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# Stress echocardiography: An overview for use in pediatric and congenital cardiology

Peter Ermis, MD

Department of Cardiology, Texas Children's Hospital, Baylor College of Medicine, Houston, Texas

**Correspondence**
Peter Ermis, Department of Cardiology, Texas Children's Hospital, Baylor College of Medicine, 6621 Fannin Street, Suite 19345-C, Houston, TX 77030.
Email: prermis@texaschildrens.org

## Abstract

Currently, the role of stress echocardiography primarily resides in diagnosing acquired coronary artery disease (CAD) in adults. Besides an increasing concern for traditional CAD in young patients due to obesity and other chronic pediatric diseases, there is also a growing population of adolescents and young adults with "at risk" coronary arteries due to: reimplanted coronaries in congenital heart disease, anomalous origin of the native coronary arteries, coronary abnormalities in Kawasaki's disease, and posttransplant coronary vasculopathy. Stress echocardiography is well suited for routine screening and monitoring in these patients. Also, due to the ability of stress echocardiography to provide real-time cardiac imaging, it is useful in areas beyond coronary ischemia. Utilizing Doppler derived velocities and pressure gradients, one is able to further evaluate and risk-stratify patients with valvular heart disease. In addition, stress echocardiography is useful in evaluating other areas including ventricular and coronary reserve. The benefits of stress echocardiography are it is: readily available, portable, and relatively cheap. It can be performed without sedation or radiation exposure which becomes very important in younger patients that require periodic monitoring. Stress echocardiography can also evaluate functional abnormalities instead of relative perfusion defects. Overall, stress echocardiography is currently an underutilized imaging modality that has a wide, and expanding, range of application in the practice of pediatric and congenital cardiology.

**KEYWORDS**
echocardiography, exercise testing, stress echocardiography

## 1 | INTRODUCTION

Almost one hundred years ago, Bousfield first noted ST segment depression during an episode of angina.[1] Not 20 years later, Tennant and Wiggers showed how coronary occlusion induced myocardial wall motion abnormalities.[2] These works, demonstrating both electrical and mechanical abnormalities of the myocardium caused by decreased coronary blood flow, culminated in 1970 when Kraunz and Kennedy first demonstrated stress echocardiography.[3] During the subsequent 40 years, advances in echocardiography have allowed stress echocardiography to become an important modality in cardiac diagnostic testing.

At present, the role of stress echocardiography primarily resides in diagnosing acquired coronary artery disease (CAD) in adults. Stress echocardiography and nuclear myocardial perfusion imaging (MPI) serve as the major modalities to evaluate adult patients for CAD. This primarily consists of cardiac risk stratification in adult patients both with known and unknown CAD. Stress echocardiography is typically indicated in those patients with moderate to high baseline risk who present with chest pain. It is also indicated for preoperative assessment in patients with high baseline risk prior to undergoing major noncardiac surgery. In addition to risk assessment, stress echocardiography has been shown to provide prognostic data in patients following myocardial infarction.[4]

Stress echocardiography builds from the basic concept that Tennant and Wiggers first showed 80 years ago: coronary stenosis and ischemia cause myocardial wall motion abnormalities.[2] A century of research in cardiac ischemia has led us to a better understanding of the ischemic cascade. This pathway begins with subclinical metabolic abnormalities, progresses to myocardial wall motion abnormalities, and eventually results in the symptoms of angina.[5] Using the knowledge of the ischemic cascade, stress echocardiography can allow for the diagnosis of CAD prior to appearance of either resting electrocardiographic abnormalities or angina.

  

Due to the ability of stress echocardiography to provide real-time cardiac imaging, it also is useful in areas beyond coronary ischemia. Utilizing Doppler derived velocities and pressure gradients, one is able to further evaluate and risk-stratify patients with valvular heart disease. In addition, stress echocardiography has been found to be useful in evaluating ventricular reserve. This looks at the general contractile response to exercise as opposed to focusing on regional wall motion abnormalities.[6]

As is typical with most testing modalities, stress echocardiography has only more recently been utilized in the pediatric population. While Alpert et al. first described stress echocardiography in a pediatric patient in 1980, it has only been within the last two decades that it has begun to be discussed in literature as a viable mainstream stress imaging modality.[7] As the pediatric population with acquired CAD increases, stress echocardiography may continue to expand its role in the pediatric age group.[8]

## 2 | PERFORMING A STRESS ECHO

One of the main components of stress echocardiography is the stressor which can be either exercise or pharmacologic. In terms of exercise, stress echocardiography utilizes either a traditional treadmill or a cyclic ergometer. The goals for stress testing are to achieve maximal stress (typically to achieve a predetermined heart rate response) and maximum oxygen uptake in a time period of 8–12 minutes. The Bruce Protocol is most commonly used for treadmill stress testing. It consists of three minute stages of increasing speed and treadmill elevation. Cyclic ergometers allow an increasing workload to be performed in cycling positions ranging from supine to upright. Cyclic ergometer protocols mirror those of the treadmill: ranging from staged to progressive.[9]

