Exercise electrocardiography in the management of obstructive coronary artery disease and other cardiac disorders

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Abstract
Exercise electrocardiography (exercise ECG) is the least expensive and most readily available functional test for obstructive coronary artery disease (CAD). Its major weakness is limited accuracy, with a false negative rate of around 50% (sensitivity 50%), and a false positive rate of around 10% (specificity 90%). We discuss the information yielded by exercise ECG and its use in decision-making for patients with suspected or known CAD. The role of exercise ECG in the management of other cardiac disorders is also reviewed. We summarize the practical aspects of performing exercise ECG.

Keywords Aortic stenosis; chest pain diagnosis; coronary artery disease; exercise ECG; exercise electrocardiography; exercise stress test

What's new?

- European Society of Cardiology guidelines published in 2013 endorsed the use of exercise ECG as a diagnostic and prognostic test in a subset of patients with suspected stable coronary artery disease
- Exercise ECG is recommended in the assessment of physically active patients with asymptomatic severe aortic stenosis

Introduction

Exercise electrocardiography (exercise ECG) is an inexpensive and readily available test with broad applications in cardiology. These include the diagnosis of chest pain resulting from cardiac ischaemia, the assessment of patients with known obstructive coronary artery disease (CAD), and risk stratification in patients with valve disease and hypertrophic cardiomyopathy. The procedure is summarized in Box 1. If patients with major contraindications are excluded (Box 1, part A), exercise ECG is generally safe: the incidence of serious complications (ventricular arrhythmia or acute coronary syndrome) is around one in 2500 tests.[1]

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Cardiopulmonary exercise testing (CPX) is an extension of exercise ECG that includes measurement of oxygen uptake and carbon dioxide production. CPX has applications in the diagnosis and risk stratification of patients with a range of cardiorespiratory disorders, the investigation of unexplained exertional dyspnoea and assessment before major surgery, but is not widely available. The clinical uses of CPX are the subject of a recent review[2] and are not discussed further in this article.

Exercise ECG and coronary artery disease

Many tests can be used to diagnose obstructive coronary artery disease, broadly divided into those that show the anatomy of epicardial coronary arteries, and those that reveal the functional effects of CAD. In the presence of flow-limiting CAD, coronary perfusion is insufficient during exercise to match myocardial oxygen demand; this results in subendocardial ischaemia and abnormal ventricular repolarization, apparent as ST-segment depression on the surface ECG. As well as its ability to demonstrate inducible myocardial ischaemia and the haemodynamic response to exercise, exercise ECG can also clarify the cause of non-specific exertional symptoms and provide an objective measure of exercise tolerance and symptom burden.

Information derived from the exercise ECG

Exercise duration – prognosis is closely related to the tolerated duration of exercise. As a rule of thumb, patients who can exercise into stage 4 of the Bruce protocol (or into stage 3 without ST segment change) are in a good prognostic group.

Symptoms – typical angina during exercise is predictive of CAD, particularly when associated with ST depression.

Haemodynamic response – a decrease in systolic blood pressure during exercise below that recorded while standing at rest is a poor prognostic sign when caused by myocardial ischaemia.

ST segment elevation – exercise-induced ST elevation is relatively common in leads showing Q waves from previous MI. ST elevation in patients with a normal resting ECG represents transmural ischaemia and identifies the affected coronary artery. ST elevation in aVR may be seen in severe left main stem disease. If this is seen, the test should be stopped and the patient admitted for stabilization.

ST segment depression – down-sloping or horizontal ST depression of 1 mm or more, measured 80 ms after the inflection point between the QRS complex and the ST segment (J point), in at least two contiguous leads for at least three consecutive beats (with baseline stability), is the most reliable ECG sign of myocardial ischaemia. The following points should be noted:

How to do an exercise ECG

Exercise is performed on a motor-driven treadmill or bicycle ergometer. In the UK, exercise ECG is usually carried out with treadmill exercise. The exercise protocol (e.g. Bruce or modified Bruce) specifies the speed and gradient of the treadmill, and the number and duration of exercise stages. The patient should not have eaten for 3 hours before the test. At least two trained people qualified in advanced life support are needed to supervise an exercise ECG. Exercise stress testing for suspected or known stable coronary artery disease can be safely done by cardiac physiologists or nurses; an experienced doctor should be present for tests in patients with severe aortic stenosis or other major cardiac diseases.

