NONINVASIVE MODALITIES
FOR THE ASSESSMENT OF CORONARY ARTERY DISEASE
Frontline providers are increasingly responsible for a growing, aging population at risk for coronary artery disease (CAD).

Those who see at-risk patients first may become more involved in disease evaluation and care coordination for appropriate cardiac testing.

The more we can understand about the noninvasive cardiac testing options available, the more we can work together to help improve the quality of care for what matters most—the patient.
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INTRODUCTION

Evaluating an At-Risk Population

Appropriate noninvasive cardiac testing modalities can provide essential information for the risk assessment and evaluation of CAD.¹

As the aging US population continues to grow, understanding risk assessment and evaluation options for CAD may become increasingly important for frontline providers² in determining whether patients need treatment or further testing. Learning more about noninvasive cardiac testing may help with quality of care for patients with known or suspected CAD.

This information is an introduction to noninvasive cardiac testing. It should not be used independently for patient risk assessment or diagnosis, and it is not intended to replace clinical judgment. This information should be used as a starting point for further reading.

¹Frontline providers are the first to see patients at risk for CAD and may include primary care physicians (PCPs), obstetrician/gynecologists, internists, hospitalists, nurse practitioners (NPs), physician assistants (PAs), or other referring or ordering providers.
Coronary Artery Disease

CAD, or atherosclerosis of the coronary arteries, is a serious health threat in the United States (Figure 1). Also known as ischemic heart disease (IHD), CAD is a progressive condition where plaque builds up in the coronary arteries over time (Figure 2).\(^5\)

CAD encompasses a wide spectrum of manifestations and symptoms, ranging from patients who are completely asymptomatic to those who have already experienced myocardial infarction (MI) and/or revascularization procedures.\(^1\)

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**Coronary Artery Disease**

CAD, or atherosclerosis of the coronary arteries, is a serious health threat in the United States (Figure 1). Also known as ischemic heart disease (IHD), CAD is a progressive condition where plaque builds up in the coronary arteries over time (Figure 2).\(^5\)

**Figure 1. Heart Disease Is a Major Threat to Public Health**

It is estimated that more than 1 in 3 adults in the United States (about 92.1 million) live with some form of CVD.\(^2\)

More than half of those with CVD (about 46.7 million) are estimated to be 60 years or older.\(^2\)

The number of adults who are 65 years or older is projected to increase by more than 8 million from 2015 to 2020.\(^3\)

Approximately 1 of every 3 deaths in the United States is attributed to CVD, and the leading cause of death for both men and women is also the most common type of heart disease—CAD.\(^2,4,5\)

**CAD = coronary artery disease; CVD = cardiovascular disease.**
Figure 2. Progression of Atherosclerosis\textsuperscript{6,7}

1 Healthy artery
2 Plaque\textsuperscript{a} forms in the lining of the artery
3 Plaque collects, restricting arterial blood flow
4 Plaque ruptures, forming blood clots and limiting blood flow

\textsuperscript{a}Made up of calcium, fat, cholesterol, and other substances in the blood.

\section*{Initial Evaluation}

A variety of methods are available to assess patient risk for a future cardiac event based on the following\textsuperscript{1}:

- Clinical classification of chest pain
- Risk factors
- Physical examination results
- Age
- Sex
- Electrocardiogram (ECG) results
- History of MI
- Presence of typical angina

The initial evaluation of a patient with known or suspected CAD can help determine the short-term risk for adverse cardiovascular events and whether immediate treatment is required.\textsuperscript{1}

Each patient is different and should be evaluated according to his or her specific needs.\textsuperscript{1}
Chest Pain

In patients presenting with chest pain, the first goal is to determine if the patient has acute coronary syndrome (ACS), which would require immediate intervention. Patient history may help classify the chest pain as typical, atypical, or noncardiac (Table 1).1

Risk Assessment

Once ACS has been ruled out, and after thorough characterization of any chest pain, patient risk factors for CAD can be evaluated.1

**Patient Risk Factors**

- Smoking
- Physical inactivity
- Hypertension
- Hyperlipidemia
- Dyslipidemia
- Diabetes mellitus
- Frequency of angina
- Chronic kidney disease (CKD)
- Obesity or metabolic syndrome
- Chronic pulmonary disease or heart failure
- History of cerebrovascular or peripheral artery disease (PAD)
- Sociodemographic characteristics, including age, sex, and socioeconomic status
- Family history of premature CAD (onset before age 55 years in a male relative or 65 years in a female relative)

Risk Score Calculators

Several risk assessment formulas have been derived in order to determine the probability of adverse cardiovascular events following examination of the patient, including the Atherosclerotic Cardiovascular Disease (ASCVD) Risk Estimator* (also referred to as the Pooled Cohort Equations),8 the Framingham Risk Score,9 and the Reynolds Risk Score.10 These and other risk assessment algorithms, which are easily accessible online, may be helpful as part of an initial evaluation of patients with known or suspected CAD.

