Clinical Appropriateness Guidelines: Advanced Imaging

Appropriate Use Criteria: Imaging of the Heart

Effective Date: January 1, 2018

Proprietary

Date of Origin: 03/30/2005
Last revised: 11/14/2017
Last reviewed: 11/14/2017

8600 W Bryn Mawr Avenue
South Tower - Suite 800
Chicago, IL 60631
P. 773.864.4600
www.aimspecialtyhealth.com

Table of Contents

Description and Application of the Guidelines

AIM's Clinical Appropriateness Guidelines (hereinafter "AIM's Clinical Appropriateness Guidelines" or the "Guidelines") are designed to assist providers in making the most appropriate treatment decision for a specific clinical condition for an individual. As used by AIM, the Guidelines establish objective and evidence-based, where possible, criteria for medical necessity determinations. In the process, multiple functions are accomplished:

- To establish criteria for when services are medically necessary
- To assist the practitioner as an educational tool
- To encourage standardization of medical practice patterns
- To curtail the performance of inappropriate and/or duplicate services
- To advocate for patient safety concerns
- To enhance the quality of healthcare
- To promote the most efficient and cost-effective use of services

AIM's guideline development process complies with applicable accreditation standards, including the requirement that the Guidelines be developed with involvement from appropriate providers with current clinical expertise relevant to the Guidelines under review and be based on the most up to date clinical principles and best practices. Relevant citations are included in the "References" section attached to each Guideline. AIM reviews all of its Guidelines at least annually.

AIM makes its Guidelines publicly available on its website twenty-four hours a day, seven days a week. Copies of AIM's Clinical Appropriateness Guidelines are also available upon oral or written request. Although the Guidelines are publicly-available, AIM considers the Guidelines to be important, proprietary information of AIM, which cannot be sold, assigned, leased, licensed, reproduced or distributed without the written consent of AIM.

AIM applies objective and evidence-based criteria and takes individual circumstances and the local delivery system into account when determining the medical appropriateness of health care services. The AIM Guidelines are just guidelines for the provision of specialty health services. These criteria are designed to guide both providers and reviewers to the most appropriate services based on a patient's unique circumstances. In all cases, clinical judgment consistent with the standards of good medical practice should be used when applying the Guidelines. Guideline determinations are made based on the information provided at the time of the request. It is expected that medical necessity decisions may change as new information is provided or based on unique aspects of the patient's condition. The treating clinician has final authority and responsibility for treatment decisions regarding the care of the patient and for justifying and demonstrating the existence of medical necessity for the requested service. The Guidelines are not a substitute for the experience and judgment of a physician or other health care professionals. Any clinician seeking to apply or consult the Guidelines is expected to use independent medical judgment in the context of individual clinical circumstances to determine any patient's care or treatment.

The Guidelines do not address coverage, benefit or other plan specific issues. If requested by a health plan, AIM will review requests based on health plan medical policy/guidelines in lieu of AIM's Guidelines.

The Guidelines may also be used by the health plan or by AIM for purposes of provider education, or to review the medical necessity of services by any provider who has been notified of the need for medical necessity review, due to billing practices or claims that are not consistent with other providers in terms of frequency or some other manner.

Administrative Guideline: Ordering of Multiple Studies

Requests for multiple imaging studies to evaluate a suspected or identified condition and requests for repeated imaging of the same anatomic area are subject to additional review to avoid unnecessary or inappropriate imaging.

Simultaneous Ordering of Multiple Studies

In many situations, ordering multiple imaging studies at the same time is not clinically appropriate because:

- Current literature and/or standards of medical practice support that one of the requested imaging studies is more appropriate in the clinical situation presented; or
- One of the imaging studies requested is more likely to improve patient outcomes based on current literature and/or standards of medical practice; or
- Appropriateness of additional imaging is dependent on the results of the lead study.

When multiple imaging studies are ordered, the request will often require a peer-to-peer conversation to understand the individual circumstances that support the medically necessity of performing all imaging studies simultaneously.

