

Update on Exercise Stress Testing

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Exercise stress testing is an important diagnostic tool for the evaluation of suspected or known cardiac disease. In 2002, the American College of Cardiology (ACC) and the American Heart Association (AHA) revised their guidelines for exercise testing. Ten categories from the ACC/AHA 1997 guidelines were modified: ST heart rate adjustment, unstable angina, older patients, acute coronary syndromes, chest pain centers, acute myocardial infarction, asymptomatic patients, valvular heart disease, rhythm disturbances, and hypertension. Adjustment of the ST heart rate can identify myocardial ischemia in asymptomatic patients with elevated cardiac risk. Intermediate- and low-risk patients with unstable angina, acute coronary syndromes, or chest pain should undergo exercise stress testing when clinically stable. Provided they are stable, patients who have had acute myocardial infarction can undergo a submaximal exercise test before discharge or a symptom-limited exercise stress test any time after two to three weeks have elapsed. In asymptomatic patients with cardiac risk factors, the exercise stress test may provide valuable prognostic information. Aortic regurgitation is the only valvular heart disorder in which there is significant evidence that exercise stress testing is useful in management decisions. The stress test also can be used in older patients to identify the presence of coronary artery disease. However, because of other comorbidities, a pharmacologic stress test may be necessary. Exercise stress testing can help physicians successfully evaluate arrhythmia in patients with syncope. The exercise stress test also can help identify patients at risk of developing hypertension if they show an abnormal hypertensive response to exercise. (*Am Fam Physician* 2006;74:1749-54. Copyright © 2006 American Academy of Family Physicians.)

Electrocardiographic (ECG) exercise stress testing is a reliable and widely used method of evaluating patients who have or are at risk of developing cardiovascular disease. In addition to the data from ECG changes (ST segment, T- and U-wave abnormalities), other significant data such as arrhythmias, heart rate, blood pressure, exercise capacity, and rating of perceived exertion can be derived from the test to aid in patient treatment and evaluation. The American College of Cardiology/American Heart Association (ACC/AHA) 2002 guidelines for exercise stress testing provide an evidence-based update (*Table 1*) and clearly identify the specific patients who should undergo exercise stress testing.¹

Ten categories from the 1997 guidelines were changed or modified, and the most salient points, including Class 1 and 2a evidence, are emphasized in this review. A discussion of cardiac imaging in conjunction with exercise stress testing is beyond the scope of the update. However, the sensitivity

and specificity of testing may be improved with stress echocardiography or stress nuclear perfusion studies. These should be considered in nondiagnostic ECG exercise stress testing and in certain patient groups (e.g., patients with diabetes, those with bundle branch blocks, patients who are unable to exercise to an adequate end point).

ST Heart Rate Adjustment

The ST heart rate slope or index (i.e., the ST depression difference at peak exercise divided by the exercise-induced increase in heart rate)² was not found in recent studies to be more accurate than single measurement of the ST segment.³ However, in certain asymptomatic patients (i.e., those with hypertension or hyperlipidemia), more cardiac risk was seen with an abnormal ST heart rate index than with an abnormal result on standard exercise stress testing.⁴ Therefore, heart rate adjustment for ST segment changes on ECG may be valuable in certain populations or when there is an equivocal ST response.

TABLE 1
Evidence-Based ACC/AHA Classifications*

<i>Class 1</i>	<i>Class 2</i>	<i>Class 3</i>
Conditions for which there is evidence and/or general agreement that a given procedure or treatment is useful and effective	Conditions for which there is conflicting evidence and/or a divergence of opinion about the usefulness/efficacy of a procedure or treatment 2a: Weight of evidence/opinion is in favor of usefulness/efficacy. 2b: Usefulness/efficacy is less well established by evidence/opinion.	Conditions for which there is evidence and/or general agreement that the procedure/treatment is not useful/effective and in some cases may be harmful

ACC = American College of Cardiology; AHA = American Heart Association.

*—Data in this review are presented in the format of the ACC/AHA evidence-based classification system. This differs from the Strength of Recommendation Taxonomy system used by American Family Physician.