Resting ECG

A resting ECG can be used as part of the initial risk assessment in patients with known or suspected CAD. Patients with CAD who have the following abnormalities on a resting ECG have a worse prognosis than those with normal results1:

- Evidence of prior MI
- Left bundle-branch block (LBBB)
- Bifascicular block
- Second- or third-degree atrioventricular block
- Ventricular tachyarrhythmia
- Left ventricular (LV) hypertrophy
- Persistent ST-T-wave inversions

Further Evaluation

For patients with known or suspected CAD, further testing beyond the initial evaluation may be necessary. Once it is determined that more information is needed, the next step is choosing the most appropriate diagnostic and therapeutic strategies to optimize patient care.

*Access the ASCVD Risk Estimator on CardiacTesting.com
### Table 1. Clinical Classifications of Chest Pain

<table>
<thead>
<tr>
<th>TYPICAL ANGINA (DEFINITE)</th>
<th>ATYPICAL ANGINA (PROBABLE)</th>
<th>NONCARDIAC CHEST PAIN</th>
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<tbody>
<tr>
<td><strong>1</strong> Substernal chest discomfort with a characteristic quality and duration that is provoked by exertion or emotional stress and relieved by rest or nitroglycerin</td>
<td>Meets 2 of the typical angina characteristics</td>
<td>Meets 1 or none of the typical angina characteristics</td>
</tr>
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Adapted from Fihn SD, et al. J Am Coll Cardiol 2012;60:e44-164.
Assessing Cardiac Testing Options

In many cases, more than one test may be appropriate for the same indication. The choice of which test to use may be influenced by several factors. These include diagnostic and prognostic considerations, results of prior testing, local availability of equipment, expertise in performing and interpreting the test, and patient preference.
Noninvasive cardiac tests are used for 2 distinct purposes: diagnosis and prognostic risk assessment. There are several tests that can help in diagnosing CAD. Once a diagnosis has been made, noninvasive testing may also be used as a prognostic tool to determine the risk for disease-related events, such as MI or death. Risk stratification based on the results of cardiac testing can help guide clinical decision-making toward medical therapy and/or revascularization.1

Although each cardiac test provides distinct and, in some cases, complementary information, performing multiple tests on a single patient is warranted only when test results are equivocal or technically unsatisfactory.1

### Risk vs Benefit

The potential risks of a particular cardiac test should be weighed against the potential benefit of acquiring information regarding disease extent and severity. Noninvasive cardiac testing may be most useful in patients with an intermediate likelihood of CAD.1

The American College of Cardiology Foundation (ACCF) and the American Heart Association (AHA) discourage the use of cardiac assessments as routine screening tests in asymptomatic individuals.1

- Further testing is not warranted in patients with a low likelihood of CAD (<5%) because testing of these patients may lead to a false-positive test result (a positive result in the absence of obstructive CAD)
- For patients with a high likelihood of CAD on the basis of personal history, frontline providers should be aware that a subsequent negative exercise test result would likely be a false negative

When weighing risks vs benefits, it’s important to understand radiation and allergy risks.

Nuclear perfusion imaging and CCTA use ionizing radiation to obtain images of the heart. Although no studies have directly linked this type of low-level radiation exposure to an increased cancer risk, there is general agreement that the overriding principle of “As Low As Reasonably Achievable” (ALARA) should be applied in all cardiac CT and MPI
Clinical Considerations

**SENSITIVITY** is the frequency that a patient with angiographic CAD will have a positive test result.

**SPECIFICITY** is the frequency that a patient without underlying CAD will have a negative test result.

Both measurements are subject to referral bias, which occurs when patients with positive stress testing results are referred for invasive coronary angiography, whereas patients with negative results are not referred. This may increase measured sensitivity and decrease specificity in relation to their true values.

Sensitivity and specificity may vary among the different modalities due to inherent differences between the tests.

The sensitivity and specificity (unadjusted for referral bias) of common noninvasive cardiac imaging modalities are listed in Table 2.