Examples of multiple imaging studies that may require a peer-to-peer conversation include:

- CT brain and CT sinus for headache
- MRI brain and MRA brain for headache
- MRI cervical spine and MRI shoulder for pain indications
- MRI lumbar spine and MRI hip for pain indications
- MRI or CT of multiple spine levels for pain or radicular indications
- MRI foot and MRI ankle for pain indications
- Bilateral exams, particularly comparison studies

There are certain clinical scenarios where simultaneous ordering of multiple imaging studies is consistent with current literature and/or standards of medical practice. These include:

- Oncologic imaging – Considerations include the type of malignancy and the point along the care continuum at which imaging is requested
- Conditions which span multiple anatomic regions – Examples include certain gastrointestinal indications or congenital spinal anomalies

Repeated Imaging

In general, repeated imaging of the same anatomic area should be limited to evaluation following an intervention, or when there is a change in clinical status such that imaging is required to determine next steps in management. At times, repeated imaging done with different techniques or contrast regimens may be necessary to clarify a finding seen on the original study.

Repeated imaging of the same anatomic area (with same or similar technology) may be subject to additional review in the following scenarios:

- Repeated imaging at the same facility due to motion artifact or other technical issues
- Repeated imaging requested at a different facility due to provider preference or quality concerns
- Repeated imaging of the same anatomic area (MRI or CT) based on persistent symptoms with no clinical change, treatment, or intervention since the previous study
- Repeated imaging of the same anatomical area by different providers for the same member over a short period of time

Administrative Guideline: Pre-Test Requirements

Critical to any finding of clinical appropriateness under the guidelines for specific imaging exams is a determination that the following are true with respect to the imaging request:

- A clinical evaluation has been performed prior to the imaging request (which should include a complete history and physical exam and review of results from relevant laboratory studies, prior imaging and supplementary testing) to identify suspected or established diseases or conditions.
- **For suspected diseases or conditions:**
  - Based on the clinical evaluation, there is a reasonable likelihood of disease prior to imaging; and
  - Current literature and standards of medical practice support that the requested imaging study is the most appropriate method of narrowing the differential diagnosis generated through the clinical evaluation and can be reasonably expected to lead to a change in management of the patient; and
  - The imaging requested is reasonably expected to improve patient outcomes based on current literature and standards of medical practice.
- **For established diseases or conditions:**
  - Advanced imaging is needed to determine whether the extent or nature of the disease or condition has changed; and
  - Current literature and standards of medical practice support that the requested imaging study is the most appropriate method of determining this and can be reasonably expected to lead to a change in management of the patient; and
  - The imaging requested is reasonably expected to improve patient outcomes based on current literature and standards of medical practice.
- If these elements are not established with respect to a given request, the determination of appropriateness will most likely require a peer-to-peer conversation to understand the individual and unique facts that would supersede the pre-test requirements set forth above. During the peer-to-peer conversation, factors such as patient acuity and setting of service may also be taken into account.

Nuclear Cardiology
Myocardial Perfusion Imaging

CPT Codes

78451..... Myocardial perfusion imaging, tomographic (SPECT) (including attenuation correction, qualitative or quantitative wall motion, ejection fraction by first pass or gated technique, additional quantification, when performed); single study, at rest or stress (exercise or pharmacologic)

78452..... Myocardial perfusion imaging, tomographic (SPECT) (including attenuation correction, qualitative or quantitative wall motion, ejection fraction by first pass or gated technique, additional quantification, when performed); multiple studies, at rest and/or stress (exercise or pharmacologic) and/or redistribution and/or rest reinjection

78453..... Myocardial perfusion imaging, planar (including qualitative or quantitative wall motion, ejection fraction by first pass or gated technique, additional quantification, when performed); single study, at rest or stress (exercise or pharmacologic)

78454..... Myocardial perfusion imaging, planar (including qualitative or quantitative wall motion, ejection fraction by first pass or gated technique, additional quantification, when performed); multiple studies, at rest and/or stress (exercise or pharmacologic) and/or redistribution and/or rest reinjection

Commonly Used Radiopharmaceuticals

- Thallium-201 Chloride
- Technetium-99m Sestamibi
- Technetium-99m Tetrofosmin

Uses of Myocardial Perfusion Imaging (MPI)

- The primary use of MPI is in the diagnosis, exclusion or evaluation of obstructive coronary artery disease (CAD).
- MPI is also used for management of established coronary artery disease.
- MPI may be used for assessment of myocardial viability in patients who have had myocardial infarction.

