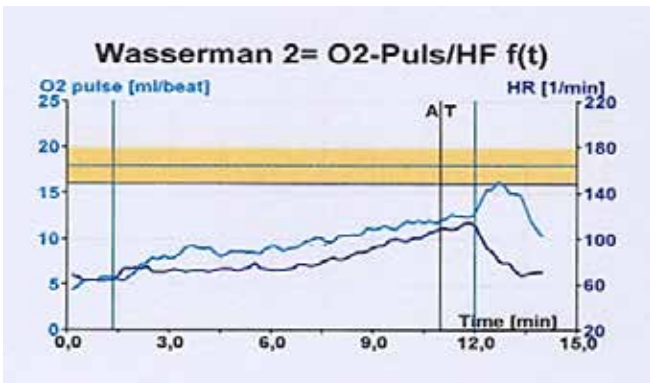

Figure 2. Oxygen pulse flattening in the presence of mzocardial ischemia folloed by increase in stroke volume at recovery
O2 pulse- oxygen pulse; HR- heart rate; AT- anaerobic threshold;

Disscusion

CPET is a well-accepted physiologic evaluation technique in patients with heart failure and in individuals presenting with unexplained dyspnea on exertion[4]. Several variables obtained during CPET, including oxygen consumption relative to heart rate (VO2/HR or O2-pulse) and work rate (VO2/Watt) were shown to be a sensitive marker of myocardial ischemia[1,2,3]. It provides a physiologic quantification of the work rate, heart rate and O2 uptake at which myocardial ischemia develops. The potential value of adding CPET with gas exchange measurements is likely to be of great value in diagnosing and quantifying both overt and asymptomatic myocardial ischemia and the improvement of ischemic threshold with optimal medical treatment[3]. The presence of functionally significant ischemia can be due to macro-vascular disease or microvascular disease or both[4]. We present the patient with the LBBB and unexplained dyspnea who demonstrated the CPET signs of myocardial ischemia and significant obstructive heart disease on coronary angiography.

CPET has the great potential to quantify the global ischemic burden regardless of mechanism and location of lesions[4]. parameters of CPET are peak myocardial oxygen consumption (PeakVO2) and assessment of ventilatory function, when it comes to ischemia, there are specific CPET markers. Significant myocardial ischemia > 10% of the left ventricular myocardium i.e 3 segments) leads to significant dyssynergia (hypo or akinesia) inducing transient decrease in the ejection fraction.

Bellardineli et al.[2] prospectively studied CPET in 1265 consecutive subjects without documented coronary heart disease. As compared with ECG parameters, sensitivity and specificity, were all improved significantly. Patients with both peak VO2 > 91% of predicted VO2 max and absence of VO2-related signs of myocardial ischemia had no evidence of CAD in 100% of cases.

As oxygen pulse (VO2/HR) is O2 volume from O2 delivered to tissue (SV) during every heart beat (ml/beat), it represents SV, respectively. During the transient exercise induced myocardial ischemia, we can detect the O2 pulse flattening, while reduced SV can be compensated by additional increase in arterio-venous O2 difference (C(a-v)O2), to maintain O2 supply on submaximal workload[4]. The interesting sign appears immediately after test termination immediately after test termination. In normal subjects O2 pulse decreases, while but in the presence of ischemia it increases paradoxically (as a consequence of improved SV at recovery period)[1,4]. Also the working efficacy - slope ΔVO2/Δwork rate (rate of O2 expenditure during linear increase of workload. It shows cardiovascular response and muscle efficiency and should be linear and constant (10 ml/min/WATT). ΔVO2/ΔWR slope is normal at lower workload and decreases in the presence of significant myocardial ischemia. ECG changes and angina can be absent[3,4]. Our patient had the LBBB and did not have chest pain during the test in the presence of CPET markers of myocardial ischemia.

These markers appear after echocardiographic changes, and before the appearance of ECG changes and chest pain on the ischemic cascade of events[1,2,3].

