



National Imaging Associates, Inc.		
Clinical Guidelines STRESS ECHOCARDIOGRAPHY	Original Date:	February, 2010
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INTRODUCTION: This guideline is organized around eight clinical scenarios:

- I. Suspected Coronary Artery Disease (CAD)
- II. Incompletely Evaluated CAD
- III. Follow-up of Known Ischemic CAD
- IV. CAD in Presence of Other New Cardiac Concerns
- V. Chronic Valvular Disease and Pulmonary Hypertension
- VI. Prior to Noncardiac Surgery
- VII. Prior to Cardiac Rehabilitation or Exercise Program
- VIII. Post Cardiac Transplantation

This guideline is for stress imaging, specifically stress echocardiography, with exercise or dobutamine, with appropriate preference for suitable alternatives, such as stress EKG alone or stress testing with myocardial perfusion imaging, when more suitable, using the following stream of logic:

- A stress EKG alone is often appropriate. A baseline EKG, which does not allow interpretation of ischemic findings with exercise, will sometimes, but not always, require the addition of stress imaging (echo or MPI).
- When stress imaging is appropriate, as an addition to stress EKG alone, stress echo is preferred when the patient is able to exercise, MPI when the patient cannot exercise. This document does not actively endorse dobutamine echocardiography as a recommended alternative to stress myocardial perfusion imaging for pragmatic reasons, but dobutamine echocardiography can certainly be an acceptable alternative to stress myocardial perfusion imaging when preferred by the clinical provider.
- When stress echo is precluded by specific imaging difficulties (e.g. poor quality image despite contrast medium, uncontrolled atrial fibrillation, ventricular paced rhythm, baseline wall motion abnormalities, etc., as listed in the Additional Information section), then MPI is referred to as the preferable or **default** strategy.
- Echocardiographic contrast medium is appropriate for those studies in which at least 2 contiguous myocardial segments (of the 16 ACC/AHA myocardial segments) are not visible on the study.
- Hemodynamic assessment can be a reason for preference of stress echocardiography over alternative stress testing.

Compelling indications (e.g. ACC Class I or IIA or Appropriate Use Criteria ‘A’) for stress imaging (echo and MPI) are the foundation, and the less compelling indications (IIB or ‘M’) have been selected as appropriate for those scenarios in which the clinical presentation incurs high risk. If a patient fits two or more clinical scenarios, the scenario which endorses stress echo (MPI only if the **default**) supersedes any category which does not.

Issues such as pretest probability, global risk of coronary or cardiovascular disease, anginal equivalent, aspects of different types of stress testing, etc. are discussed in the Additional Information section at the end of this document, and the reader is encouraged to refer to that section, in order to optimally utilize this guideline.

Initial Clinical Reviewers (ICRs) and Physician Clinical Reviewers (PCRs) must be able to apply criteria based on individual needs and based on an assessment of the local delivery system.

INDICATIONS FOR STRESS ECHO (MPI only if the default) BY CLINICAL SCENARIO

I. SUSPECTED (CAD):

High Global Risk asymptomatic OR

Stable symptomatic OR

Low risk “unstable” symptomatic (Tables 6 & 7)

- **SYMPTOMATIC: LOW PRETEST PROBABILITY** patients should undergo a treadmill exercise stress EKG alone, with stress echocardiography reserved for those whose EKG is uninterpretable. (MPI is to be chosen only when it is the **default** strategy.)
- **SYMPTOMATIC: INTERMEDIATE OR HIGH PRETEST PROBABILITY** patients are appropriate for stress echo (or MPI if it is the **default** strategy).
- **REPEAT STRESS TESTING FOR SIMILAR SYMPTOMS AND SAME PRETEST PROBABILITY** should not be performed for at least 5 years following prior stress testing or invasive coronary arteriography, unless there has been a change in clinical presentation.
- **ASYMPTOMATIC HIGH GLOBAL RISK (>20% coronary or vascular event rate over ensuing 10 years) based upon a COMPELLING HISTORY**, such as patients with peripheral arterial disease (defined in additional information), cerebrovascular disease (history of stroke or TIA), or multiple simultaneous anti-rejection medications (e.g. cyclosporine, tacrolimus, mycophenolate mofetil, azathioprine, long term supraphysiologic doses of glucocorticoids, but not everolimus or sirolimus/rapamycin), should be assessed with **EKG STRESS TEST** alone, with stress echocardiography reserved for those whose EKG is uninterpretable. (MPI is to be chosen only when it is the **default** strategy.)
- **ASYMPTOMATIC HIGH GLOBAL RISK (>20% coronary or vascular event rate over ensuing 10 years, based upon Framingham-ATP IV, Reynolds, Pooled Cohort Equation (includes cerebrovascular risk), ACC/AHA Risk Calculator, MESA Risk Calculator (includes calcium score), or very similar risk calculator) or based upon COMPELLING NON-INVASIVE DATA**, such as clearly pathologic Q waves on the EKG, marked ST-segment and/or T wave abnormalities of myocardial ischemia without symptoms, clear

