Exercise tolerance testing after myocardial infarction

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Risk stratification after acute myocardial infarction (AMI) is essential in identifying those at high risk of future events. Treadmill exercise tolerance testing is one of a series of investigations commonly used to help determine AMI patients’ prognosis. This article looks at the role of this investigation in risk stratification.

Exercise tolerance testing (ETT) was introduced in the 1940s and has been the focus of many investigations (Detry and Fox, 1996). It was originally used to aid the diagnosis of coronary artery disease (CAD), but is now also used in the prognostic assessment of those who have already been diagnosed (Detry and Fox, 1996; Hill and Timmis, 2002; McGhie, 2001). The purpose is to increase myocardial oxygen consumption and the demands for coronary blood flow. The resting myocardium extracts 70 per cent of the oxygen from the arterial supply – most resting tissues extract 20 per cent. Extraction does not increase during exercise, so an increased blood flow is needed to meet the increased demands. Myocardial ischaemia can result from either an increase in oxygen demand or a reduction in blood supply; an increased heart rate increases oxygen demand but by shortening diastole, supply is also reduced.

Testing is performed on a treadmill or bicycle, with electrocardiograph (ECG), haemodynamic and symptomatic responses being monitored (Cleland et al, 1993; McGhie, 2001; Hill and Timmis, 2002). Contraindications to ETT include:

- Acute myocardial infarction (within 4–6 days);
- Unstable angina (rest pain in previous 48 hours);
- Uncontrolled heart failure;
- Acute myocarditis or pericarditis;
- Acute systemic infection;
- Severe aortic stenosis;
- Severe hypertrophic obstructive cardiomyopathy;
- Untreated life-threatening arrhythmias;
- Aortic dissection;
- Recent aortic surgery.

There are limitations to the interpretation of ST changes if the resting ECG is abnormal due to left bundle branch block, left ventricular hypertrophy and the effects of digoxin (Hill and Timmis, 2002). If patients are selected appropriately, ETT is a low-risk investigation. The rate of AMI and death is around one per 25,000. At highest risk are those post AMI, for whom there is a 0.03 per cent risk of fatal MI or cardiac rupture (Gibbons et al, 2002; McGhie, 2001). Table 1: Normal ECG responses during exercise.

<table>
<thead>
<tr>
<th>Response</th>
<th>Significance</th>
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<tbody>
<tr>
<td>P wave</td>
<td>Increases in height</td>
</tr>
<tr>
<td>PR segment</td>
<td>Shortens and slopes downwards</td>
</tr>
<tr>
<td>QRS complex</td>
<td>R waves decreases in amplitude</td>
</tr>
<tr>
<td>J point</td>
<td>Becomes depressed</td>
</tr>
<tr>
<td>ST segment</td>
<td>Sharply upsloping</td>
</tr>
<tr>
<td>QT interval</td>
<td>Shortens</td>
</tr>
<tr>
<td>T wave</td>
<td>Amplitude decreases</td>
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are often modified to be sub-maximal or symptom-limited. A sub-maximal test will have predetermined endpoints such as achieving 70 per cent of maximum predicted heart rate, whereas a symptom-limited test will allow the patient to continue until signs and symptoms demonstrate the need to stop the test (Gibbons et al, 2002). Reasons for stopping include (Hill and Timmis, 2002; British Cardiac Society, 2003):

- ST segment depression >3mm;
- ST segment elevation >1mm in non-Q wave lead;
- Frequent ventricular extrasystoles;
- Onset of ventricular tachycardia;
- Atrial fibrillation or supraventricular tachycardia;
- Development of new bundle branch block;
- New second or third-degree heart block;
- Patient request;
- Severe chest pain, dyspnoea or dizziness;
- Fall in systolic blood pressure (>20mmHg);
- Rise in systolic blood pressure (230mmHg);
- Fall in heart rate >20 per cent of starting rate;
- Predicted heart rate maintained for one minute.

A higher than expected heart rate may be observed in patients with left ventricular dysfunction, but this can occur in those who are physically unfit, hypovolaemic or anaemic (McGhie, 2001). During exercise, systolic blood pressure is expected to rise to 160–220mmHg. Diastolic pressure does not usually alter by more than +/– 10mmHg. An inadequate rise or a fall in systolic pressure can indicate severe CAD or left ventricular dysfunction. The latter is indicated as systolic blood pressure at peak exertion and can be used to approximate the inotropic capacity of the heart (McGhie, 2001).

**ECG changes**

During exercise in normal subjects, all components of the ECG will alter (Table 1). ST-segment shifts are the most frequent presentation of myocardial ischaemia. The ST segment is measured relative to the isoelectric line at 60 or 80ms after the J point (Fig 1), with the standard accepted ‘positive’ result being 1mm or greater ST depression that is horizontal or downsloping (Cleland et al, 1993; Myers, 2000). Exercise-induced U-wave inversion is also considered a marker of myocardial ischaemia (McGhie 2001; Hill and Timmis 2002).

**Predictive value of exercise testing**

The sensitivity and specificity of diagnostic exercise testing vary widely depending on the population studied. Hall and Timmis (2002) estimate 78 per cent sensitivity and 70 per cent specificity.