Checklist before starting an exercise stress test

- Check the equipment works (ECG monitoring, treadmill, resuscitation equipment)
- What is the indication for the test?
- Check the patient has no contraindications to exercise stress testing (**see A below**)
- Has the patient's clinical condition changed since the referral?
- What medications are being taken?
- Check the blood pressure
- Check the resting ECG — has it changed since the referral?
- Explain the test to the patient and obtain oral or written consent

ECG electrodes are placed in the standard chest positions and at the base of the limbs (shoulders and hips). A 12-lead ECG is recorded before exercise, and the blood pressure is measured with the patient standing. The patient is asked to exercise for as long as possible and to report any symptoms. He/she then begins to exercise and continues until an end-point is reached (see B below), after which he/she rests on a chair for at least 5 minutes and until any symptoms or ECG changes have fully resolved.

The ECG is monitored continuously during the test, and further 12-lead ECGs are recorded at the end of each stage of exercise, at peak exercise, immediately on stopping, and during each minute of recovery. Blood pressure is measured during the last minute of each stage of exercise, and at peak exercise, with further measurements in recovery if clinically indicated.

A. Contraindications to exercise stress testing

- Acute coronary syndrome (within 2 days)
- Uncontrolled cardiac arrhythmia
- Symptomatic severe aortic stenosis
- Uncontrolled heart failure
- Acute pulmonary embolism
- Acute myocarditis or pericarditis
- Acute aortic dissection
- Acute systemic illness
- Resting systolic blood pressure >200 mmHg or diastolic >20 mmHg
- Significant risk of falling because of neurological or musculoskeletal disorder

B. End-points of exercise ECG

- Limiting symptoms or a request by the patient to stop
- Target heart rate achieved
- ST depression >2 mm (horizontal or downsloping)
- ST elevation >2 mm in leads without pathological Q waves
- Sustained arrhythmia
- Fall in systolic BP of >10 mmHg with evidence of myocardial ischaemia or low cardiac output
- Rise in systolic BP to >250 mmHg
- Technical difficulties in monitoring ECG or BP

Box 1

- The absence of ST depression does not exclude flow-limiting coronary disease; the exercise ECG has a false negative rate of around 50% (i.e. sensitivity 50%). The test should be classed as inconclusive rather than negative if the patient does not experience angina, or the ECG does not show ST depression, but a heart rate of 85% or more of the predicted maximum has not been achieved.
- ST depression may occur in healthy people without heart disease, more commonly in women than in men (false positive rate around 10% [i.e. specificity 90%]). Cardiac causes of ST depression other than flow-limiting CAD include bundle branch block, left ventricular hypertrophy, pre-excitation and treatment with digoxin.
- The greater the degree of ST depression, the more likely is CAD. Down-sloping ST depression is a stronger predictor of CAD than horizontal (plane) ST depression, and both are more predictive than up-sloping ST depression.
- ST depression caused by CAD is most often seen in lead V5. ST depression confined to the inferior leads is seldom indicative of CAD. The location of ST depression is a poor predictor of the site of coronary stenoses.
- ST depression appears only in the recovery period in around 15% of patients with CAD.

Ventricular arrhythmia — ventricular tachycardia or fibrillation may be seen in patients with critical CAD. Frequent ventricular ectopy in the recovery period is associated with increased mortality.

Heart rate recovery — delayed heart rate recovery after exercise is also associated with increased mortality.

Combined data — combinations of clinical and ECG data yield more prognostic information than is contained in single elements. The most widely used of these is the Duke treadmill score, which combines duration of exercise, maximum degree of ST-segment shift and the presence and severity of angina during the test, to yield a score that divides patients into groups at low risk (mortality <1% per year), intermediate risk, and high risk (mortality >3% per year).[3] A Duke score calculator is available online (http://www.cardiology.org/tools/medcalc/duke/). This score also correlates with the angiographic severity of coronary disease; patients with high-risk scores are likely to have three-vessel or left main-stem coronary disease.

Diagnosis, prognosis and management of stable CAD: the place of exercise ECG

Diagnostic testing — assessing the likelihood that CAD is the cause of chest pain begins with a carefully taken history, a focused clinical examination and the analysis of a 12-lead ECG. If