

Exercise Echocardiography

Introduction

Although exercise test cannot define the degree of coronary artery stenosis, it can determine the pathological coronary artery flow reserve. Exercise test evaluates only the consequences of a fix coronary artery stenosis and it can't detect the presence of a vulnerable plaque. Estimation of the ECG, during exercise, provides an indirect assessment of ischemia, which could be of limited sensitivity and specificity.

Since, Tennant and Wiggers observed that occlusion of coronary artery, in dogs, reduced, either temporarily, or permanently myocardial performance, purpose of the investigators is direct evaluation of segmental myocardial function.

2D echocardiography represents a valuable tool for the estimation of patients with CAD, since it provides useful information for both segmental and global left ventricular function.

Stress echocardiography (pharmacological stress test, or treadmill echocardiography) leads to increased myocardial oxygen demands and to new/or worsened wall motion abnormalities, due to ischemia. Experimental studies have shown, that as myocardial blood flow is decreased, systolic wall thickening is reduced and this relationship is almost linear.

A decrease of at least 50% of flow (with regard to rest flow values) and additionally ischemia affecting at least 5% of total myocardial mass are necessary, in order to detect wall motion abnormality.

For quantitation of ischemic muscle the current approach recommended by the American Society of Echocardiography, is to use a wall scoring index based on the 16-segment approach. Each segment is judged as to whether or not it is normal or abnormal based on a scheme giving a value of 1 for a normal segment, 2 for hypokinetic, 3 for akinetic, 4 for dyskinetic and 5 for aneurismal. The left ventricular score index is then derived by summing the scores and dividing by the number of segments evaluated.

The segments are assigned to different coronary artery distributions, so that one obtains data for both global and regional function.

This method is used not only for diagnosis of CAD, but also for prognostic estimation in patients with chronic CAD, as well as after myocardial infarction and CABG.

Definition of the culprit vessel for ischemia is of major importance for evaluation of CAD patients and stress echocardiography seems to be the appropriate method, with a diagnostic accuracy of 80-90%. Moreover, this method provides useful prognostic information in patients with valvular diseases, pulmonary hypertension and heart failure.

Limitation of stress echocardiography is the subjective evaluation of WMA, thus there is a need for an expert performer.

Recent studies showed that Tissue Doppler Imaging (TDI) can be used in conjunction with exercise test and help us for detection of myocardial ischemia, especially in LAD and LCX territories (post-exercise decreased tissue systolic velocities in basal and mid segments of interventricular septum and lateral wall).

Taking into consideration ischemic cascade we know, that diastolic function of left ventricle is affected earlier, than systolic performance. Thus, evaluation of (LV) diastolic function could reliably detect ischemia, by exercise echocardiography and this approach has higher sensitivity and specificity for diagnosis of CAD. In this particular case, estimation of (LV) diastolic function is predominantly based on the change of E/Ea ratio, during exercise. This ratio is known to be well correlated with (LV) filling pressures and mural tension. An increase of BNP plasma levels was also found in cases of myocardial ischemia, possibly due to the aforementioned changes. It seems reasonable, that myocardial ischemia leads to elevation of diastolic mural (parietal) tension, to an increase of E/Ea ratio and to higher BNP plasma levels. In such a way, by avoiding the disadvantage of subjectivity, evaluation of ischemia seems to become more objective and documented.

Protocol of exercise echocardiography

Exercise echocardiographic studies involved bicycle exercise (supine or upright) and treadmill exercise. The last form of exercise is the most popular in USA. The principle problem with doing echocardiographic studies with the treadmill examination is the inability to obtain studies during the procedure; one must rely on the immediate post-treadmill

examination. Fortunately, treadmill exercise is the most vigorous form of stress. With stress induced ischemia, a form of stunned myocardium occurs, and the recovery of ventricular function is delayed depending on the severity and duration of ischemia. The Echo-performer should try to complete the post-treadmill examination within 2 minutes.

With the treadmill echocardiographic approach, the patient is supine during the examination, and two parasternal and two apical views are obtained. The patient then exercises on the treadmill and then immediately returns to the examining table for the post-exercise examination.

