THE POSSIBILITIES OF USING A COMBINED CARDIOPULMONARY STRESS TEST AND STRESS ECHOCARDIOGRAPHY IN OUTPATIENT SETTINGS

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Abstract
The widespread occurrence of various pathologies of the cardiovascular system (CVS) among the human population requires the creation of non-invasive instrumental methods and diagnostic tools aimed at early detection and prevention of pathological conditions of the myocardium. Stress testing is most often used as a non-invasive and reproducible method for diagnosing the condition and prognosis of treatment of human CVD. The stress testing system includes simulators on which the patient performs physical activities of a certain capacity (bicycle ergometer, treadmill), sensors for recording human biological signals (for example, an electrocardiogram of blood pressure) and computing devices for processing the data obtained with the necessary software. Cardiopulmonary stress testing (CPNT) refers to stress stress testing with additional measurement of gas exchange parameters at rest, during exercise and during recovery.

Keywords: cardiopulmonary stress test, cardiovascular system, bicycle ergometer, treadmill, electrocardiogram, blood pressure, echocardiography.

Introduction

Currently, KPNT has a wide range of clinical and diagnostic application points and allows specialists to get the following opportunities:

1) to assess the level of physical performance and carry out a differential diagnosis of pathologies that affect its decrease;
2) examine and monitor the dynamics of patients with cardiovascular diseases (stable angina pectoris and initially altered ECG, pain-free myocardial ischemia, cardiomyopathies, etc.), diagnose the early stages of CHF and evaluate the prognosis of survival, select candidates for heart transplantation;
3) make differential diagnosis of lung diseases (interstitial lung diseases, COPD, pulmonary vascular diseases, etc.), plan and determine indications for oxygen therapy;
4) diagnose exercise-induced bronchospasm;
5) to make a differential diagnosis of dyspnea syndrome, to identify psychogenic behavioral dyspnea associated with anxiety, aggression;
6) to identify combined cardiopulmonary pathology: to determine the contribution of each of them to the genesis of dyspnea syndrome;

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7) diagnose a number of diseases in which the bioenergetic function of skeletal muscles is impaired (myopathy, etc.);
8) to select training programs aimed at the rehabilitation of patients with cardiovascular and pulmonary pathology;
9) to evaluate the long-term effectiveness of the treatment in dynamics;
10) to evaluate the prognosis before surgical interventions;
11) to assist in the examination of permanent disability.

As a result, the following main indicators are measured: the volume of oxygen consumed O2·V, the volume of exhaled carbon dioxide CO2·V, ventilation parameters, and electrocardiographic parameters are also evaluated: heart rate (HR) and blood pressure. This test is a reliable diagnostic tool that provides significant diagnostic and prognostic information about the condition of patients with cardiovascular and pulmonary diseases, as well as allows you to assess the risks and effects of various therapies. One of the causes of coronary heart disease (CHD) is obesity, which affects exercise tolerance and, consequently, the results of CPNT. Currently, obesity is one of the most important medical and social problems in the world, being one of the 5 main risk factors for death. According to WHO, the average body mass index in Uzbekistan is 26.5 kg per square meter, which is the highest in Central Asia. By 2060, the damage to the economy from obesity is expected to increase to $21.6 billion, equivalent to 4.7% of GDP. According to the World Health Organization, overweight and obesity determine the development of up to 44-57% of all cases of type 2 diabetes mellitus, 17-23% of cases of coronary heart disease, 17% of cases of arterial hypertension, 30% of cases of gallstone disease, 14% of cases of osteoarthritis and 11% of cases of malignant neoplasms. According to WWF forecasts, by 2030 and 2060, the proportion of overweight or obese adults will increase to 59% and 80%, respectively. For obese adults, it will increase from 18.9% in 2020 to 25% by 2030 and to 50% by 2060. In early December, the Committee for Sanitary and Epidemiological Welfare and Public Health, citing WHO, reported that half of the population of Uzbekistan aged 18 to 64 years is overweight and 20% is obese. In order to study the prognosis and the effect of treatment on the duration of the disease in dynamics in patients with coronary heart disease and CHF, a number of studies were conducted in the course of which it was revealed that conducting CPNT gives an opportunity to take a different look at the relationship between shortness of breath in obesity and/or pulmonary pathology and the prognosis of survival in patients with heart failure and reduced left ventricular ejection fraction. In a study conducted at the Department of Faculty Therapy of the Faculty of Medicine of the Russian National Research University N.I. Pirogov Medical University" Ministry of Health of the Russian Federation, (2023) determined that obesity is directly related with important cardiovascular risk factors (arterial hypertension, diabetes mellitus, dyslipidemia), with increased morbidity and mortality and the risk of heart failure. Obesity is a chronic multifactorial heterogeneous disease manifested by excessive formation of adipose tissue, progressing in its natural course, usually having a high cardiometabolic risk, specific complications and associated concomitant diseases. Obesity can be both an independent disease and a syndrome that develops against the background of other diseases. Obesity and associated metabolic disorders are an urgent problem of modern medicine, as they lead to the development of a number of serious diseases.