regional wall motion abnormalities of the left ventricle, or reduced ejection fraction below 50%, should be assessed with **EKG STRESS TEST** alone, with stress echocardiography reserved for those whose EKG is uninterpretable. (Patients with ejection fraction < 50%, with contraindication to invasive coronary arteriography, are reasonable candidates for stress echocardiogram, with MPI used only if it is the **default** strategy, e.g. segmental wall motion abnormality, ejection fraction < 40%, unable to exercise, etc.).

- **REPEAT EKG STRESS TEST ALONE OF ASYMPTOMATIC HIGH GLOBAL RISK patients** (as described in the 2 bullets immediately above), whose last invasive or non-invasive test was over two years ago and was negative for hemodynamically significant obstructive coronary artery disease (i.e. no ischemia on stress testing, no Fractional Flow Reserve (FFR) ≤ 0.80 for a major vessel, or no angiographic stenosis >70% for a major vessel), **is reasonable**.
- **HIGH OCCUPATIONAL RISK patients** (e.g. associated with public safety, airline and boat pilots, bus and train drivers, bridge and tunnel workers/toll collectors, police officers, and firefighters) or **HIGH PERSONAL RISK patients** (e.g. scuba divers, etc.), **should be assessed with EKG STRESS TEST alone, with stress echocardiography reserved for those whose EKG is uninterpretable.** (MPI is to be chosen only when it is the **default** strategy.) Determinations for screening of asymptomatic patients (without known coronary artery disease) in high-risk occupations should be deferred to those agencies that manage such non-medical necessity.

II. **INCOMPLETELY EVALUATED CAD:**

Requires further evaluation within 2 years of a prior coronary evaluation for CLARIFICATION OF DIAGNOSIS OR DISEASE SEVERITY

- **NORMAL EXERCISE STRESS TEST EKG within the past 2 years and currently compelling coronary history or symptoms should be considered appropriate indication for a repeat stress test with stress echocardiography** (or MPI if it is the **default** strategy), particularly if there are reasons to avoid cardiac catheterization (CKD, dye allergy, etc.), unless invasive coronary arteriography is strongly indicated (e.g. compelling presentation of moderate or high risk unstable angina).
- **ABNORMAL OR INDETERMINATE EXERCISE STRESS EKG or CCTA (coronary computed tomographic angiography) within the past 2 years, for whom a noninvasive approach is preferable to proceeding to invasive coronary arteriography** (unclear nature of symptoms, mildly abnormal or borderline EKG stress test or CCTA, CKD, dye allergy, etc.), **is an appropriate indication for stress echocardiography** (or MPI only if it is the **default** strategy).
- **A WELL DOCUMENTED MYOCARDIAL INFARCTION OR moderate to high risk ACUTE CORONARY SYNDROME WITHIN THE PAST 2 YEARS, when stable, without subsequent stress imaging or invasive coronary arteriography, can be appropriate for stress echocardiography, (MPI only if it is the default strategy), especially when a non-invasive approach is documented to be preferable to invasive coronary arteriography.**
- **SEVERITY/EXTENT OF ISCHEMIA ASSESSMENT, in order to assist with the management strategy, in patients with prior invasive coronary arteriography within the**

past 2 years and unclear lesional significance, is an appropriate indication for stress echo (MPI only if it is the default strategy), if it will affect management.

