Stress Echocardiography today: current application

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Abstract

Stress echocardiography today has matured into a robust and reliable technique not only for the diagnosis of suspected coronary artery disease (CAD) but also for the accurate risk stratification of patients with suspected and established CAD. This is mainly due to rapid advances in image acquisition, digital display and development of harmonic and contrast imaging. Stress echocardiography today is also utilised in patients with heart failure both for assessing cause of heart failure and determining the extent of hibernating myocardium. With advances in myocardial perfusion imaging, stress echocardiography now allows simultaneous assessment of myocardial function and perfusion. Ready availability and reliability makes stress echocardiography a cost-effective technique for the assessment of CAD.[1-3]

Stress echocardiography which was introduced in the early eighties has matured over the years as a reliable and cost-effective method for both the diagnosis and risk stratification of patients with suspected or known coronary artery disease (CAD). As a result, the uptake of stress echocardiography as the non-invasive method of choice for the assessment of CAD has increased exponentially worldwide and is continuing to expand. In the USA alone approximately 3 million stress echoes were performed last year. The hallmark of myocardial ischemia during stress echocardiography is the occurrence of reduced systolic wall thickening when myocardial 0_2 demand exceeds myocardial blood supply. This precedes the occurrence of chest pain and ST-T changes. The induction of reduced regional systolic wall thickening is specific for CAD. The advent of harmonic imaging and availability of contrast microbubbles together with advancement of digital imaging/display technology, have made stress echocardiography today a reliable and reproducible technique for the assessment of CAD.[1-3]

The diagnostic accuracy of any test varies according to the pre-test likelihood of CAD in the population tested. For example, if a pre-test likelihood of CAD is low then a positive test is likely to be false and conversely if the pre-test likelihood is high a negative test is likely to be false negative. It is also clear that non-invasive tests will have the greatest clinical value only in the population with intermediate likelihood of CAD. In a meta-analysis based on 44 studies where radionuclide perfusion imaging (another widely used investigation for the detection of CAD) were directly compared in patients without prior acute myocardial infarction and without past history of known ischemic heart disease, i.e. in patients with high-intermediate likelihood of CAD, stress echocardiography had a sensitivity of 85% (95% CI, 83-87%) with a specificity of 77% (95% CI, 74%-50%) while SPECT had a sensitivity of 87% (95% CI 86%-88%) with a specificity of 64% (95% CI, 60%-68%).[12] In models comparing the discriminatory abilities of stress echocardiography and SPECT versus exercise testing with ECG alone, both stress imaging techniques performed significantly better than exercise ECG. However, the incremental improvement in performance was greater for stress echocardiography (3:43%; 95 CI, 2.74-4.11) than for SPECT (1.49%; 95% CI, 0.91-2.08).[12]

Another attribute of an ideal non-invasive test is to identify patients at high risk of having multivessel coronary artery disease because these patients have poor outcome even in presence of normal LV function. Clinical variables on their own can identify such patients

and exercise ECG also improves detection of multivessel disease. Does stress echocardiography improve detection of MVD over and above the clinical and exercise data? In a study by Rogers and colleagues, the presence of wall motion abnormality in multiple vascular territories during exercise echocardiography identified additional patients with MVD.[14] This was also shown by another study using dobutamine echocardiography.[6]

Risk Stratification

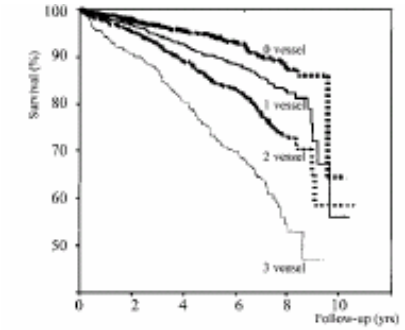
Outcome after normal stress echocardiography

The outcome of a normal stress echocardiography has been assessed in several large studies. In a study of 2829 patients with normal rest and exercise echocardiography followed-up for 6 years, mortality was less than 1% per annum.[7] The cardiac mortality in 4479 patients with normal pharmacological stress echocardiography was 0.7% per patient per year in another study.[8] In a smaller study involving 252 patients studied in a busy district general hospital in UK, the patients with a normal stress echocardiogram in a group with a predominantly intermediate pre-test likelihood of CAD who were followed up for a mean of 2-8 years, cardiac mortality was only 0.4% per year and a combined end-point of cardiac mortality and AMI was 0.8% per year.[9]

Outcome after an abnormal stress echocardiography

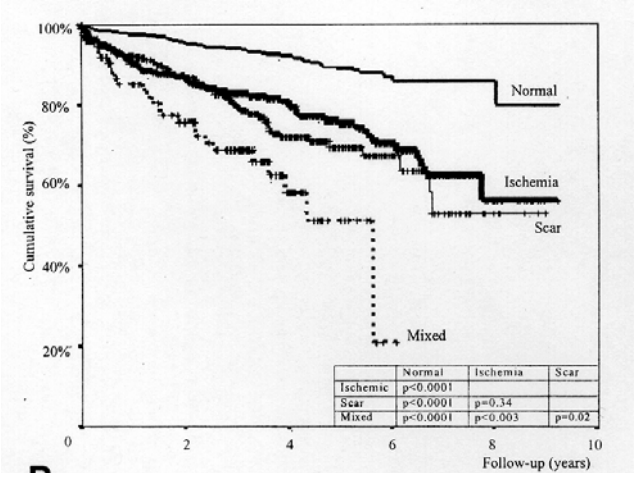
Stress echocardiography can quantify the severity and extent of myocardium in jeopardy and thereby predict risk. The total amount of myocardium in jeopardy can be assessed at peak stress by adding the peak stress score and dividing by the number of segments (summed stress score) assessed in a polar map using the American Society of Echocardiography 16 segment left ventricular model. In a study involving 5375 patients undergoing exercise echocardiography in which the patients were followed-up for 10.6 years the extent of wall motion abnormality calculated as summed stress score incrementally predicted cardiac mortality (Fig. 1).[7]