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### Table 2. Sensitivity and Specificity of Noninvasive Cardiac Imaging Modalities\(^1,2\)

<table>
<thead>
<tr>
<th>TEST</th>
<th>SENSITIVITY</th>
<th>SPECIFICITY</th>
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<tr>
<td>Exercise ECG(^b)</td>
<td>61%</td>
<td>70%-77%</td>
</tr>
<tr>
<td>Exercise stress echo</td>
<td>70%-85%</td>
<td>77%-89%</td>
</tr>
<tr>
<td>Exercise stress MPI (SPECT, PET)</td>
<td>82%-88%</td>
<td>70%-88%</td>
</tr>
<tr>
<td>CAC scoring</td>
<td>98%</td>
<td>40%</td>
</tr>
<tr>
<td>CCTA</td>
<td>93%-97%</td>
<td>80%-90%</td>
</tr>
<tr>
<td>Pharmacologic stress CMR perfusion</td>
<td>91%</td>
<td>81%</td>
</tr>
<tr>
<td>CMR angiography</td>
<td>87%-88%</td>
<td>56%-70%</td>
</tr>
</tbody>
</table>

\(^a\)Unadjusted for referral bias.

\(^b\)Accuracy in women is lower. Diagnostic accuracy is improved when non-ECG factors are considered.

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Procedures to reduce radiation exposure as much as possible without compromising image quality.\(^1\)

The contrast agents that are used in CMR and CCTA tests may cause allergic reactions and affect renal function, and should therefore be avoided in patients with CKD.\(^1\)

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2 Diagnostic Accuracy

Diagnostic accuracy is measured in terms of sensitivity and specificity, which are calculated by comparing test results to the results of invasive coronary angiography.\(^1\)

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CAC = coronary artery calcium; CCTA = coronary computed tomography angiography; CMR = cardiovascular magnetic resonance; ECG = electrocardiogram; Echo = echocardiography; PET = positron emission tomography; SPECT MPI = single-photon emission computed tomography myocardial perfusion imaging.
**3 Functional vs Anatomic Testing**

Cardiac imaging modalities can be divided into those that provide anatomic data on coronary stenosis and plaque composition, such as CCTA and CMR angiography, and those that provide functional information about ischemia, such as echo, SPECT MPI, and CMR perfusion. Functional imaging relies on the principles embodied within the ischemic cascade (Figure 3). Functional imaging modalities are able to provide information about the changes that occur in cardiac function during the ischemic cascade. Various types of imaging tests provide different but complementary information. The choice of test depends on the type of information needed to assess the presence and severity of CAD in individual patients. 

**4 Local Expertise and Availability**

Choosing a cardiac test may depend on local expertise and availability. Not all modalities are widely available, and some are more dependent on local expertise to achieve high quality.

**5 Cost-effectiveness**

The cost-effectiveness of a diagnostic test involves not only the cost of the test but also the cost of any further testing, procedures, or treatment that might be required based on the test results. In addition, the potential expenses associated with a misdiagnosis (false-positive test results) or undiagnosed CAD (false-negative test results) must be considered.
As ischemia becomes progressively worse in severity and duration, it produces a cascading sequence of functional changes (abnormalities) in:

- Perfusion
- Relaxation and contraction
- Wall motion
- Repolarization

Figure 3. Ischemic Cascade

Vascular Dysfunction
Decreased Subendocardial Perfusion
Myocardial Metabolism Abnormalities
Diastolic Dysfunction
Decreased Epicardial Perfusion
Wall Motion Abnormalities
Global Systolic Dysfunction
Electrocardiogram Abnormalities
Appropriate Use Criteria (AUC)

AUC are not intended to replace sound clinical judgment and practice experience, but are designed to help support clinical decision-making in the evaluation of advanced cardiac imaging tests.\(^\text{12}\)

The concept of AUC for cardiac imaging was developed by the ACCF, in conjunction with other professional societies, in an effort to improve quality of care and outcomes, and to help ensure proper utilization of healthcare resources.\(^\text{12}\)

Multiple AUC were established for cardiac testing—from the ACCF/AHA,\(^\text{12}\) the American College of Radiology (ACR),\(^\text{13}\) and several other key specialty and subspecialty societies.

The ACCF/AHA Multimodality AUC cover appropriateness ratings for 7 testing modalities, listed below, for the detection of stable IHD and risk assessment across 80 common patient presentations.\(^\text{12}\)

1. Exercise ECG
2. Stress radionuclide imaging (RNI), including SPECT and PET
3. Stress echo
4. Stress CMR imaging
5. CAC scoring
6. CCTA
7. Invasive coronary angiography

Each imaging test is rated by appropriateness for each indication, based on technical capabilities, evidence, and clinical experience (see Figure 4 for appropriateness ratings).\(^\text{12}\)
Figure 4. AUC Ratings for Cardiac Imaging Tests Based on the ACCF/AHA Multimodality AUC¹²

**APPROPRIATE**
- Benefits generally outweigh risks
- Generally an effective option
- Dependent on physician judgment and patient-specific preferences

**MAY BE APPROPRIATE**
- Variable evidence regarding the risk-benefit ratio
- Potentially an effective option
- Dependent on clinical variables, physician judgment, and patient preferences