Obesity–hypoventilation syndrome is a condition of daytime hypercapnia and hypoxemia ($PaCO_2$ (partial pressure of carbon dioxide in arterial blood) $\geq$45 mmHg and PaO_2 (partial pressure of oxygen in arterial blood) $\leq$70 mmHg) in obese patients and often with existing respiratory disorders during sleep in the absence of any other cause of hypoventilation.

One of the main complaints with this syndrome is shortness of breath during exercise. The pathogenesis of this syndrome is associated with impaired respiratory function in obesity. The accumulation of adipose tissue leads to a decrease in the ventilation capacity of the lungs in both adults and children. An increase in body mass index (BMI) is usually associated with a decrease in forced expiratory volume in 1 second, forced vital lung capacity, vital lung capacity, functional residual capacity and reserve expiratory volume. The decrease in lung ventilation associated with obesity is usually not pronounced and occurs due to the mechanical action of fat mass on the diaphragm and chest walls, which prevents the excursion of the diaphragm and leads to a decrease in the pliability of the chest. Clinically significant decrease in ventilation capacity (vital lung capacity, chest malleability, decrease in functioning lung volume, or a combination of these factors. The exact prevalence of this syndrome is unknown. Among patients with obesity and excessive daytime sleepiness, the proportion of patients with this syndrome is approximately 10%. Cardiopulmonary stress testing (CPNT) is an ideal method for determining the causes and differential diagnosis of shortness of breath. To predict the outcomes of cardiovascular and pulmonary diseases, their early diagnosis, monitoring the course and evaluating the effectiveness of treatment, dosing of physical training, cardiological and pulmonological rehabilitation. Technically, KPNT differs from conventional physical activity tests in that, in addition to monitoring the electrocardiogram and blood pressure, the parameters of pulmonary gas exchange are studied during its conduct: oxygen consumption ($V{\cdot}O_2$), carbon dioxide production ($V{\cdot}CO_2$), minute pulmonary ventilation ($V{\cdot}E$) and its components – respiratory volume and respiratory rate Pulse oximetry or invasive examination of blood gases is also performed .

In 2006, S.E. Hassani et al. The results of their observations were published: in overweight patients with coronary artery disease who underwent endovascular treatment of coronary arteries, the incidence of restenosis and mortality from cardiovascular causes were significantly lower than in patients with normal body weight. In 2008, G.D. Lundberg confirmed that in patients with HF, the presence of obesity does not worsen the cardiovascular prognosis. Exercise tolerance depends on body weight in both healthy individuals and those with HF and reduced LVEF. In the HF-ACTION study, patients with HF and reduced LVEF were divided into groups according to BMI: with body weight deficiency (with grade I obesity (30-34.9 kg/m2), with grade II obesity (35-39.9 kg/m2) with grade III obesity ($\geq$40 kg/m2m2). $V{\cdot}O_2$ peak was the lowest in the group of patients with grade III obesity, but in patients with normal body weight, overweight and grade I obesity, indicators such as oxygen pulse, oxygen consumption at the AP level, ventilation equivalent in carbon dioxide and test execution time decreased in direct proportion to an increase in BMI. At the same time, the degree of influence of BMI was more pronounced in women than in men. The CPNT provided an opportunity to take a different look at the relationship between obesity and prognosis in patients with HF and reduced LVEF.

In a study by C.J. Lavie et al. The data of 2066 patients with HF and reduced LVEF were analyzed . Patients with V· O2peak values below 14 ml/kg/min and a BMI above 30 kg/m2 had a more favorable prognosis than patients with low and normal BMI (18.5–25.0 kg/m2), and a similar prognosis with overweight patients (25-30 kg/m2) with comparable working capacity. At the same time, patients with V· O2peak above 14 ml/kg/min had a good prognosis regardless of BMI. In another study, 704 patients with HF and reduced LVEF were divided into 3 groups according to BMI: group 1 – with a BMI of 18.5–24.9 kg/m2; group 2 – with a BMI of 25.0–29.9 kg/m2; group 3 – with a BMI of ≥30 kg/m2 . In group 3, the V·E/V· O2 ratio was significantly reduced, while the ventilation carbon dioxide equivalent maintained its predictive value throughout the observation period. This indicator indicates the amount of air required to release 1 liter of carbon dioxide, and serves as an index of ventilation adequacy. Normally, its value is less than 32-34 at the AP level. The value of V· E/V· CO2 >34 in patients with HF is a strong independent predictor of an unfavorable prognosis.

