The prognostic value of stress echocardiography among patients with coronary artery disease

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Stress echocardiography (SE) was first proposed as a non invasive clinical tool for coronary artery disease diagnosis and risk stratification in 1979. Since then, there have been over 7,000 publications validating the use of SE in the management of patients with coronary disease, valve disease, heart failure and cardiomyopathy. This article will focus on the prognostic utility of SE among patients with ischaemic heart disease. The test is especially popular as it is very safe and cost effective.

Principles of SE

The test utilises cardiac ultrasound, which is completely safe for the patient. There are no issues with claustrophobic patients and patients with metallic implants. The ultrasound transducer is placed on the chest, which transmits high frequency soundwaves. These are reflected by the cardiac structures back to the transducer and interpreted into electrical impulses and interpreted as images and cine loops of the cardiac structures by the echocardiography machine. Left and right ventricular size, systolic and diastolic function can be accurately determined. Additionally, Doppler ultrasound can be used to assess movement of blood and cardiac tissue of the heart, which allows an assessment of mechanism and severity of valvular stenosis, regurgitation and intracardiac shunts. Resting wall motion abnormalities (hypokinesia and akinesia) are detected from baseline transthoracic echocardiography.

The test requires a cardiac sonographer or doctor for image acquisition and a second person (nurse or doctor) to administer drugs or supervise exercise. The team must be certified in Advanced Life Support and have had specific training in the technique.

Image acquisition, optimisation and analysis

Advances in harmonic imaging and the use of intravenous contrast agents means that good endocardial border definition can be obtained in all patients. Digital acquisition and quad screen display for offline analysis allows for systematic reporting. The added role of three-dimensional echo and quad screen display for offline analysis allows for systematic observation of the patient. Furthermore, unlike nuclear perfusion or x-ray angiography, this test does not use ionising radiation.

The procedure

The procedure takes 40 minutes and is as safe as exercise ECG, irrespective of the stress modality used. The reported incidence of adverse events is one in 2,000 with mortality one in 5,000.

The heart can be stressed either with exercise, pharmacological agents or pacing.

- Exercise is preferred as it provides other physiological parameters that are useful in assessing cardiac risk (walking time, cardiac workload in metabolic equivalents (METS), heart and blood pressure response). Exercise can be performed according to standard treadmill Bruce protocol or semi supine bicycle. However, not all patients are able to exercise – a typical Bruce protocol involves walking on a treadmill for around 10 minutes, with increased speed and incline at three minute intervals.
- Pharmacological stress – for patients unable to exercise, dobutamine is often used which causes an increased heart rate and force of contraction through stimulation of β1 adrenergic receptors of the heart and causes increased myocardial oxygen demand. Dobutamine should be avoided in patients with severe hypertension or uncontrolled arrhythmias. Dipyridamole acts by the dilatation of coronary vessels and decrease of subendocardial flow supply, and is sometimes preferred for myocardial contrast perfusion echo. This agent should be avoided in patients with severe asthma or significant bradyarrhythmias.
- Pacing – an implanted pacemaker can be programmed to achieve target heart rate.

The different methods of stress have similar sensitivities and therefore the procedure can be tailored to individual patient characteristics, preference and medical history. A baseline echocardiogram is performed to assess biventricular function, valvular disease, the great vessels and pericardium. Subsequently, cine images at rest, stress, peak stress and recovery are acquired of the left ventricle in different planes. This includes the four-chamber, two-chamber, three-chamber, short axis and parasternal long axis views. These cine images for each view (ie four-chamber, two-chamber etc) are analysed offline with baseline, during stress, peak stress and recovery in quad screen format to assess for changes in wall motions (figure 2).

Safety

Stress echocardiography is a relatively safe technique with risk of death in less than 1:5000 and very small risk of arrhythmias. The choice of stress agent should be planned with the characteristics of each individual patient. A healthcare professional should be present with regular measurement of blood pressure, continuous ECG monitoring and observation of the patient. Furthermore, unlike nuclear perfusion or x-ray angiography, this test does not use ionising radiation.