Acute Coronary Syndrome/Acute Myocardial Infarction

Acute coronary syndrome (ACS) represents an acute cardiac event, specifically unstable angina or acute myocardial infarction (MI). Unstable angina is diagnosed clinically when a patient has new-onset angina, increasing angina, or angina occurring at rest. A thrombosis superimposed on a fixed coronary obstruction often causes unstable angina. However, the clinical definition of unstable angina is based on the symptoms described above rather than on specific pathophysiology.⁵

ACS may be a presenting feature or it may interrupt a clinically stable phase in a patient with chronic coronary artery disease (CAD; *Table 2*).^{1,6} The natural history of ACS can progress to MI and/or death or return to stable CAD over a period of about four to six weeks. Therefore, the role and timing of exercise stress testing in ACS encompass the acute and convalescent periods.¹ Clinically, patients are treated using risk stratification (*Table 2*).^{1,6}

Risk groups are based on history and physical examination, cardiac markers, and ECG; and risk stratification is based on the highest risk factor derived from these criteria. Thus, even if a patient has only one high-risk feature and other features in the intermediate- and low-risk categories, the patient is classified

as high risk. The timing of the exercise stress test also depends on risk (*Table 3*).¹ Currently available evidence supports the use of exercise stress testing in patients with ACS when they are clinically stable. In a review of three studies involving 632 patients with stabilized unstable angina, the rate of death or MI within 24 hours of stress testing was 0.5 percent.¹ Recommendations regarding the treatment of patients with acute MI and the associated timing of exercise stress testing are listed in *Table 4*.^{1,6,7}

Chest Pain Centers

Exercise stress testing in emergency department chest pain centers has become increasingly popular. These centers can provide rapid and effective risk stratification and treatment for patients with chest pain who are thought to have acute CAD. Exercise stress testing in this setting is reserved for patients who are low risk on the basis of history and physical examination, ECG, and biochemical cardiac markers.⁹

Most patients presenting to chest pain centers are low risk and this population has a low prevalence of CAD. Adverse outcomes from exercise stress testing in these patients are rare.¹ In one trial, investigators examined the usefulness of chest pain unit exercise stress testing in 424 intermediate-risk patients with unstable angina

TABLE 2
Risk Stratification in Patients with Acute Coronary Syndrome

<i>High risk (at least one of the following features must be present)</i>	<i>Intermediate risk (no high-risk features, but must have one of the following features)</i>	<i>Low risk (no high- or intermediate-risk features, but may have any of the following features)</i>
Rest pain longer than 20 minutes, ongoing <i>Any of the following:</i> Pulmonary edema; new or worsening mitral regurgitation murmur; ventricular “gallop” or worsening rales; hypotension, bradycardia, tachycardia; age older than 75 years <i>Any of the following:</i> Angina at rest with transient ST changes (> 0.05 mV); new bundle branch block; sustained ventricular tachycardia	Rest pain longer than 20 minutes, now resolved, with moderate to high likelihood of CAD* Rest pain less than 20 minutes or relieved with rest or sublingual nitroglycerin Age older than 70 years but younger than 75 years <i>Any of the following:</i> T-wave inversions (> 0.2 mV); pathologic Q waves Slightly elevated biochemical cardiac markers (troponin > 0.01 ng per mL [0.01 mcg per L] but < 0.1 ng per mL)	New-onset or progressive angina in the previous two weeks with moderate to high likelihood of CAD* Normal or unchanged results on ECG during an episode of angina Normal biochemical cardiac markers
Elevated biochemical cardiac markers (troponin > 0.1 ng per mL [0.1 mcg per L])		

CAD = coronary artery disease; ECG = electrocardiography.

*—Moderate or high likelihood of CAD includes diabetes, hypertension, other atherosclerotic disease, cigarette smoking, high-density lipoprotein cholesterol level of less than 40 mg per dL (1.05 mmol per L), or a family history of CAD.