Disease prevalence also influences the predictive value of investigations. Bayes’ theorem is used to assess the accuracy of the test by computing the post-test likelihood from the result and the pretest probability of the disease (Fig 2, p30). In those patients with a low pretest likelihood of the disease a positive result does not substantially increase the post-test likelihood of the disease being present. Conversely, disease cannot be excluded in those with a high pretest probability and a negative result. Exercise testing is then of most use in those with an intermediate risk of CAD (Hall and Timmis, 2002; Mark, 2001).

**Prognostic exercise testing**

The use of ETT in prognostic assessment post AMI is usually overshadowed by the emphasis on left ventricular function. Markers of dysfunction are more accurate predictors of adverse cardiac events (Froelicher, 2001; McGhie, 2001). No investigation should be considered in isolation, but ETT can still add value to the assessment of post-AMI patients. The information required from the test is concerned with the likelihood of future ischaemic events or death following AMI (Mark, 2001). CAD is a chronic disease with an unpredictable course. Ischaemic events and fatal or non-fatal MI occur predominately because of plaque rupture. This is clinically unpredictable, though lipid-rich plaques with a thin fibrous cap are believed to be a high risk (Davies, 2000). The traditionally used determinants of a ‘positive’ exercise test such as ST segment depression do not provide any information regarding the probability of a lipid-rich plaque rupturing. This limitation is true of a number of risk stratification techniques (Mark, 2001).

A meta-analysis of risk stratification measures (Shaw et al, 1996) demonstrated that the positive predictive value of exercise-induced ST depression for cardiac death or MI was only 8 per cent in patients with a low pretest likelihood of the disease. Performing exercise testing in those at high risk provides additional information regarding the probability of CAD. Determinants such as exercise-induced ST depression, measured at 80ms from J point, provide additional and important information regarding the likelihood of future ischaemic events (Mark, 2001).

**FIG 1: COMPARISON OF ST SEGMENTS (HILL AND TIMMIS, 2002)**

Top: At rest
Bottom: Pathological ST segment depression, measured at 80ms from J point

**REFERENCES**


patients treated with thrombolysis (Gibbons et al, 2002). The study did conclude an odds ratio of 1.7 (95 per cent confidence interval 1.2–2.5) for cardiac death in those with ST depression of >1mm compared with those without. ST depression may be an indicator of future events and could justify the use of angiography in these patients for further clarification. The meta-analysis was not limited to pre-discharge studies but included studies up to six weeks post AMI. It concluded that the positive predictive value of post-discharge testing is low.

Non-ischaemic factors may also add to the value of pre-discharge ETT (Timmis, 2000). A low level of exercise is considered a poor prognostic sign (Gibbons et al, 2002; Timmis, 2000). Failure to increase systolic blood pressure by 10–30mmHg is also an indicator of high risk (Gibbons et al, 2002).

The negative predictive value of ETT post AMI is, however, high (Shaw et al, 1996; Timmis, 2000) and the completion of a normal test is a good prognostic sign. Such patients have an annual mortality of 1–3 per cent (Alexander et al, 2001).

The exercise test is valuable in order to identify low-risk patients, facilitating early discharge and eliminating the need for further, more expensive or invasive investigations. Several scoring systems have been developed to help classify patients (Mark, 2001). However, these scores include many variables and could contradict clinical common sense when dealing with individual patients.

The ability to perform an ETT is itself a good prognostic sign (Detry and Fox, 1996).

If a patient can walk independently without symptoms and perform daily activities then they could be classified as low risk and avoid the albeit small risk associated with performing a pre-discharge ETT post AMI.

Other factors

Exercise testing is less sensitive in women, but it is unclear if this is because of lower prevalence (Barolsky et al, 1979; Veronique et al, 1995). The American College of Cardiology/American Heart Association guidelines for AMI (Ryan et al, 1996) do not differentiate between benefits or rationale of ETT post myocardial infarction between men and women. In this prognostic setting the ETT may produce similar results for both men and women.

There are other advantages of pre-discharge ETT. AMI can cause anxiety and depression (Andreoli et al, 1983), and taking an ETT can increase the patient’s confidence in their ability to return to a normal life (Julian et al, 1998). Rehabilitation can also be guided by an ETT, providing exercise is prescribed on an individualised basis as recommended by the National Service Framework for Coronary Heart Disease (DoH, 2000). ETT can also be used to evaluate drugs prescribed post AMI, such as beta-blockers (Ryan et al, 1996). These are not thought to interfere with functional capacity and so should be taken at the time of testing. Data can be gathered on their ability to control heart rate, blood pressure and prevent ischaemic arrhythmias (Gibbons et al, 2002).

Conclusion

ETT post AMI is widely used and can successfully identify low-risk patients and facilitate their early discharge. The added benefits include assessment of medication, increased patient confidence and the provision of additional data for rehabilitation.

The ability to perform a pre-discharge ETT is a good sign and the risks should be measured against the benefits for patients who appear to have good functional capacity. The blanket use of ETTs should be questioned if the positive predictive information can be gathered without testing.

ETT post AMI has a low positive predictive value and cannot be used alone in risk stratification. Left ventricular function is considered a more accurate guide to prognosis and thus should always be included in any risk stratification process.