Imaging Considerations

- A recent EKG is strongly recommended, preferably within 30 days of request for a Myocardial Perfusion Imaging exam. The findings on the resting EKG may be important in determining the need for imaging, the selection of the appropriate imaging protocol and may also show evidence of ischemia at rest or interval myocardial infarction.
- Age, gender and the character of the chest pain provide useful predictors of CAD, as stratified in Table 1 below.

Table 1*: Pre-Test Probability of Coronary Artery Disease by Age, Gender and Symptoms

Very Low < 5% Low Probability < 10%	Intermediate probability 10-90% High Probability > 90%

*Reference for Table 1: Gibbons RJ, Balady GJ, Beasley JW, et al. ACC/AHA Guidelines for Exercise Testing: Executive Summary. Circulation. 1997;96:345-354.

Age (yr)	Gender	Typical/Definite Angina Pectoris	Atypical/Probable Angina Pectoris	Non-Anginal Chest Pain	Asymptomatic
30-39	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
60-69	Men	High	Intermediate	Intermediate	Low
	Women	High	Intermediate	Intermediate	Low

Imaging Considerations

Myocardial Perfusion Imaging and Stress Echocardiography may provide useful information on Coronary Heart Disease. Comparison data on Sensitivity and Specificity are provided in Table 2 below. Due to regional variation in technical expertise and interpretive proficiency, the clinician should use the diagnostic imaging modality that has been proven most accurate in his/her practices.

Table 2**: Comparison of Non-Invasive Diagnostic Imaging

** Reference for Table 2: Zaret BL, Bellar GA. *Clinical Nuclear Cardiology*. 3rd Edition. Philadelphia: Elsevier Mosby Publishers; 2005, page 539

	Nuclear Imaging Sensitivity (%)	Stress Echo Sensitivity (%)	Nuclear Imaging Specificity (%)	Stress Echo Specificity (%)
Exercise (7 studies)	83%	78%	83%	91%
Dobutamine (8 studies)	86%	80%	73%	86%
Adenosine (3 studies)	89%	63%	73%	86%
Dipyridamole (4 studies)	83%	68%	88%	89%

Several clinical indications listed for Myocardial Perfusion Imaging include standard methods of risk assessment, such as the SCORE (Systematic Coronary Risk Evaluation) or the Framingham risk score calculation. These risk calculation systems include consideration of the following factors:

Age	Sex
Abnormal Lipid Profile	Hypertension
Diabetes Mellitus (always = high risk)	Cigarette Smoking

Other coronary risk factors such as family history of premature CAD, coronary artery calcification, C reactive protein levels, obesity, etc., are not included in the standard methods of risk assessment but are thought to contribute to CAD risk.

- Selection of the optimal diagnostic work-up for evaluation or exclusion of coronary artery disease should be made within the context of available studies (which include treadmill stress test, stress myocardial perfusion imaging, stress echocardiography, cardiac PET imaging and invasive cardiac/coronary angiography), so that the resulting information facilitates patient management decisions and does not merely add a new layer of testing.
- Occasionally, it may be appropriate to do a second non-invasive test for diagnosis or exclusion of CAD when the initially selected test is technically suboptimal and the diagnosis of CAD cannot be established or excluded.
- In order to optimize image quality, imaging protocols may need to be modified in specific patient populations. Thus, patients who are obese may benefit from 2 day imaging protocols and/or prolonged image acquisition times. Similarly, imaging in the prone position may improve accuracy in patients who are obese and women with high likelihood of breast attenuation artifact. Patients whose baseline EKG demonstrates left bundle branch block, may be better suited to pharmacologic stress imaging than to exercise stress protocols.
- Rarely, absolute or relative contraindications to MPI will be encountered. MPI should not be used in pregnant or lactating women. Patients who are unable to remain motionless for several minutes or comprehend simple instructions are not suitable candidates for MPI. Image quality in morbidly obese patients (BMI >40) is usually suboptimal such that consideration should be given to other imaging modalities. If imaging studies using other radioactive tracers have been recently performed, adequate time must elapse to allow for clearance of activity from the heart and surrounding regions.
- For patients who are unable to walk on a treadmill for non-cardiac reasons (orthopedic limitations, claudication, neurological conditions, advanced lung disease, etc.), exercise stress testing is not an option. These patients will require pharmacological testing with echo or nuclear imaging.
- It is anticipated that the evaluation of patients with acute chest pain will occur in the emergency room or in an inpatient setting and MPI performed in these locations is not included in the AIM preauthorization program.