**RARELY APPROPRIATE**
- Lack of evidence that benefits clearly outweigh risks
- Rarely an effective option
- Exceptions should have documentation of clinical reasons

ACCF = American College of Cardiology Foundation; AHA = American Heart Association; AUC = appropriate use criteria.
Figure 5. The Hierarchy of Indications for Ordering Tests Based on the ACCF/AHA Multimodality AUC\textsuperscript{12,a}

**PREOPERATIVE CARDIAC ASSESSMENT**

- Preoperative assessment? \(\text{YES} \rightarrow \text{Noncardiac surgery indications}

**PRIOR EVALUATION OR KNOWN CAD**

- Prior procedure? \(\text{YES} \rightarrow \text{Cardiac rehab evaluation}

**NO PRIOR EVALUATION OF CAD**

- Symptomatic (ischemic equivalent)? \(\text{YES} \rightarrow \text{Symptomatic indications}


*Refer to the published guidelines for further information on test appropriateness for specific patient indications.

\textbf{ACCF} = American College of Cardiology Foundation; \textbf{AHA} = American Heart Association; \textbf{AUC} = appropriate use criteria; \textbf{CABG} = coronary artery bypass graft; \textbf{CAD} = coronary artery disease; \textbf{CV} = cardiovascular; \textbf{PCI} = percutaneous coronary intervention.
For patients who may have multiple clinical indications, a flowchart that places conditions into a hierarchy can be used to help assess test appropriateness (Figure 5).\textsuperscript{12}

The Protecting Access to Medicare Act of 2014 set forth a mandate for the development or endorsement of AUC by national professional medical societies or other provider-led entities. Adherence to AUC will be required for Medicare reimbursement of advanced diagnostic imaging services (including MPI, CT, and CMR)\textsuperscript{14} in the outpatient setting. For outlier ordering professionals (those with low adherence to AUC), prior authorization will be required for advanced diagnostic imaging services.\textsuperscript{15, b}

\begin{quote}
An appropriate imaging study is one in which the expected incremental information, combined with clinical judgment, exceeds the expected negative consequences\textsuperscript{c} by a sufficiently wide margin for a specific indication that the procedure is generally considered acceptable care and a reasonable approach for the indication.
\end{quote}

From the ACCF/AHA Multimodality Appropriate Use Criteria.\textsuperscript{12}

\textsuperscript{b}Learn more about the Centers for Medicare & Medicaid Services (CMS) federal mandate at CardiacTesting.com

\textsuperscript{c}Negative consequences of cardiovascular imaging include the risks of the procedure (ie, radiation or contrast exposure) and the downstream impact of poor test performance, such as delay in diagnosis (false negatives) or inappropriate diagnosis (false positives).
EXERCISE ECG

The Standard Stress Test

Exercise ECG has served as the cornerstone of cardiovascular testing for several decades.¹

It can be performed in the outpatient office setting, and is a relatively low-cost and accessible test.¹⁶,¹⁷
What Does Exercise ECG Reveal?

In both men and women with known or suspected CAD, exercise capacity is one of the strongest indicators of long-term risk. Exercise ECG not only provides information about exercise-induced chest pain but also measures exercise capacity, hemodynamic response to exercise, and the presence of cardiovascular abnormalities, all of which can be used to predict the risk for a cardiac event.1,16

The goal of exercise testing is to either exclude the presence of obstructive CAD, or predict the likelihood of obstructive CAD based on the extent and severity of ECG changes and angina during exercise-induced ischemia.1

Patients capable of performing at least moderate physical functioning (eg, moderate household, yard, or recreational work, and most activities of daily living) and who have no disabling comorbidity (including frailty, advanced age, marked obesity, PAD, chronic obstructive pulmonary disease, or orthopedic limitations) are optimal candidates for exercise testing. However, the ability to detect ischemia may be suboptimal in patients who cannot achieve at least moderate physical function.1

Patients incapable of at least moderate levels of physical exercise or who have comorbidities that limit their mobility should be considered for pharmacologic stress testing.1

Exercise ECG for Diagnosis, Prognosis, and Risk Stratification

To utilize an exercise ECG test for diagnosis and CAD risk assessment, patients must be able to exercise and have an interpretable resting ECG. Abnormalities on the resting ECG, such as resting ST-segment abnormalities related to LV hypertrophy,
LBBB, or ventricular-paced rhythm, will interfere with the interpretation of any exercise-induced ECG changes. It may also be difficult to interpret ST-segment changes in patients with right bundle-branch block (RBBB) and in patients taking certain medications, such as digitalis. The effect of anti-ischemic therapies on heart rate and myocardial workload can lead to false-negative exercise ECG results.1