III. FOLLOW-UP of KNOWN ISCHEMIC CAD:

- A. In need of FOLLOW-UP TESTING for known ischemic coronary artery disease, either ASYMPTOMATIC OR WITH STABLE symptoms
- **ROUTINE FOLLOW-UP** when last invasive or non-invasive assessment of coronary artery disease showed **HEMODYNAMICALLY SIGNIFICANT CAD** (ischemia on stress test or $\text{FFR} \leq 0.80$ for a major vessel or stenosis $\geq 70\%$ of a major vessel) over two years ago, without supervening coronary revascularization, is an appropriate indication for stress echocardiography (MPI only if it is the default strategy) in patients with high risk clinical scenarios, such as left ventricular dysfunction (ejection fraction less than 50%) or severe un-revascularized multivessel CAD (if it will alter management), OR in patients with **HIGH RISK OCCUPATIONS** (e.g. associated with public safety, airline and boat pilots, bus and train drivers, bridge and tunnel workers/toll collectors, police officers, and firefighters) or a **HIGH PERSONAL RISK** (e.g. scuba divers, etc.).
 - **SEVERITY/EXTENT OF ISCHEMIA ASSESSMENT**, in order to assist with the management strategy, in patients with recent invasive coronary arteriography AND suspected residual ischemia post incomplete coronary revascularization, is an appropriate indication for stress echo (MPI only if it is the default strategy), if it will affect management.
 - **MYOCARDIAL VIABILITY TESTING BY Dobutamine Stress Echocardiography** (myocardial perfusion imaging at rest is equally suitable), prior to coronary revascularization is reasonable in patients with ejection fraction less than or equal to 50%, if it could significantly alter the revascularization strategy.
- B. NEW, RECURRENT, OR WORSENING (PROGRESSIVE) SYMPTOMS in patients with known ischemic CAD (ischemia on stress testing, lesion stenosis $\geq 70\%$, or $\text{FFR} \leq 0.80$), which has not been revascularized.
- **PRIOR LOW RISK CORONARY EVALUATION AT LEAST TWO YEARS EARLIER** (e.g. limited extent of CORONARY ARTERY DISEASE, $< 5\%$ myocardium at risk), AND NOW WITH NEW STABLE (or low risk unstable), RECURRENT, OR SLOWLY WORSENING (PROGRESSIVE) SYMPTOMS of coronary ischemia, is an appropriate indication for stress echo (MPI only if it is the default strategy) in this patient group. However, regardless of timing of prior non-invasive assessment, clinical documentation of continued problematic symptoms or moderate to highly likely acute coronary syndrome (Table 6) of even low mortality risk (Table 7) is often better assessed with invasive coronary arteriography, particularly when stress testing in the last 2 years and current clinical findings are at odds. This category is very documentation-sensitive and requires judgment.
 - **INVASIVE CORONARY ARTERIOGRAPHY IS GENERALLY PREFERABLE** in those patients, who have a PRIOR MODERATE OR HIGH RISK STRESS TEST RESULT (especially if NOT previously evaluated by invasive coronary arteriography) or a current diagnosis of moderate to high risk UNSTABLE ANGINA, and inappropriate for repeat stress echo (or MYOCARDIAL PERFUSION IMAGING when it is the default strategy), unless supervening reasons to prefer a non-invasive approach are documented in the

record (e.g. very unclear symptoms, CKD, dye allergy, etc.), and it could alter management.

C. FOLLOW-UP OF PATIENTS POST CORONARY REVASCULARIZATION

- **ASYMPTOMATIC, ROUTINE FOLLOW-UP, stress echocardiography** (MPIx only if it is the **default strategy**) **at a minimum of 2 YEARS post coronary artery bypass grafting or 2 YEARS post percutaneous coronary intervention (whichever was the latter) is appropriate only for patients with high direct CORONARY-related risk**, such as incomplete coronary revascularization with feasible additional revascularization of residual severe multivessel disease, need for otherwise unevaluated follow up of stenting of unprotected left main coronary artery (LM) disease or left ventricular dysfunction (ejection fraction less than 50%), **OR for patients with HIGH OCCUPATIONAL RISK** (e.g. associated with public safety, airline and boat pilots, bus and train drivers, bridge and tunnel workers/toll collectors, police officers, and firefighters) or **HIGH PERSONAL RISK** (e.g. scuba divers, etc.).
- **NEW, RECURRENT, OR WORSENING SYMPTOMS POST CORONARY REVASCULARIZATION, with good documentation, are an indication for stress echocardiography** (MPI only if it is the **default strategy**) **if it could affect management.**