However, De Lorenzo et al, did not find the significant relationship between abnormal O2 pulse curve and myocardial ischemia defined by scintigraphy[5]. This can be overcome by the combination of CPET with ESE integrating the diagnostic power offered by both the tools[6]. This combined approach has been demonstrated to be valuable for diagnosing several cardiac diseases, including heart failure with preserved or reduced ejection fraction, cardiomyopathies, pulmonary arterial hypertension, valvular heart disease and coronary artery disease[6]. Using combined ESE-CPET in our case, we confirmed the presence of segmental wall motion abnormalities during the CPET.

Conclusion

Simultaneous flattening in ΔVO2/ ΔWR and O2 pulse with increasing work rate confirms the development of myocardial ischemia during exercise (Table 1). We also showed the potential of ESE - CPET in the detection of asymptomatic myocardial ischemia, as well as in persons with ECG changes that make interpretation difficult (LBBB, myocardial hypertrophy).

Table 1. CPET and exercise test parameters in patients with and without myocardial ischemia[4]

PRIMARY CPET VARIABLES		
O2 pulse trajectory	% Peak VO2 pred.	ΔVO2/ΔW trajectory
Cont. rise and possible plateau approaching maximal exertion	≥ 100%	Continual rise throughout ET
Early and sustained plateau	75 - 99%	Early and sustained plateau
	50-75%	
Continual rise throughout ET	<50%	Continual rise throughout ET
STANDARD EXERCISE VARIABLES		
Haemodynamics	EKG	
Rise in systolic BP during ET	No sust. arrh, ectopic foci, and/or ST changes and/or in recovery	
Flat systolic BP response during ET	Altered rhythm, ectopic foci, and or ST changes and/or in recovery: did not lead to test termination	
Drop in systolic BP during ET	Altered rhythm, ectopic foci, and or ST changes and/or in recovery: led to test termination	
SYMPTOMS		
Lower extremity muscle fatigue	Angina	Dyspnea

ΔVO2 – Change of the myocardial oxygen consumption; ΔW – change of the workload; ET- exercise test;

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Sažetak

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Pokazano je da samostalni EKG test fizičkim opterećenjem (TFO) ima nisku senzitivnost u otkrivanju miokardne ishemije i ovo ograničenje se uspešno prevazilazi kombinacijama sa viziualizacionim tehnikama (stres ehokardiografija, nuklearna medicina, magnetna rezonanca). Uprkos tome, ove kombinacije ne mogu precizno odrediti funkcionalni značaj oštećenja. Tako je primenom ergospirometrije sa analizom ekspiratornih gasova značajno poboljšana senzitivnost EKG TFO. Pored činjenice da su najvažniji parametri CPET-a vršna potrošnja kiseonika (PeakVO2) i procena ventilacione funkcije, kada je ishemija u pitanju, postoje specifični markeri. Značajna ishemija miokarda (> 10% miokarda leve komore, tj. 3 segmenta) dovodi do takvih ispada kinetike (hipo ili akinezije) koji izazivaju značajno smanjenje ejekcione frakcije i pad udarnog volumena. Ovu tačku možemo detektovati kao prerani plato kiseoničnog pulsa (VO2/HR) i, takođe, neadekvatnog povećanja VO2 uprkos povećanju opterećenja. Ovi markeri se javljaju nakon ehokardiografskih promena, a pre pojave EKG promena i bolova u grudima na ishemijskoj kaskadi događaja. Mi smo predstavili slučaj bolesnika sa kompletnim blokom leve grane i sumnjom na koronarnu bolest srca koji je tokom CPET pokazao tipične promene , a na koronarografiji značajno suženje LAD. Ishemija je potvrđena istovremenom primenom CPET i stres ehokardiografije (ESE-CPET).

Ključne reči: ergospirometrija, ishemija miokarda, kombinovana stres ehokardiografija sa kardiopulmonalnim testom