Beyond ECG changes, the following factors measured during the exercise test may be helpful in CAD diagnosis1:

- Exercise duration
- Chronotropic incompetence
- Chest pain
- Ventricular arrhythmias
- Heart rate recovery
- Hemodynamic changes

Several scoring systems have also been developed that combine multiple endpoints to improve the diagnostic accuracy of exercise ECG, such as the Duke Treadmill Score and the Lauer score.1 Calculating the Duke Treadmill Score (Figure 6) can help evaluate patient cardiovascular risk.18

It should be noted that for ECG, the diagnostic accuracy of exertional ST-segment changes is lower in women than in men, although marked ST-segment changes (≥1 mm of horizontal or downsloping ST-segment depression or elevation for ≥60 to 80 ms after the end of the QRS complex) are diagnostic for all patients.1
SPECT MPI

The Most Widely Used Nuclear Imaging Modality

For more than 40 years, noninvasive RNI has been used to evaluate myocardial perfusion.¹⁹

As the most commonly used imaging modality in nuclear cardiology, SPECT MPI plays an essential role in the risk assessment and evaluation of CAD.¹⁹,²⁰
These scans show the heart at stress and rest. Color indicates areas of perfusion where the radiotracer has entered the myocardium. Areas that appear lighter in color at rest and darker during stress indicate stress-induced ischemia, where blood flow is blocked. The reversibility bull’s-eye scan shows the extent that an abnormality is reversible on rest imaging.\cite{19,21}

**A Modality by Many Names**

You may have heard SPECT MPI—single-photon emission computed tomography myocardial perfusion imaging—referred to as one of the following terms:

- Nuclear stress test
- Noninvasive cardiac imaging
- Cardiac nuclear scan
- Radionuclide imaging (RNI)

**What Does SPECT Reveal?**

SPECT scans are taken using a gamma camera, which captures images of photons emitted by radiotracers as they are taken up by viable myocytes. Imaging can be done at stress and at rest.\cite{19,21}

The standard MPI procedure uses ECG data as the heart beats to guide image acquisition (also known as ECG-gated SPECT).\cite{19}

The radiotracers used in SPECT include technetium-99m (Tc-99m) and thallium-201 (Tl-201).\cite{22}

A series of images (sections of the heart) show radiotracer distribution throughout the myocardium. The images are then reassembled by the computer to produce a 3D image of the heart, providing information about the extent, severity, and location of perfusion defects.\cite{19}
Image quality and diagnostic accuracy of SPECT MPI may be affected by attenuation artifacts, which can be seen in obese patients or those with a large amount of breast tissue. However, these attenuation artifacts may be reduced with the following techniques:

- Using Tc-99m radiotracers
- Imaging patients in the prone position
- Applying attenuation correction algorithms in image-processing software

**SPECT for Diagnosis, Prognosis, and Risk Stratification**

SPECT MPI scans show vital clinical information about a patient’s heart health (Figure 7) and can help detect perfusion defects. Perfusion defects may be reversible, with perfusion abnormalities at stress and normal perfusion at rest, or irreversible, with perfusion defects visible on both stress and rest images, indicating greater risk for MI.\(^1\)

Multiple perfusion defects in different coronary territories may indicate severe CAD. Of note, SPECT images may underestimate ischemia in patients with left-main or 3-vessel CAD who may have global, balanced reduction in myocardial blood flow rather than regional hypoperfusion.\(^1\)

The extent and severity of stress-induced perfusion abnormalities are directly correlated with the degree of risk for ischemic events, namely, cardiovascular death and MI (Figure 8).\(^1\)

- Normal test results are associated with a very low annual risk for cardiovascular death or MI (<1%)
- Moderate to severe abnormalities are associated with an annual risk for cardiovascular death or MI of ≥5%

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**Focus on SPECT MPI**

- The most commonly used imaging modality in nuclear cardiology\(^19\)
- As a functional imaging test, SPECT can help detect perfusion defects\(^1\)\(^2\)\(^1\)
- Can be used with exercise or pharmacologic stress\(^1\)\(^2\)\(^1\)
OTHER NONINVASIVE OPTIONS

Taking a Closer Look at Available Tests

Several other noninvasive cardiac imaging tests are available to help evaluate and assess risk in patients with known or suspected CAD.