Respiratory interference from hyperventilation is a common problem during or immediately after exercise.

Although treadmill echocardiography is the more difficult approach, has the advantage of causing significant ischemia with regard to pharmacologic stress tests.

Indications of exercise echocardiography

Coronary Artery Disease

Assessment of regional left ventricular dysfunction

Exercise echocardiography seems to be the better technique for the estimation of (LV) function, both during ischemia, as well as after myocardial infarction. Experimental studies have already shown the relation of the echocardiographically determined local (LV) dysfunction on the one side and the extent of infarct size or ischemia at the other side.

Clinical studies have documented strong relation among location - extent of wall motion abnormality and ECG, clinical status and perfusion defect.

Experience of the Echocardiographer, rotation of the heart, as well as sufficient visualization of the endocardium significantly affect the interpretation of echocardiographic findings.

Quantitative evaluation of regional (LV) dysfunction

Γράψε στα Αγγλικά, τα αποσπάσματα από τις βιβλιογραφικές παραπομπές 61, 62.

Regional wall thickening

Systolic thickening of myocardial walls is independent of systolic movement of neighboring segments.

Thus, assessment of decreased systolic wall thickening, during exercise, improves sensitivity and specificity of the method and documents the presence of ischemia. It is obvious, that distinct visualization of both endocardium and epicardium is necessary.

Exercise Doppler echocardiography (evaluation by conventional and Tissue Doppler study)

Tissue Doppler Echocardiography has been recently established, as a reliable method for the estimation of diastolic function, by measuring mitral annulus diastolic velocities. In addition to the above, the aforementioned data in conjunction with early transmitral flow velocity and in particular E/E' ratio provides evidence of (LV) filling pressures. Measurement of the E/E' ratio before and after exercise is feasible and is highly sensitive and specific for detection of ischemia.

From previous studies, it has been found, that early diastolic velocity at ischemic segments is reduced.

It is well known, that early diastole is an energy – demanded process, which takes place at a higher energetic expenditure, than late diastolic motion.

During ischemia, an increase of early transmitral flow velocity, with a concomitant decrease of annulus early diastolic velocity is observed and thus the E/E' ratio is increased.

The presence of abnormal diastolic relaxation in ischemic (LV) wall segments is a complex phenomenon, which depends on a variety of factors. Coronary flow, loading conditions and metabolic disorders; intracellular phosphate depletion, myofilament disruption and action potential disturbances all modify diastole. Moreover, relaxation is more sensitive to ischemia, than systolic contraction and may motivate subtle abnormalities, without systolic impairment.

Evaluation of Tissue Doppler Echocardiography

Measurement of tissue velocities, via Pulse Doppler TDE, has been recently induced, both at rest, as well as after exercise. The E/E' ratio seems to be useful for identifying CAD and has a complementary role in the evaluation of WMA, since stress echo has important limitations concerning the reproducibility and variability of the subjective interpretation.

Both systolic and diastolic tissue velocities can easily be measured, via TDE.

Usefulness of this new technique in everyday clinical practice could be established through well designed clinical studies.

Valvular diseases

Aortic stenosis

Γράψε στα Αγγλικά τα αποσπάσματα από τις παραπομπές 63, 64, 65, 66.

Mitral stenosis

Γράψε στα Αγγλικά τα αποσπάσματα από τις βιβλιογραφικές παραπομπές 67, 68, 69, 70.

Evaluation of myocardial viability

Many patients with akinetic, but viable segments, exhibit functional recovery after revascularization.

Revascularization of CAD patients with heart failure improves prognosis.

Thus, presence of a considerable amount of viable myocardium predicts improvement of (LV) function, after revascularization (not delayed).

There are various methods, helping us to define the presence, as well as the amount of viable myocardium. Some of them are assessment of metabolic activity with FDG, PET and SPECT.

From the echocardiographic point of view, during dobutamine stress test, we can observe biphasic response in an already akinetic segment,

that means improvement of systolic thickening in low doses and deterioration in high doses of dobutamine, a characteristic (typical) finding of viable myocardium.

Recent studies have shown, that TDE reliably estimates regional function of left ventricle.