IV. CAD IN PRESENCE OF OTHER NEW CARDIAC CONCERNS

- **NON-CORONARY CARDIAC DIAGNOSES support use of stress echocardiography** (MPI only if it is the **default strategy**) in newly diagnosed systolic or diastolic heart failure, sustained VT (> 100 bpm), VF, exercise induced VT or nonsustained VT, frequent PVCs (over 30 per hour), and/or required initiation of antiarrhythmic drug (AAD) therapy when invasive coronary arteriography is not necessarily indicated.
- **NEW ONSET ATRIAL FIBRILLATION, in patients with coronary artery disease and/or moderate or high global risk, are candidates for stress echocardiography** (MPI only if it is the **default strategy**) if there has been no coronary evaluation by stress imaging or invasive coronary arteriography within the preceding two years.
- **SYNCOPE** (specifically, transient loss of consciousness due to global cerebral hypoperfusion characterized by rapid onset, short duration and spontaneous complete recovery, not just any light headedness or dizziness alone) **with otherwise intermediate or high global risk of coronary artery disease warrants stress echocardiography** (MPI only if it is the **default strategy**). Documentation supporting classic vasovagal syncope does not warrant stress testing.
- **LEFT BUNDLE BRANCH BLOCK, when the history, physical examination, and/or noninvasive ejection fraction together support further evaluation, and invasive coronary arteriography is not already indicated, is an indication for stress echocardiography** (MPI only if it is the **default strategy**).
- **EKG STRESS TESTING without imaging is reasonable for EVALUATION OF EXERCISE-INDUCED ARRHYTHMIA** (or long QT interval evaluation when the resting QTc is normal), when coronary artery disease is not suspected.
- **KAWASAKI DISEASE long-term surveillance is better performed with CCTA, which includes aneurysm assessment.**

V. **CHRONIC VALVULAR DISEASE AND PULMONARY HYPERTENSION - HEMODYNAMIC ASSESSMENT:**

EXERCISE HEMODYNAMICS can be obtained with Stress echocardiography with Doppler when it will affect management of chronic valvular heart disease (e.g. lead to surgery, valvuloplasty, transvalvular heart valve replacement, mitral clip, etc.) and/or pulmonary hypertension (e.g. lead to major change in medical management, surgery for congenital heart disease, etc.):

- **Asymptomatic patients with moderate or severe chronic valvular heart disease**, is an appropriate indication for **stress echocardiography**, if it will affect management.
- **Symptomatic patients with mild or moderate mitral stenosis, moderate mitral regurgitation, or equivocal aortic stenosis (low cardiac output, low stroke volume index <35 ml/sq. M, and/or left ventricular systolic dysfunction)**, if it will affect management, is an appropriate indication for **stress echocardiography**, with dobutamine required for the patients with equivocal aortic stenosis.
- **For documented suspicion of pulmonary hypertension with normal or borderline elevated pressures on resting echocardiogram, and when needed to assess the effect of therapy for pulmonary hypertension**, if it will affect management, **stress echocardiography** is appropriate.

VI. **Prior to NONCARDIAC SURGERY**

- **THORACOABDOMINAL AORTIC VASCULAR SURGERY** is an indication for **PREOPERATIVE Stress echo** (MPI only if it is the **default** strategy) **if the patient has less than a 4 MET** (see Additional Information section) exercise functionality, **AND** that patient has at least **one OPERATIVE clinical risk factor from the list**: ischemic coronary artery disease (by study more than two years ago with lesions, which are: $\geq 70\%$ or ischemia producing on prior stress testing or with FFR ≤ 0.80), cerebrovascular disease, insulin-requiring diabetes mellitus, history of congestive heart failure or ejection fraction less than 40%, or CKD with creatinine ≥ 2 mg/dl. (Such stress imaging is restricted to patients who have not had either stress imaging or invasive coronary arteriography within the past year.) **If invasive coronary arteriography is preferable, then preoperative stress imaging is not appropriate.**
- **UNRELATED TO THE PLANNED SURGICAL PROCEDURE**, stress imaging might be indicated for other reasons at the time patients are seen for preoperative cardiac risk evaluation. When such indications for stress imaging are **unrelated to the need for the intended non-cardiac surgery**, then the **record must document** those reasons in order to support proceeding with appropriate stress echocardiography (MPI only if it is the **default** strategy).
- **BARIATRIC SURGERY** is not considered an indication for preoperative stress testing.
- **SOLID ORGAN TRANSPLANTATION** is an indication for preoperative stress echocardiography (MPI only if it is the **default** strategy) if: invasive coronary arteriography is not intended as the initial preoperative evaluation of choice, **AND** there has not been an adequate coronary evaluation within the past year.