Each test has benefits and limitations that should be considered before selecting a procedure for a specific patient scenario.
Other Noninvasive Options
Positron Emission Tomography Myocardial Perfusion Imaging (PET MPI)

Similar to SPECT, PET MPI can be used for the evaluation and risk stratification of CAD, and it can help in making decisions for medical therapy or revascularization. PET has a high diagnostic sensitivity and specificity, with high spatial resolution and attenuation correction. It also has the potential to quantify regional perfusion.19,23

PET can calculate coronary flow reserve, which can provide useful information to estimate the risk for future events. PET can also be used to measure the viability of myocardial tissue, helping to distinguish between scar and tissue that is “stunned” but still viable (Figure 9).19

Figure 9. PET MPI Scans

Sections of the myocardium are imaged in 3 axes to view perfusion defects at different orientations.19

- SHORT AXIS
- VERTICAL LONG AXIS
- HORIZONTAL LONG AXIS
Despite its expanded applications, PET requires an onsite cyclotron or monthly generator replacement for the radiotracers used in imaging. The high cost of PET equipment and imaging may continue to limit its more widespread use. Furthermore, the short half-lives of PET radiotracers limit stress procedures to pharmacologic stress tests only.\textsuperscript{19}

Focus on PET MPI

- High sensitivity and specificity for the diagnosis of CAD\textsuperscript{19}
- Can be used to detect perfusion defects\textsuperscript{19}
- Limited use with pharmacologic stress\textsuperscript{19}
- Able to quantify coronary blood flow\textsuperscript{20}

Stress images demonstrate an extensive moderate perfusion defect involving the inferior wall and inferolateral wall. Rest images demonstrate normal perfusion throughout the myocardium.

\textbf{PET MPI} = positron emission tomography myocardial perfusion imaging.
Echocardiography (Echo)

Echo images are taken at rest and after either exercise or pharmacologic stress, using reflected ultrasound beams to visualize cardiac anatomic features in real time. Intravenous contrast agents may be used to enhance image quality.24

Baseline ECG performed during stress echo includes an assessment of ventricular function, chamber size, wall motion thickness, aortic root, and valve function.25

Diagnosis of CAD with stress echo is based on the presence of new or worsening wall motion abnormalities and LV function during or immediately after stress. Stress echo results can also be compared with resting echo results to assess changes in ventricular function that may be caused by demand ischemia.1

Echo may be performed with intravenous contrast agents that help define the endocardial border and improve diagnostic accuracy—a technique that may be particularly helpful when imaging obese patients or those with chronic lung disease.1

A normal exercise echo result is associated with a very low risk for MI or cardiovascular death (see Figure 10 for a normal rest/stress echo result).1

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Figure 10. Echo Images

Normal echo, with rest images on the left and stress images on the right.
The extent and severity of exercise-induced wall motion abnormalities are directly correlated with disease risk. Patients with stress echo results showing wall motion abnormalities in multiple LV segments or in more than 1 coronary territory and evidence of transient ischemic dilation have a high likelihood of severe CAD.\(^1\)

Resting 2-dimensional echo (Figure 11) is recommended for the assessment of LV function and abnormalities of the myocardium, heart valves, or pericardium, specifically in patients with known or suspected CAD and a prior MI, pathological Q waves, symptoms or signs suggestive of heart failure, complex ventricular arrhythmias, or an undiagnosed heart murmur.\(^1\)

Three-dimensional echo provides 3D images of the heart, which can improve assessment of cardiac size and function.\(^1,26\)

**Focus on Echo\(^{24}\)**

- Rapid assessment provides immediate data on cardiac structure and function
- Relatively low cost and widely available
- No ionizing radiation involved

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**Figure 11. Resting 2D Echo Images**

Resting echo is useful for assessing cardiac structure and function, including identifying the mechanism of heart failure and differentiating systolic LV from diastolic dysfunction.

*Echo = echocardiography; LV = left ventricular.*

Images courtesy of HC Lewin, MD.
**Cardiovascular Magnetic Resonance (CMR) Imaging**

CMR imaging allows physicians to evaluate CAD in a number of ways. It can assess cardiac structure and function, valvular and great vessel flow hemodynamics, and 3D angiography.27

With pharmacologic stress, CMR imaging can be used to study wall motion abnormalities and LV function. No ionizing radiation exposure is involved.1,27

MPI can be used with a contrast agent (eg, gadolinium) to differentiate between the reversible ischemia that is characteristic of CAD and areas of scar tissue that are associated with acute MI (Figure 12).1,27

CMR angiography can be used to assess the extent and severity of obstructive CAD (Figure 13).1

Due to the generation of strong magnetic fields in CMR, it is not recommended for certain patients with cochlear implants.

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**Figure 12. CMR Perfusion Images**

CMR images of perfusion defects in the anterior and anteroseptal walls.
metal-containing ocular implants, pacing wires, pacemakers, or other implants that could be hazardous. Image acquisition can also be challenging in the context of cardiac arrhythmias and because of the need for extended breath holding.27

CMR testing is limited by the number of centers experienced in CMR protocols, differences in the imaging techniques and equipment, and changing interpretative standards.1

**Focus on CMR**27

- No iodine-containing dyes are used
- No ionizing radiation involved
- Can be used with pharmacologic stress

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**Figure 13. CMR Angiography Images**

CMR angiography images of a patient with a suspected coronary artery anomaly—images are of excellent image quality, demonstrating normal coronary arteries.