In a study involving 4,623 patients with HF and reduced LVEF, the mortality rate from all causes was 28.6% and the cardiovascular mortality rate was 17.4%, which somewhat negates the "obesity paradox". When parameters such as age, gender, LVEF, and percentages of predicted V·O2max are included in the analysis, the prognostic significance of BMI decreases. Usually, V·O2peak is normalized in relation to the total body weight. At the same time, fat deposits, which make up a significant part of the total body weight, do not participate in oxygen consumption. Normalized relative to fat-free body weight V·O2peak is a prognostic factor in HF. In 225 patients with HF and reduced LVEF, the normalized V·O2peak in relation to fat-free body weight, both in general and at a value less than 19 ml/kg/min, had greater prognostic value than the non-normalized V·O2peak, which is an important fact for obese patients, especially for women. Thus, in obesity, oxygen consumption, expressed as a percentage of the predicted, may be normal or low, however, being normalized to body weight, it is reduced, and the greater the body weight, the more. An increase in the metabolic needs of the body against the background of obesity is expressed in an upward shift in the V·O2 /load power ratio curve. Pulmonary ventilation for this load capacity is also increased, which reflects more than normal work performed, however, the ventilation reserve remains at a normal level or may be lowered. There is often a tendency for increased breathing and a decrease in its depth. At submaximal loads, the heart rate can be increased, approaching normal at maximum load, therefore, the heart rate reserve is small or absent. Under load, the ventilation-perfusion ratio may improve, in this case PaO2 and the alveolar-arterial oxygen gradient increase. In the course of the study, it was revealed that CPNT is an informative method for assessing human physical health, providing additional diagnostic information about the working capacity and functional state of the respiratory and cardiovascular systems to identify performance limitations in the absence of clinical manifestations, as well as to clarify the causes of functional disorders.

It should also be noted that at the end of the 80s of the XX century was marked by the appearance of many works in which the prognostic value of individual KPNT indicators in patients with CHF was evidently confirmed. The primary position among these parameters is occupied by peak V·O2. Of great importance is the well-known Mancini study in the cardiac surgery community, in which, provided the patient reaches VAP, it was found that peak V·O2 less than 14 ml/kg/min indicates unfavorable short-term prognoses. Based on these data, the European Society of Cardiology with the American College of Cardiology/The American Heart Association (ACC/ANA) has identified peak V·O2 of less than 14 ml/kg/min as the threshold value determining selection for heart transplantation. In the early 2000s, the focus of researchers shifted towards the problem of LV diastolic dysfunction, and works appeared analyzing the KPNT indicators in patients with HFpEF. The first studies in this area showed mixed results, while some patient populations (women and elderly patients) turned out to be poorly studied. Some of the KPNT variables measured in several foreign studies have identified a number of KPNT indicators recognized by independent and reliable predictors of prognostic outcomes of the disease. Among them, peakVO2, predicted maximum oxygen uptake (ppMVO2), respiratory power (VE/VCO2) and oscillatory load ventilation (EOV) were noted. The ability of these variables to refine the prognosis for patients with CHF with reduced AD was unambiguously established, however, there was insufficient data to extrapolate them in relation to patients with Reason.

Of great interest is the Guazzi study, which included 409 patients with CHF. In this study, VE/VCO2 showed greater prognostic value in HFpEF patients than peak V·O2. The disadvantage of the study was the low proportion of patients with LVEF ≥ 45% (only 22.7%), and the proportion of women included in the study was also insignificant (only 12%). In addition, about 30% of the examined patients did not receive therapy with angiotensin converting enzyme inhibitors (ACE inhibitors) or angiotensin II receptor blockers (ARBs), and more than 50% did not receive pharmacotherapy with beta-blockers. In 2008, in a study of 151 patients with HFpEF, it was reported that EOV was the strongest predictor of cardiac events in a multivariate analysis of isolated exercise data (without demographic variables), followed by VE/VCO2 and peakVO2 in prognostic significance. In the review, Baladi et al., based on previous studies, revealed that patients with HFpEF and reduced PV have the same degree of impaired aerobic performance compared to healthy people, which is reflected in a decrease in the oxygen consumption efficiency coefficient (OUES), an indicator that is closely related to peakVO2. In addition, it was noted that peakVO2 and VE/VCO2 significantly correlate with pulmonary hemodynamics and contribute to the effective detection of patients with pulmonary hypertension.

In conclusion, it can be said that KPNT provides clinicians with a significant amount of additional information compared to conventional studies, which, if properly applied and interpreted, can improve the quality of management of patients with cardiovascular and pulmonary diseases. A special selection of the research protocol with a gradual or rapid increase in the load for each specific case is a necessary element of the correct application of KPNT in practice. It should be noted that recently additional KPNT parameters, such as the indicator of the efficiency of O2 consumption, respiratory and cardiac power, have acquired significant diagnostic and prognostic value. To date, a number of new indications for CPNT have appeared, including congenital heart defects, preoperative assessment during lung surgery, pulmonary hypertension, etc., and further studies are needed to identify additional diagnostic and prognostic significance of CPNT.

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