VII. Prior to CARDIAC REHABILITATION or EXERCISE PROGRAM

- **CARDIAC REHABILITATION ENTRY or DETERMINATION OF EXERCISE CAPACITY** is an indication for stress testing with **EKG alone**, when performed as part of the cardiac rehabilitation program or for purposes of exercise prescription.

VIII. Post CARDIAC TRANSPLANTATION

- **During the first five years post cardiac transplantation, patients with glomerular filtration rates less than 40 mL/min/1.73 sq M**, or who otherwise should not undergo invasive coronary arteriography every 1-2 years, are appropriate for **stress echocardiography** (MPI only if it is the **default** strategy) every 1-2 years.
- **After the first five years post cardiac transplantation**, in lieu of invasive coronary arteriography: 1) **patients considered at low risk for transplant vasculopathy** (i.e., with normal invasive coronary arteriography) can have annual **stress echocardiography** (MPI only if it is the **default** strategy), and 2) **patients with transplant coronary vasculopathy can have annual stress echocardiography** (MPI only if it is the **default** strategy), **if the risk of annual invasive coronary arteriography is not acceptable** (i.e., high risk of contrast nephropathy).

ADDITIONAL INFORMATION:

Definitions of Coronary Artery Disease:

1. Percentage stenosis refers to diameter stenosis when angiography is the method and refers to cross sectional narrowing when IVUS (intravascular ultrasound) is the method of determination.
2. Coronary artery calcification is a marker of risk, as measured by Agatston score on coronary artery calcium imaging. It is not a diagnostic tool so much as it is a **risk stratification** tool (similar to an ankle brachia index, family history of coronary artery disease, or high sensitivity C-reactive protein). Its incorporation into Global Risk can be achieved by using the MESA risk calculator.
3. Stenoses less than 50% are considered nonobstructive coronary artery disease, while stenoses of 50% or more are considered obstructive coronary artery disease. However, the contents of this Guideline are very clear about specifying that **ischemic heart disease** requires one of three possible determinants:
 - i. Percentage stenosis of at least 70% - by angiography or IVUS (intravascular ultrasound), as described above, for a major vessel
 - ii. FFR (fractional flow reserve) of 0.80 or less for a major vessel
 - iii. Demonstrable ischemic findings on stress testing (acceptable EKG or imaging), that are at least mild in degree
4. A major vessel would be a coronary vessel that would typically be substantial enough for revascularization, if it were indicated. Lesser forms of coronary artery disease would be labeled as “limited.” (i.e. A 50% lesion in a tiny septal would be limited obstructive coronary artery disease.)
5. Microvascular ischemic coronary artery disease, as might be described by a normal FFR (fractional flow reserve) above 0.80 with a reduced CFR (coronary flow reserve less than 2.5), has not otherwise been addressed in this manuscript, because it is very rarely an issue in compliance determinations. However, it would constitute a form of ischemic heart disease.

6. FFR (fractional flow reserve) is the distal to proximal pressure ratio across a coronary lesion during maximal hyperemia induced by either intravenous or intracoronary adenosine. Less than or equal to 0.80 is considered a reduction in coronary flow.

Definition of Peripheral Arterial Disease/Cerebrovascular Disease:

Non-coronary arterial narrowing causing symptoms (claudication, related tissue demise, threatened limb loss), asymptomatic 70% or more narrowing by non-invasive or invasive evaluation, atherosclerotic arterial aneurysm by non-invasive or invasive evaluation, or aortic atheroma of at least 4 mm thickness. As a subset of peripheral arterial disease, cerebrovascular disease is also defined as a history of stroke or TIA.

What is a valid *anginal equivalent*?

Development of an anginal equivalent (e.g. shortness of breath, fatigue, or weakness) either with or without prior coronary revascularization should be based upon the documentation of reasons to suspect that symptoms other than chest discomfort are not due to other organ systems (e.g. dyspnea due to lung disease, fatigue due to anemia, etc.), by presentation of clinical data such as respiratory rate, oximetry, lung exam, etc. (as well as d-dimer, chest CT(A), and/or PFTs, when appropriate), and then incorporated into the evaluation of coronary artery disease as would chest discomfort. Syncope by itself is generally not considered an anginal equivalent, and is handled under a separate category in this guideline.

Pretest Probability of CAD for Symptomatic Patients:

Pretest probability is a reference to symptoms that need evaluation as potentially coronary in origin.