Adapted from *Unstable angina: diagnosis and management*. Rockville, Md.: U.S. Department of Health and Human Services, Public Health Service, Agency for Health Care Policy and Research, National Heart, Lung, and Blood Institute, 1994. Clinical practice guideline no. 10; AHCPR publication no. 94-0602, with additional information from reference 1.

randomized to a chest pain unit or standard hospital admission.¹⁰ No significant differences in the rates of death, MI, or heart failure were noted between the two groups. Of the patients in the chest pain unit group, 60 met hospitalization criteria before stress testing, 55 had an intermediate- or high-risk test result, and 97 had a negative stress test. No complications were related directly to the performance of a stress test in these patients. These results illustrate that exercise stress testing is safe in low-risk and appropriately selected intermediate-risk patients who present to the emergency department.

Older Patients

Few studies have been published on the use of exercise stress testing for prognostic and diagnostic assessment of CAD in older patients (i.e., at least 65 years of age). The prevalence and risk of CAD increase with advancing age. In 1989, the National Health Interview Survey reported that the prevalence of diagnosed CAD was 1.5 percent in women older than 75 years and 1.8 percent in men older than

TABLE 3
Exercise Testing Recommendations in Patients with Acute Coronary Syndrome

- Patients undergoing initial evaluation with suspected or known CAD, including those with complete right bundle branch block or less than 1 mm of resting ST depression (**Class 1 Evidence**)
- Patients with suspected or known CAD, previously evaluated, now presenting with significant change in clinical status (**Class 1 Evidence**)
- Low-risk patients with unstable angina eight to 12 hours after presentation who have been free of active ischemic or heart failure symptoms (**Class 1 Evidence**)
- Intermediate-risk patients with unstable angina two to three days after presentation who have been free of active ischemic or heart failure symptoms (**Class 1 Evidence**)
- Intermediate-risk patients with unstable angina who have initial cardiac markers that are normal, repeat electrocardiography without significant change, and cardiac markers that are normal six to 12 hours after the onset of symptoms and no other evidence of ischemia during observation (**Class 2a Evidence**)

CAD = coronary artery disease.

NOTE: Exercise testing generally is recommended in the above patients who present with an episode of suspected unstable angina.

Information from reference 1.

TABLE 4

Timing of Stress Testing in Treatment of Patients with Acute Myocardial Infarction

Before discharge for prognostic assessment, activity prescription, evaluation of medical therapy (submaximal stress test at four to six days) **(Class 1 Evidence)**

Early after discharge for prognostic assessment, activity prescription, evaluation of medical therapy, and cardiac rehabilitation if the pre-discharge exercise test was not done (symptom-limited test at 14 to 21 days) **(Class 1 Evidence)**

Late after discharge for prognostic assessment, activity prescription, evaluation of medical therapy, and cardiac rehabilitation if the early exercise test was submaximal (symptom-limited test at three to six weeks) **(Class 1 Evidence)**

After discharge for activity counseling and/or exercise training as part of cardiac rehabilitation in patients who have undergone coronary revascularization **(Class 2a Evidence)**

NOTE: A submaximal stress test is defined as a peak heart rate of 120 beats per minute, or 70 percent of the maximum predicted heart rate.⁶ Symptom-limited tests are designed to continue until the patient demonstrates signs or symptoms that necessitate termination of exercise (e.g., angina, fatigue, > 2 mm ST depression).⁷

Information from references 1, 6, and 7.

75 years.¹¹ However, silent ischemia is present in an estimated 15 percent of 80-year-old patients.¹² Because of the higher rates of CAD in the older population, exercise ECG has a slightly higher sensitivity (84 percent) and lower specificity (70 percent) than in younger populations.¹³ This makes ruling out significant disease more difficult.

In one cohort study, investigators evaluated the use of exercise stress testing for prognostic assessment in older patients compared with their younger counterparts.¹⁴ The older population had more comorbidity, achieved a lower workload, and had a significantly worse unadjusted survival rate than the younger patients.