The choice of treadmill versus cyclic ergometer should be individualized to physician and patient preference. Younger children have greater familiarity with ambulation thus treadmill testing may be more easily performed in a younger population. This, however, must be weighed with the fact that the treadmill is a more dangerous testing modality. Many providers prefer treadmill testing as the maximal oxygen uptake achieved is typically approximately 10% higher than that achieved on a cyclic ergometer.[9] If patients are able to perform adequately on the cyclic ergometer, studies have shown that both the patient and sonographer prefer this modality.[10]

Pharmacologic stress testing is sometimes required when exercise via a treadmill or cyclic ergometer is unable to be performed. Dobutamine is by far the most commonly used medication in conjunction with stress echocardiography. Dobutamine is typically administered via a continuous infusion starting at 5–10 mcg/kg/min and increasing every 2–3 minutes to a maximum dose of 40–50mcg/kg/min. Additionally, Atropine can be administered in small boluses of 0.01 mg/kg (max 0.25 mg per dose for maximum of 1–2 mg total) to augment heart rate response to achieve an adequate maximum heart rate.[9]

Modern ultrasound equipment typically contains preprogrammed protocols that enable relatively easy performance of stress echocardiography. A well-trained sonographer, with specific experience in stress echocardiography, is required due to the time sensitive nature of image capture (especially for postexercise imaging). For all stress echocardiography, baseline resting images are captured prior to beginning the stress test. For evaluation of wall motion abnormalities, images are typically captured in: parasternal long axis, parasternal short axis, apical four chamber, and apical two chamber views. Stress imaging protocols vary based on the type of stressor utilized. In treadmill testing, stress imaging is performed once immediately post peak exercise. The same four views captured at baseline are again captured. It is important that imaging is completed within approximately 60 seconds following termination of exercise to insure it represents peak stress. For cyclic ergometer and pharmacologic testing a series of images can be obtained at different levels of stress.[6]

Stress echocardiography studies should be interpreted by a cardiologist with experience in reading both stress echo and wall motion abnormalities. Training for adult cardiologists require performance/interpretation of at least 100 stress studies to gain proficiency in their performance and interpretation. The expected wall motion response to stress involves both segment hypercontractily and wall thickening (greater than 50%). With stress, the overall left ventricular chamber size becomes smaller in both systole and diastole.[11]

## 3 | APPLICATIONS IN SPECIFIC POPULATIONS

Currently in the pediatric population, stress echocardiography is most commonly utilized to evaluate for ischemia in patients at risk for, or who have known, coronary abnormalities. This applicability stems from the large amount of data derived from stress echocardiography utilization in adult CAD patients. While traditional CAD is an increasing concern in the young patient due to obesity and other chronic pediatric diseases (diabetes, hyperlipidemia, and chronic kidney disease), atherosclerotic CAD continues to be a relatively rare occurrence. However, there is a growing population of adolescents and young adults with "at risk" coronary arteries due to: reimplanted coronaries in congenital heart disease, anomalous origin of the native coronary arteries, coronary abnormalities in Kawasaki's disease, and posttransplant coronary vasculopathy.[6]

In addition to evaluating for coronary abnormalities, stress echocardiography is uniquely suited to obtain exercise information in patients with valvular heart disease. These gradients are often noted to be markedly increased during exercise compared to relatively mild to moderate abnormalities present at rest. This additional information may serve to better guide exercise restriction and/or timing of intervention in these patients.[6]

A relatively new area of stress echocardiography is evaluating ventricular contractile reserve in patients who have, or who are at risk, for structural cardiac disease. This includes patients with congenital heart disease, cardiomyopathies, and disorders. There is some data suggesting that stress echocardiography evaluating contractile reserve can be prognostic in patients with previous exposure to cardiotoxic chemotherapy agents.[12]

## 4 | COMPARISON WITH OTHER MODALITIES

In addition to stress echocardiography, other cardiac imaging modalities are: MPI, cardiac magnetic resonance (CMR), and positron emission tomography. An in-depth comparison among these modalities is beyond the scope of this review. In adult studies, stress echocardiography has displayed similar sensitivities/specificities in detecting significant coronary ischemia when compared with both MPI and CMR.[13] The benefits of stress echocardiography are it is: readily available, portable, and relatively cheap. It can be performed without sedation or radiation exposure. In utilizing exercise or dobutamine as a stressor, stress echocardiography evaluates functional abnormalities instead of relative perfusion defects. MPI, which evaluates relative perfusion, has been shown to have decreased sensitivity in detecting proximal coronary defects (left main or triple vessel disease) in adult patients with CAD.[14] The major disadvantages are it requires a very proficient and experienced sonographer and requires good echocardiographic windows (which can likely be improved with the utilization of an ultrasound contrast agent[6]).

## 5 | POTENTIAL FUTURE APPLICATIONS

More recent technologic advances in the use of real-time 3D echocardiography, ultrasound contrast perfusion imaging, and utilization of echocardiographic strain imaging with stress hope to add further to the utility and applications of stress echocardiography.

### CONFLICT OF INTEREST

None.

### DISCLOSURES

None.

### AUTHOR CONTRIBUTIONS

The author contributed in the concept/design, drafting, critical revision and approval of the article.

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