- **Typical Angina (Definite):** Defined as 1) substernal chest pain or discomfort that is 2) provoked by exertion or emotional stress and 3) relieved by rest and/or nitroglycerin.
- **Atypical Angina (Probable):** Chest pain or discomfort that **lacks 1** of the characteristics of definite or typical angina.
- **Nonanginal Chest Pain:** Chest pain or discomfort that **meets 1 or none** of the typical angina characteristics.

Once the presence of symptoms (Typical Angina/Atypical Angina/Non angina chest pain/Asymptomatic) is determined, the probabilities of CAD can be calculated from the risk algorithms as follows:

Age (Years)	Gender	Typical/Definite Angina Pectoris	Atypical/Probable Angina Pectoris	Nonanginal Chest Pain	Asymptomatic
<39	Men	Intermediate	Intermediate	Low	Very low
	Women	Intermediate	Very low	Very low	Very low
40–49	Men	High	Intermediate	Intermediate	Low
	Women	Intermediate	Low	Very low	Very low
50–59	Men	High	Intermediate	Intermediate	Low
	Women	Intermediate	Intermediate	Low	Very low
>60	Men	High	Intermediate	Intermediate	Low
	Women	High	Intermediate	Intermediate	Low

- **Very low:** Less than 5% pretest probability of CAD
- **Low:** Less than 10% pretest probability of CAD
- **Intermediate:** Between 10% and 90% pretest probability of CAD

- **High:** Greater than 90% pretest probability of CAD

Global Risk of CAD or Vascular Disease

Global risk of CAD is defined as the probability of developing CAD, including myocardial infarction or CAD death over a given time period and refers to asymptomatic patients without known coronary artery disease. It should be determined by the Framingham Risk Score (ATP IV risk tool), the Reynolds Risk Index, or the Pooled Cohort Equation (which includes cerebrovascular risk). A high risk is considered greater than a 20% risk of a coronary or major vascular event over the ensuing 10 years.

- **CAD Risk—Low**
Defined by the age-specific risk level that is below average. In general, low risk will correlate with a 10-year absolute CAD risk less than 10%.
- **CAD Risk—Moderate**
Defined by the age-specific risk level that is average or above average. In general, moderate risk will correlate with a 10-year absolute CAD risk between 10% and 20%.
- **CAD Risk—High**
Defined as the presence of peripheral arterial disease, cerebrovascular disease, or a 10-year absolute CAD risk of greater than 20%.

Duke Treadmill Score

The equation for calculating the Duke treadmill score (DTS) is,

$$\text{DTS} = \text{exercise time in minutes} - (5 * \text{ST deviation in mm or } 0.1 \text{ mV increments}) - (4 * \text{exercise angina score})$$
 with angina score being 0 = none, 1 = non limiting, and 2 = exercise-limiting. The score typically ranges from -25 to +15. These values correspond to low-risk (with a score of $\geq +5$), intermediate risk (with scores ranging from -10 to +4), and high-risk (with a score of ≤ -11) categories.

What Type of Stress Test is Appropriate?

EKG Stress Test versus Stress Echocardiography versus Stress Myocardial Perfusion Imaging

Appropriate resource utilization, cost effectiveness, and radiation exposure limitation dictate choices in stress testing options.

Five prominent scenarios for an EKG stress test WITHOUT imaging (i.e. exercise treadmill EKG test) are endorsed by the guidelines presented above, often (but not always) requiring that the patient can exercise for at least 3 minutes of Bruce protocol with achievement of near maximal heart rate AND has an interpretable EKG for ischemia during exercise:

- The (symptomatic) low pretest probability patient who is able to exercise and has an interpretable EKG
- The (asymptomatic) high global risk patient who is able to exercise and has an interpretable EKG
- The patient who is under evaluation for exercise induced arrhythmia (or long QT interval evaluation when the resting QTc is normal), and coronary artery disease is not suspected
- The patient who requires an entrance stress test EKG for a cardiac rehab program or for an exercise prescription

An uninterpretable baseline EKG includes:

- Abnormalities of ST segment depression of 0.1 mV (1 mm with conventional calibration) or more
- Ischemic looking T wave inversions of at least 0.25 mV (2.5 mm with conventional calibration)
- EKG findings of probable or definite LVH, WPW, a ventricular paced rhythm, or left bundle branch block
- Digitalis use or hypokalemia
- Resting HR under 50 bpm on a beta blocker and an anticipated suboptimal workload (e.g. rate-pressure product less than 20-25K)
- Prior false positive stress EKG