*CMR = cardiovascular magnetic resonance.*
Coronary Computed Tomography Angiography (CCTA)

Multisection CCTA produces high-resolution images of the coronary anatomy and identifies areas of obstructive CAD (Figure 14). Noninvasive CCTA and invasive angiography are both anatomic tests and show a high degree of correlation. CCTA is more sensitive than nuclear MPI in detecting obstructive CAD at $\leq 70\%$ stenosis, when perfusion defects may not yet be evident. In addition to stenotic lesions, CCTA can visualize arterial remodeling and nonobstructive plaque, including calcified, noncalcified, or mixed plaque.\textsuperscript{1}

CCTA has a high negative predictive value (specificity) to rule out obstructive CAD.\textsuperscript{28} However, several studies have demonstrated that there is a poor correlation between the presence of obstructive CAD on anatomic imaging with CCTA and evidence of myocardial ischemia on functional imaging with nuclear MPI or echo. Ischemia can occur as a consequence of stenoses in smaller epicardial vessels that are not

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**Figure 14. CCTA Images**

CCTA image of a normal right coronary artery.
as easily detected by CCTA, and some obstructive lesions may not lead to myocardial ischemia.¹

False-positive results may occur when calcification of coronary artery plaques (part of the atherosclerotic process) interferes with accurate CCTA imaging of lesion severity. Patients who have extensive calcification or who are considered to be at high risk for CAD based on clinical assessment or previous test results may not be appropriate candidates for CCTA.¹

Focus on CCTA

- High-resolution images of coronary anatomy¹
- High specificity to rule out CAD in low-risk patients¹
- Can show stenotic lesions, arterial remodeling, and plaque¹,²⁸

CCTA image of the left coronary system with a >50% stenosis (blockage) of the left anterior coronary artery (arrow).

CCTA = coronary computed tomography angiography.
Coronary Artery Calcium (CAC) Scoring

CT scans can also be used to measure calcium levels in coronary arteries (Figure 15), producing a CAC score. This score has been shown to have prognostic value in assessing CAD risk in asymptomatic patients, and in predicting the presence of coronary stenosis in symptomatic patients (on coronary angiography).¹

The CAC score has high diagnostic sensitivity to detect obstructive CAD, but it is not clear how well the CAC score correlates to functional measures of CAD, ie, myocardial perfusion abnormalities in symptomatic patients.¹

Patients with a CAC score of zero may still have perfusion defects on nuclear MPI. Obstructive CAD may be present in younger patients despite lower CAC scores, because calcification of atherosclerotic plaques occurs later in the disease progression.¹

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Focus on CAC Scoring¹

- Measures calcium levels in coronary arteries
- High sensitivity but low specificity for detecting CAD

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Figure 15. CT Scan for CAC Scoring

This CT scan obtained for CAC scoring shows calcification of the left anterior descending coronary artery.

Image courtesy of HC Lewin, MD.
**Hybrid Imaging**

Combination or “hybrid” cardiac imaging protocols use complementary datasets from anatomic and functional tests to provide comprehensive information about the heart.¹

PET or SPECT MPI combined with CT scanning allows concurrent assessment of arterial remodeling, plaque composition, extent and severity of coronary stenoses, and functional consequences during a single imaging session. The combined dataset can provide comprehensive information about both functional and anatomic endpoints. This information may improve diagnostic accuracy and assessment of patient risk to better inform clinical decisions.¹

Cardiac CT scanning has also been used to improve attenuation correction of SPECT MPI images (Figure 16).¹⁹ Although less common, hybrid imaging protocols that combine MPI and CMR are also being explored. Despite the potential benefits, hybrid imaging may increase the radiation dose patients are exposed to, as it involves more than 1 test procedure.¹

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**Focus on Hybrid Imaging**¹⁹

- Functional and anatomic information can be gathered in a single imaging session
- Combined dataset may improve diagnostic accuracy and attenuation correction

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**Figure 16. Hybrid Imaging**

Stress images display CT-based attenuation-corrected stress imaging, and show homogenous and normal tracer uptake in the entire inferior wall. Rest images at the bottom show a persistent and fixed severe perfusion defect in the basal inferior wall.

CAC = coronary artery calcium; CT = computed tomography.

Images courtesy of WA Jaber, MD.
CARE COORDINATION

Working Together for Patient-Centered Care

Patients with heart disease are often managed by multiple providers and for a range of medical conditions beyond CVD.