Comparison of exercise echocardiography with dobutamine stress echocardiography

It is well known that under resting conditions, patients with CAD may have normal (LV) function. Thus, there has been considerable interest for many years in combining echocardiography with stressful interventions, that will produce ischemia.

Most of the early exercise echocardiographic studies involved supine bicycle exercise. There are, however, limitations to supine exercise. Leg fatigue is frequently a limiting factor, especially in older patients. Furthermore, the best echocardiographic images are usually obtained with the patient in the left lateral position, rather than totally supine. Thus, the examination should be done so that the patient can roll over either immediately after exercise or for the patient to be in that position during exercise.

Upright bicycle exercise has the advantage of less leg fatigue, because the legs need not to be supported against gravity.

More patients can tolerate this form of exercise and the level of exercise is greater. This technique however, is limited by the availability of acoustic windows. The parasternal approach is frequently unsatisfactory and one is restricted to either apical or subcostal examinations.

Treadmill exercise is the most popular form of stress testing in USA. The main problem with doing echocardiographic studies with the treadmill examination is the inability to obtain images during the procedure; one must rely on the immediate post-treadmill examination. As a result, with vigorous exercise, such as treadmill exercise, one usually has several minutes during which WMA persist and can be recorded on the echocardiogram. With such an approach, one should try to complete the post-treadmill examination within 2 minutes. It should be emphasized, however, that the delay in recovery of ventricular function depends on the duration and severity of the

ischemia. If one does not exercise the patient vigorously, one should not expect a long recovery time.

Nevertheless, many patients are not suitable for exercise testing. Handgrip and cold pressor tests are not practical. Handgrip alone does not produce much stress; it has been used in conjunction with pharmacologic testing. Cold pressor tests are painful and have poor patient acceptance.

Pharmacologic stress testing is probably the most popular non-exercise form of stress echocardiography.

The most popular pharmacologic agent is dobutamine. This drug has a strong inotropic and modest chronotropic effect on the heart. The safety and acceptance of dobutamine is good. Transient arrhythmias or hypotension are the most serious side effects, none of which have been life-threatening. The strong inotropic effect of dobutamine can produce intraventricular obstruction and hypotension.

Comparison of exercise echocardiography with thallium scintigraphy

Although exercise test is the most frequent method for identifying ischemia, its sensitivity is low.

Thallium scintigraphy has the advantage of high sensitivity, but on the other side drawbacks consist radiation exposure, limited availability, and high cost.

Exercise echocardiography (by evaluating WMA) seems to be a good alternative choice for detection of myocardial ischemia, since this method is really the combination of two forms of stress testing (the exercise component has useful clinical information, such as the duration of exercise, the patient's symptoms the ECG findings and the echo-component ensures detection of ischemia via wall motion abnormalities). Moreover, there are inherent limitations in this technique, such as the subjective interpretation of data, or the interpreter lack of experience.

It is well known, that ischemia leads earlier to diastolic dysfunction, before systolic WMA and ECG occur.

Thus, evaluation of (LV) diastolic function seems to be reasonable for detection of myocardial ischemia.

In patients with suspected CAD, exercise Doppler echocardiography has been found to be more sensitive for identifying ischemia, than conventional exercise test and stress test (estimation of WMA). Assessment of exercise-induced changes in E/E' ratio has the important advantage of easy application in everyday clinical practice. Given the repeatedly proven usefulness of WMA in stress echocardiography for the detection of ischemia, this new method should be used additively and not in place of WMA evaluation in patients with suspected CAD. As shown in the multivariate analysis, the presence of WMA after exercise and an exercise-induced increase of E/E' ratio were independently associated with the presence of obstructive CAD. It must be noted that thallium – scintigraphy has higher specificity, than exercise Doppler echocardiography (due to higher specificity in diagnosing one vessel disease), but this new method has higher sensitivity compared to thallium scintigraphy. In conclusion, exercise – induced changes in E/E' ratio may be used in the detection of CAD, demonstrating incremental value and furthermore seems to be a good alternative diagnostic approach in comparison with thallium scintigraphy.