Exercise remains a valid stressor:

- In patients who can exercise to near maximal heart rate
- For entrance to cardiac rehabilitation or determination of an exercise prescription
- For exercise induced arrhythmia evaluation
- Even with an uninterpretable EKG if stress imaging is appropriate and EKG uninterpretability is acknowledged

Scenarios for choosing stress echocardiography over myocardial perfusion imaging:

- The patient can exercise to near maximal heart rate for at least 3 minutes of Bruce protocol, with usage of contrast medium if necessary to enable quality imaging

AND

There is normal baseline systolic function or mild global hypokinesia (ejection fraction 40-50%), without moderate or severe valvular disease. Stress echocardiography with Doppler is appropriate in the patient for whom determination of exercise hemodynamics is helpful.

- Exercise Doppler with hemodynamics is the main reason for stress testing.

When is Myocardial Perfusion Imaging Preferred Over Stress Echocardiography?

There are circumstances in which myocardial perfusion imaging is generally preferable to stress echocardiography:

- BMI \geq 40
- Ventricular paced rhythm, LBBB, WPW
- Frequent PVCs interfering with wall motion assessment
- Prior coronary artery bypass grafting with resultant paradoxical septal motion
- Currently in poorly controlled atrial fibrillation
- Poor cardiac window on echo (documented on echo report as technically limited or difficult, without likely benefit of contrast medium)
- Documented regional wall motion abnormality: dyskinesia, akinesia, or hypokinesia
- Unable to perform ADL's with documented extent of limitations
- Functional capacity $<$ 4 METS or $<$ 3' Bruce protocol
- Arthritis with documented limitations
- Leg/foot amputation
- Active foot wound/ulcer

- Ambulation requires cane or walker
- Confinement to a wheelchair
- Severe chronic obstructive pulmonary disease (based upon PFT findings), severe dyspnea on exertion, or requirement for home oxygen use
- Systolic congestive heart failure with ejection fraction <40%
- Recent orthopedic surgery limiting use of a lower extremity

Determinants of a 4 MET functional capacity:

Examples of activities:

<4 METs: Slow ballroom dancing, golfing with a cart, playing a musical instrument, and walking at approximately 2 mph to 3 mph

>4 METs: Climbing a flight of stairs or walking up a hill, walking on level ground at 4 mph, and performing heavy work around the house

Tools for Characterization of Unstable Angina:

Risk Stratification in Acute Coronary Syndrome from 2007 ACC/AHA Guidelines

Three Principal Presentations of Unstable Angina (as defined within a two week time frame) (Braunwald)

Class	Presentation
Rest angina*	Angina occurring at rest and prolonged, usually greater than 20 min
New-onset angina	New-onset angina of at least CCS class III severity
Increasing angina	Previously diagnosed angina that has become distinctly more frequent, longer in duration, or lower in threshold (i.e., increased by 1 or more CCS class to at least CCS class III severity)

Table 6: Likelihood that Symptoms Represent an Acute Coronary Syndrome

Feature	High Likelihood	Intermediate Likelihood	Low Likelihood
	<i>Any of the following:</i>	<i>Absence of high-likelihood features and presence of any of the following:</i>	<i>Absence of high- or intermediate-likelihood features but may have:</i>
History	Chest or left arm pain or discomfort as chief symptom reproducing prior documented angina Known history of CAD, including MI	Chest or left arm pain or discomfort as chief symptom Age greater than 70 years Male sex Diabetes mellitus	Probable ischemic symptoms in absence of any of the intermediate likelihood characteristics Recent cocaine use
Examination	Transient MR murmur, hypotension, diaphoresis, pulmonary edema, or rales	Extracardiac vascular disease	Chest discomfort reproduced by palpation
ECG	New, or presumably new, transient ST-segment deviation (1 mm or greater) or T-wave inversion in multiple precordial leads	Fixed Q waves ST depression 0.5 to 1 mm or T-wave inversion greater than 1 mm	T-wave flattening or inversion less than 1 mm in leads with dominant R waves Normal ECG
Cardiac markers	Elevated cardiac Tnl, TnT, or CK-MB	Normal	Normal

Modified with permission from Braunwald E, Mark DB, Jones RH, et al. Unstable angina: diagnosis and management. Rockville, MD: Agency for Health Care Policy and Research and the National Heart, Lung, and Blood Institute, U.S. Public Health Service, U.S. Department of Health and Human Service, 1994. AHCPR publication no. 94-0602 (124).