For patients with known or suspected CAD, provider communication and coordination are essential to achieving appropriate patient-centered care. Diagnostic and therapeutic options should be chosen through a process of shared decision-making involving the providers and the patients.
Provider Communication

Communication between the referring or ordering provider and cardiac imaging specialist can help inform decisions regarding patient management and is essential for providing coordinated care.

Timely transfer of clinical information from the referring or ordering provider to the cardiac specialist may help improve quality of care. It is also important for the cardiac specialist to relay test information back for continuity of quality care.29

Figure 17 highlights the importance of communication between referring or ordering providers and specialists in the nuclear laboratory. For each patient scenario, ongoing communication is necessary in order to coordinate appropriate patient-centered care.
**CAD** = coronary artery disease; **ED** = emergency department; **MI** = myocardial infarction; **UA** = unstable angina.

### Figure 17. Delivering Patient-Centered Care

#### Patients

- **Unstable** (eg, UA, MI, known or suspected CAD)
- **Stable symptomatic** (eg, known or suspected CAD)
- **Stable asymptomatic** (eg, follow-up previous MI, revascularization)
- **Stable inpatient** (eg, preoperative evaluation)

#### Referring or Ordering Providers

- ED physician
- ED physician
  - Internist
  - Cardiologist
- Internist
  - Cardiologist
  - Other referring/ordering provider
- Hospitalist
  - Cardiologist
  - Surgeon
  - Other referring/ordering provider
- Internist
- Cardiologist
- Other referring/ordering provider
- ED physician
- Internist
- Cardiologist
- Other referring/ordering provider

#### Coordinated Care Requires Ongoing Communication

- Cardiologist
- Nuclear Cardiologist
- Radiologist
- Imaging Specialist

#### Appropriate Patient-Centered Care

- Cardiac catheterization, revascularization
- Risk factor modification/medication
- Normal results, no treatment

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**Definitions:**

- **CAD** = coronary artery disease
- **ED** = emergency department
- **MI** = myocardial infarction
- **UA** = unstable angina
Cardiac Testing
Communication Tips for Frontline Providers

• **Reach out** to the cardiac imaging specialist or cardiologist with any questions or concerns you may have about your patients—a quick phone call may save time in the long run.

• **Coordinate** with the specialist to ensure your patients have the information they need for their cardiac imaging experience.

• **Ask** any questions you may have about the test results to help your patients understand the next steps.

Preparing Your Patients for Cardiac Testing

A comprehensive dialogue with your patients will help them understand and properly prepare for the test.

1. Explain why the test is being performed and how the test results may be used to make decisions about patient care.¹

2. Discuss test options with patients, covering risks and benefits. For an appropriate test, benefits will typically outweigh risks.¹²

3. Help your patients understand the test preparation requirements to avoid potential rescheduling.

4. Identify medications that your patients may need to abstain from that could interfere with the scheduled procedure.²²

5. Clarify fasting requirements—patients may need to fast and avoid caffeine prior to a pharmacologic stress test.²²

6. Check that your patients know the location of the testing facility, how to prepare for the test, and what they can expect on the day of the test.

7. Encourage your patients to contact the testing facility with any specific questions.

Patient Education

Informed patients are more likely to be prepared for their cardiac imaging tests. Research has shown that patients who are informed about the benefits and risks of specific tests and procedures are more likely to postpone or decline invasive procedures.¹

Patients seek health information from a variety of sources, but education from a frontline provider may be most helpful. Sharing information in terms the patient understands may lead to a higher quality of patient care.

Conclusion

Continuing advances in cardiac imaging have transformed the practice of cardiology, providing clinicians with powerful tools that have enhanced the diagnostic process and allowed physicians to make more informed treatment decisions.³³

With the growing population of older adults in the United States, it is increasingly important to understand diagnostic and therapeutic strategies for CAD. Familiarity with noninvasive cardiac testing options may help inform clinical decision-making to coordinate appropriate care across settings.¹²
RESOURCES

Learn More About Cardiac Testing

For more than 20 years, Astellas has offered practical resources to help providers make decisions focused on patient-centered care. Our educational materials are designed to increase understanding of cardiac testing and encourage communication between providers—all to help each patient get the right cardiac test at the right time.

The Cardiac Testing Educational Series is intended to be a starting point for further reading.

For the latest information in cardiovascular care, go to CardiacTesting.com

- Access online resources
- Download educational materials for your patients and practice
- Use an interactive ASCVD risk score calculator
- Register for a cardiac testing speaker event
Shared Understanding of Cardiovascular Care

Astellas is committed to bringing you the latest information on cardiac testing, so your entire care team can be better equipped to help what matters most—the patient.

Go to CardiacTesting.com to learn more about cardiovascular risk assessment and diagnosis.