Although the performance of exercise stress testing may pose several problems in older patients, it is not contraindicated.¹⁵ Functional capacity often is compromised secondary to muscle weakness and deconditioning. A bicycle or pharmacologic stress test may be more appropriate in patients with gait and coordination difficulties.¹⁶ Interpretation of exercise stress testing in older patients differs somewhat from that of younger patients. Resting ECG abnormalities,

previous MI, and intraventricular conduction delays may compromise the availability of diagnostic data obtained from ECG. However, the application of standard ST-segment response criteria has similar accuracy in older and younger patients.¹⁷

Asymptomatic Patients

Exercise stress testing may provide valuable prognostic information in asymptomatic men older than 45 years who have risk factors. The higher the number of risk factors, the higher the pretest probability. Risk factors are strictly defined as the following: hyperlipidemia as a total cholesterol level greater than 240 mg per dL (6.20 mmol per L), hypertension as a systolic blood pressure greater than 140 mm Hg or a diastolic pressure of 90 mm Hg or greater, smoking, diabetes mellitus, and history of MI or sudden death in a first-degree relative younger than 60 years.¹⁸

In asymptomatic patients with diabetes mellitus, there is a higher risk of CAD in the presence of at least one of the following factors: age older than 35 years, type 2 diabetes for more than 10 years, type 1 diabetes for 15 years or more, microvascular disease such as proliferative retinopathy or nephropathy, or autonomic neuropathy. It is recommended that patients meeting the above-mentioned criteria undergo exercise stress testing before embarking on moderate- to high-intensity exercise.¹⁹

Valvular Heart Disease

The primary value of exercise stress testing in the setting of valvular heart disease is to objectively assess atypical symptoms, exercise capacity, and extent of disability.²⁰ The revised recommendations regarding the use of exercise stress testing in patients with valvular heart disease involving Class 1- and 2a-based evidence include only aortic regurgitation (Table 5).¹ Additional recommendations may be found in the ACC/AHA Guidelines for the Management of Patients with Valvular Heart Disease.²⁰

Rhythm Disorders

Syncope may be caused by sinus node dysfunction, atrioventricular block, or

tachycardias, which may be identified during testing.¹ Although syncope is not commonly caused by CAD, exercise stress testing in patients with syncope may identify those with CAD (Table 6).¹

Hypertension

Exercise stress testing has been used to identify patients with abnormal blood pressure responses that may be a precursor of hypertension. This has the potential to be used for intervention and possibly to prevent or delay the onset of the disease.²¹ In asymptomatic, normotensive patients, an exaggerated peak systolic blood pressure greater than 214 mm Hg during exercise, or elevated systolic or diastolic blood pressure three minutes into recovery, is associated with an increased long-term risk of hypertension.²² Furthermore, exercise tolerance is lessened in patients with poor blood pressure control.²³

Severe systemic hypertension may cause exercise-induced ST depression in the absence of atherosclerosis.²⁴ In patients with a known history of hypertension, it has been suggested that a systolic blood pressure greater than 200 mm Hg, a diastolic blood pressure greater than 110 mm Hg, or both, are relative contraindications to exercise stress testing.²⁵

TABLE 5

Exercise Stress Testing in Patients with Valvular Heart Disease

In chronic aortic regurgitation, assessment of functional capacity and symptomatic responses in patients with a history of equivocal symptoms **(Class 1 Evidence)**

In chronic aortic regurgitation, evaluation of symptoms and functional capacity before participation in athletic activities **(Class 2a Evidence)**

In chronic aortic regurgitation, prognostic assessment before aortic valve replacement in asymptomatic or minimally symptomatic patients with left ventricular dysfunction **(Class 2a Evidence)**

Information from reference 1.

TABLE 6

Exercise Stress Testing in Patients with Rhythm Disorders

Identification of appropriate settings in patients with rate-adaptive pacemakers **(Class 1 Evidence)**

Evaluation of congenital complete heart block in patients considering increased physical activity or participation in competitive sports **(Class 1 Evidence)**

Evaluation of patients with known or suspected exercise-induced arrhythmias **(Class 2a Evidence)**

Evaluation of medical, surgical, or ablative therapy in patients with exercise-induced arrhythmias, including atrial fibrillation **(Class 2a Evidence)**

Information from reference 1.

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