ACS = acute coronary syndrome; CAD = coronary artery disease; CK-MB = MB fraction of creatine kinase; ECG = electrocardiogram; MI = myocardial infarction; MR = mitral regurgitation; Tnl = troponin I; TnT = troponin T.

Table 7: Short Term Risk of Death or Nonfatal MI in Acute Coronary Syndrome

Feature	High Risk	Intermediate Risk	Low Risk
	<i>At least 1 of the following features must be present:</i>	<i>No high-risk feature, but must have 1 of the following:</i>	<i>No high- or intermediate-risk feature but may have any of the following features:</i>
History	Accelerating tempo of ischemic symptoms in preceding 48 h	Prior MI, peripheral or cerebrovascular disease, or CABG; prior aspirin use	
Character of pain	Prolonged ongoing (greater than 20 min) rest pain	Prolonged (greater than 20 min) rest angina, now resolved, with moderate or high likelihood of CAD Rest angina (greater than 20 min) or relieved with rest or sublingual NTG Nocturnal angina New-onset or progressive CCS class III or IV angina in the past 2 weeks without prolonged (greater than 20 min) rest pain but with intermediate or high likelihood of CAD (see Table 6)	Increased angina frequency, severity, or duration Angina provoked at a lower threshold New onset angina with onset 2 weeks to 2 months prior to presentation
Clinical findings	Pulmonary edema, most likely due to ischemia New or worsening MR murmur S ₃ or new/worsening rales Hypotension, bradycardia, tachycardia Age greater than 75 years	Age greater than 70 years	
ECG	Angina at rest with transient ST-segment changes greater than 0.5 mm Bundle-branch block, new or presumed new Sustained ventricular tachycardia	T-wave changes Pathological Q waves or resting ST-depression less than 1 mm in multiple lead groups (anterior, inferior, lateral)	Normal or unchanged ECG
Cardiac markers	Elevated cardiac TnT, TnI, or CK-MB (e.g., TnT or TnI greater than 0.1 ng per ml)	Slightly elevated cardiac TnT, TnI, or CK-MB (e.g., TnT greater than 0.01 but less than 0.1 ng per ml)	Normal

*Estimation of the short-term risks of death and nonfatal cardiac ischemic events in UA (or NSTEMI) is a complex multivariable problem that cannot be fully specified in a table such as this; therefore, this table is meant to offer general guidance and illustration rather than rigid algorithms. Adapted from AHCPR Clinical Practice Guidelines No. 10, Unstable Angina: Diagnosis and Management, May 1994 (124).

CABG = coronary artery bypass graft surgery; CAD = coronary artery disease; CCS = Canadian Cardiovascular Society; CK-MB = creatine kinase, MB fraction; ECG = electrocardiogram; MI = myocardial infarction; MR = mitral regurgitation; NTG = nitroglycerin; TnI = troponin I; TnT = troponin T; UA/NSTEMI = unstable angina/non-ST-elevation myocardial infarction.

The **TIMI Risk Score** is determined by the sum of the presence of 7 variables at admission; 1 point is given for each of the following variables: age ≥ 65 years, at least 3 risk factors for CAD, prior coronary stenosis of $\geq 50\%$, ST-segment deviation on ECG presentation, at least 2 anginal events in prior 24 hours, use of aspirin in prior 7 days, and elevated serum cardiac biomarkers
Low-Risk TIMI Score: TIMI score < 2 ; **High-Risk TIMI Score:** TIMI score ≥ 2 . A low risk TIMI score might still warrant invasive coronary arteriography, when other features, such as symptoms, are compelling.

Abbreviations:

AAD	antiarrhythmic drug
ADLs	activities of daily living
CAD	coronary artery disease
CCS	Canadian Cardiovascular Society
CKD	chronic kidney disease
EKG	electrocardiogram
FFR	fractional flow reserve
LBBB	left bundle-branch block
LVH	left ventricular hypertrophy
MI	myocardial infarction
MET	estimated metabolic equivalent of exercise
PFT	pulmonary function test
PVCs	premature ventricular contractions
TIMI	Thrombolysis in Myocardial Infarction (Study Group)
WPW	Wolf Parkinson White

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ACC/AHA Risk Calculator (includes cardiac and cerebrovascular risk):

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