Reporting

The left ventricle is divided in 17 segments and wall motion assigned to each segment at baseline, during stress and in recovery. Wall motion is described as normal, hypokinetic (reduced thickening), akinetic (no thickening) and dyskinetic (reverse motion and no thickening). The deterioration of wall
motion of resting normal and hypokinetic segments suggests myocardial ischemia. A resting dyskinetic LV segment or an akinetic segment that fails to improve with stress is non viable. Myocardial ischaemic burden is according to the number of ischaemic segments involved: mild (< two segments), moderate (three and four segments) and severe (five or more segments). A significantly abnormal stress echocardiogram is presented in figure 3. From the baseline echo, resting LV systolic function, presence and severity of valve disease and estimated pulmonary artery pressures are also included in the report conclusion.

Coronary artery disease diagnosis

Multiple reports suggest a sensitivity of 85-92% and specificity 85-90%. This is higher than exercise ECG and similar to myocardial perfusion scintigraphy and perfusion cardiac MRI. SE has moderate sensitivity and specificity for coronary artery disease localisation.

Prognostic value

Multiple studies have highlighted that SE has an important role in predicting cardiac events. A normal stress echocardiography has a highly negative predictive value for perioperative cardiac events. A meta-analysis of over 9,000 patients demonstrated the annual event rate of myocardial infarction or cardiac death following a normal stress echocardiogram was 0.4-0.9%. This is irrespective of coronary anatomy. Patients with a negative stress echocardiogram have an even lower risk of cardiac events (<0.5% per year) if they achieved maximal stress, ejection fraction >50% and the test is performed off anti-ischaemic therapy.

Patients who have a positive stress echocardiogram are at higher risk for future cardiac events. Features that suggest highest risk (>10% year) include resting ejection fraction <40%, high ischaemic burden (>3/17 LV segments), low heart rate threshold for ischemia, slow recovery phase and dilatation of the LV cavity with reduced LVEF at peak stress. Recent European guidelines suggest these patients with high ischaemic burden should be considered for revascularisation.

Prognostic value in specific patient populations

SE is advocated for preoperative cardiac risk assessment in patients who are undergoing intermediate to high risk non-cardiac surgery who have a poor functional capacity (unable to perform more than four METS). Stress echocardiography is not advocated in patients undergoing low risk surgery. Patients with a high ischaemic burden should be considered for revascularisation prior to non cardiac surgery. Patients with low or intermediate ischaemic burdens can usually have non cardiac surgery safely but require assessment with the high risk anaesthetic team.

SE provides important prognostic information in patients with diabetes, end stage renal disease, for different ethnic groups and in octogenarians.

Key points

- Stress echocardiography is a safe, cost effective, non-invasive technique without the use of ionising radiation for the detection of ischaemic heart disease and in the preoperative period.
- The technique is more accurate than exercise ECG and compares with myocardial perfusion scanning and cardiac MRI for coronary artery disease diagnosis.
- Patients with a normal stress echocardiogram have an excellent prognosis irrespective of coronary anatomy.
- Patients with a high ischaemic burden have worst outcome and benefit most from revascularisation.

References

**Figure 1**
(A) is a four-chamber view of the left ventricle. (LA=left atrium, LV=left ventricle). There is artefact of apex of the left ventricle due to near field clutter obscuring the endocardial definition. This is as a result of high amplitude oscillations of piezoelectric crystals that decrease image quality close to the transducer. (B) demonstrates enhanced endocardial definition with opacification of the left ventricle after administration of intravenous contrast.

**Figure 2**
Quad view of the left ventricle taken at rest, low, intermediate and peak dose dobutamine. With increasing dobutamine dose, there is increasing force of contraction and thickening of the myocardium. Hence in this view, the response of the myocardium to stress is normal.

**Figure 3**
Three-chamber stress echocardiogram in a quad view. With increasing stress, there is initially an improvement of myocardial thickening in the anteroseptal wall, although at peak stress the anteroseptum is hypokinetic (arrow), demonstrating inducible ischaemia. The inferolateral wall remains akinetic. The left ventricular cavity is dilated at peak stress – compare this to figure 2. This indicates a high ischaemic burden.