Common Diagnostic Indications

Suspected coronary artery disease in asymptomatic patients

- Patients with high-risk of CAD (SCORE) who have not had evaluation of coronary artery disease (MPI, stress echo, cardiac PET, coronary CTA or cardiac catheterization) within the preceding three (3) years; **OR**
- Patients with moderate or high risk of CAD (SCORE) who have a high risk occupation that would endanger others in the event of a myocardial infarction, for example: airline pilot, law-enforcement officer, firefighter, mass transit operator, bus driver) who have not had evaluation of coronary artery disease (MPI, stress echo, cardiac PET, coronary CTA or cardiac catheterization) within the preceding three (3) years; **OR**
- Patients with diseases/conditions with which coronary artery disease commonly coexist and who have not had evaluation of coronary artery disease (MPI, stress echo, cardiac PET, coronary CTA or cardiac catheterization) within the preceding three (3) years:
  - Diabetes mellitus; **OR**
  - Abdominal aortic aneurysm; **OR**
  - Established and symptomatic peripheral vascular disease; **OR**
  - Prior history of cerebrovascular accident (CVA), transient ischemic attack (TIA) or carotid endarterectomy (CEA) or high grade carotid stenosis (>70%); **OR**
  - Chronic renal insufficiency or renal failure; **OR**
- Patients who have undergone cardiac transplantation and have had no evaluation for coronary artery disease within the preceding one (1) year; **OR**
- Patients in whom a decision has been made to treat with interleukin 2
- Patients awaiting solid organ transplantation who have not undergone evaluation for coronary artery disease within the preceding one (1) year

Suspected coronary artery disease in symptomatic patients who have not had evaluation of coronary artery disease (MPI, stress echo, cardiac PET, coronary CTA or cardiac catheterization) within the preceding sixty (60) days

- Chest pain
  - With intermediate or high pretest probability of CAD (Table 1); **OR**
  - With low or very low pretest probability of CAD (Table 1) and high risk of CAD (SCORE)
- Atypical symptoms: syncope, shortness of breath (dyspnea), neck, jaw, arm, epigastric or back pain, or sweating (diaphoresis)
  - With moderate or high risk of CAD (SCORE)
- Other symptoms; palpitation, dizziness, lightheadedness, near syncope, nausea, vomiting, anxiety, weakness, fatigue, etc.
  - With high risk of CAD (SCORE)
- Patients with any cardiac symptom who have diseases/conditions with which coronary artery disease commonly coexists such as:
  - Diabetes mellitus; **OR**
  - Abdominal aortic aneurysm; **OR**
  - Established and symptomatic peripheral vascular disease; **OR**
  - Prior history of cerebrovascular accident (CVA), transient ischemic attack (TIA) or carotid endarterectomy (CEA) or high grade carotid stenosis (>70%); **OR**
  - Chronic renal insufficiency or renal failure; **OR**
- Patients who have undergone cardiac transplantation; **OR**
- Patients in whom a decision has been made to treat with Interleukin 2; **OR**
- Patients awaiting solid organ transplantation

Established coronary artery disease in asymptomatic patients

- Patients awaiting solid organ transplantation who have not undergone evaluation for coronary artery disease within the preceding one (1) year

Common Diagnostic Indications

Established coronary artery disease (diagnosed by previous cardiac catheterization, MPI, cardiac PET, or stress echo) in patients who have new or worsening symptoms