Figure 1



Similar predictive power of a positive test was demonstrated using dobutamine stress echocardiography in a study involving 3156 patients where patients were followed-up for 9 years.[8] Ischemia and the extent of abnormal wall motion were independent predictors of cardiac death. Furthermore, the type of dobutamine response predicted outcome. Patients who showed resting LV dysfunction with additional ischemia had the worse outcome compared to ischemia alone which pathophysiologically suggest greater amounts of myocardium in jeopardy (Fig. 2). The prognostic value of pharmacological stress echocardiography relative to coronary angiography was addressed in a sub group of 4037 patients who underwent coronary angiography without an intervention. Coronary arteriorgraphy data did not add significant predictive power to the model compared with stress cardiographic variables.[8]

Figure 2



Taken from: Marwick TH et al. J Am Coll Cardiol 2001;37:754-60

Risk stratification after acute myocardial infarction

Thombolysis is widely used in the UK in patients with evolving ST elevation acute myocardial infarction (AMI). Despite its early use many patients are left with significant residual LV dysfunction. This residual LV dysfunction may be due to post-ischemic stunning or myocardial necrosis. Post-ischemic stunning implies good prognosis as patients almost always recover LV function in the absence of residual flow limiting infarct-related artery stenosis. Echocardiography during low doses of dobutamine demonstrates increased contractility in these dysfunctional segments. Several studies have confirmed the ability of dobutamine echocardiography to accurately discriminate between stunned and necrotic myocardium after AMI.[11][12] The lack of dobutamine-induced contractile response portends a poor prognosis is demonstrated by at least 2 recent studies. In one study, dobutamine echocardiography was performed in 214 patients at 12±6 days after AMI.[13]

During a follow-up period of 9±7 months, 12 cardiac deaths occurred. Absence of dobutamine response resulted in greater incidence of hard cardiac events. In another study, comprising 212 patients, performed in the UK in a similar group of patients but performed earlier (4±3 days) after AMI but with a longer follow-up for the first time indicated that the most powerful marker of mortality is the lack of dobutamine response of the infarct-related region irrespective of whether patients subsequently underwent revascularistion or medical therapy.[14]

Cost-effectiveness of stress echocardiography

One of the major arguments against the early performance of a stress imaging test as opposed to the widely used stress ECG with known or suspected CAD would be the greater cost implications of such a strategy. However, this argument does not take into account differences in downstream costs that may arise from the use of a less accurate initial test, which may precipitate the inappropriate use of more expensive investigations, as well as failing to identify patients who go on to potentially costly complications. One major study supported by the American Society of Echocardiography addressed the cost-effectiveness of stress echo compared to stress ECG for patients with known or suspected CAD[15]. Although initial procedural costs were greater, exercise echo was associated with a greater incremental life-expectation (0-2 years) and a lower cost of additional diagnostic procedures when compared with exercise ECG. Exercise echo was more cost-effective (€2615/life year saved) than exercise ECG (Table 1). The authors further concluded that patients with symptoms who need non-invasive evaluation are less likely to undergo coronary angiography and hence revascularisation if a stress echo is performed in preference to exercise ECG. In another recent randomised study conducted in UK, 432 patients presenting to the emergency department with suspected CAD, but with non-diagnostic ECG and negative cardiac enzymes underwent stress echocardiography or exercise ECG for further risk stratification. Stress echocardiography was superior to exercise ECG in risk stratifying these patients to low and high risk groups and resulted in higher rate of early hospital discharge in the stress echo arm.[16] Significantly more patients underwent additional testing based on exercise ECG results compared to stress echo. The study showed that stress echo strategy resulted in potentially significant cost-saving compared with stress ECG.[17]

Future of stress echocardiography

Rapid development of myocardial perfusion imaging using ultrasound contrast agents now may allow simultaneous assessment of both function and perfusion. [18][19] This may allow not only improved assessment of wall motion both at rest and during stress but may also enhance the diagnostic value of stress echocardiography for the detection of CAD.[19]

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Figure Legends

Figure 1 Mortality of patients according to total extent of wall motion abnormalities (summed stress score) at peak stress. (n = 5375 patients). [17]

Figure 2 Cardiac mortality after dobutamine stress echocardiography (n=3156 pts).[24]

Table 1

Cost effective analysis for Exercise ECG and echocardiography [45]

	Ex E (n = 3860)	ExECG (n = 3796)
Years of life saved	89 459	88 464
Average life expectancy	23.54	23.52
Total observed cost	€ 17 419 657	€ 16 842 611
Estimated lifetime cost	€ 373 477 439	€ 370 874 298
Total cost difference	€ 2 603 141	
Approximate cost per life year saved	€ 2615	

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