Note: *If symptoms are typical of myocardial ischemia cardiac catheterization may be more appropriate than MPI*

Established coronary artery disease (diagnosed by previous cardiac catheterization, MPI, cardiac PET, or stress echo) in patients who have not undergone revascularization and have no symptoms or stable symptoms

- No evaluation of CAD (MPI, stress echo, cardiac PET, coronary CTA or cardiac catheterization) within the preceding three (3) years
- No evaluation of CAD (MPI, cardiac PET, stress echo, coronary CTA or cardiac catheterization) within the preceding one (1) year in a patient who has undergone cardiac transplantation and has been found to have CAD since transplantation

Established coronary artery disease in patients who have undergone revascularization

- For evaluation of new or worsening cardiac symptoms
  - If symptoms are typical of myocardial ischemia cardiac catheterization may be more appropriate than MPI; **OR**
- For evaluation of stable patients who have undergone coronary artery bypass grafting more than five (5) years previously and who have not had an evaluation for coronary artery disease (MPI, stress echo, cardiac PET, coronary CTA or cardiac catheterization) within the past two (2) years
  - Stable patients whose revascularization has been incomplete may undergo MPI three (3) years following the procedure and every three (3) years thereafter; **OR**
- For evaluation of stable patients who have undergone percutaneous coronary intervention(PCI) more than three (3) years previously and who have not had an evaluation for coronary artery disease (MPI, stress echo, cardiac PET, coronary CTA or cardiac catheterization) within the past three (3) years when **any of the following** applies
  - The patient has undergone PCI of the left main (LM) coronary artery or the proximal left anterior descending (LAD) coronary artery
  - The patient has undergone PCI of more than one coronary artery
  - The patient has chronic total occlusion of a coronary artery and the vessel on which PCI was performed is supplying collateral flow to the occluded vessel
  - The patient is known to have only one patent coronary artery.
  - Left ventricular ejection fraction LVEF is <35%

Established coronary artery disease in patients who have had myocardial infarction (ST elevation or non-ST elevation) or unstable angina within the preceding ninety (90) days provided that:

- The patient did not undergo coronary angiography at the time of the acute event; **AND**
- The patient is currently clinically stable

Established Kawasaki Disease with Coronary Artery Involvement

- Every two year evaluation for confirmed small to medium coronary artery aneurysm
- Annual evaluation for confirmed large (giant) coronary artery aneurysm, multiple or complex aneurysms or coronary artery obstruction confirmed by angiography

Common Diagnostic Indications

Patients with new onset arrhythmias (patient can be symptomatic or asymptomatic)

This guideline applies to patients with suspected or established CAD

- Patients with sustained (lasting more than 30 seconds) or non-sustained (more than 3 beats but terminating within 30 seconds) ventricular tachycardia; **OR**
- Patients with atrial fibrillation or flutter and high or moderate risk of CAD (SCORE); **OR**
- Patients with atrial fibrillation or flutter and established CAD; **OR**
- Patients who have frequent premature ventricular contractions (PVC) defined as more than thirty (30) PVCs per hour on ambulatory EKG (Holter) monitoring
    - It is not clinically indicated to perform MPI for evaluation of infrequent premature atrial or ventricular depolarizations

Patients with new onset congestive heart failure or recently recognized left ventricular systolic dysfunction (patient can be symptomatic or asymptomatic)

This guideline applies to patients with suspected or established CAD

For patients in this category whose CAD risk (SCORE) is high, cardiac catheterization may be more appropriate than non-invasive evaluation

- Provided that new or worsening CAD has not been excluded as the cause of LV dysfunction/ CHF by any of the following tests: MPI, stress echo, cardiac PET, coronary CTA or cardiac catheterization

Patients with abnormal exercise treadmill test (performed without imaging)

This guideline applies to patients with suspected or established CAD

- Abnormal findings on an exercise treadmill test include (chest pain, ST segment change, abnormal BP response or complex ventricular arrhythmias)

Patients who have undergone recent (within the past 60 days) stress echocardiography

- When the stress echocardiogram is technically suboptimal, technically limited, inconclusive, indeterminate, or equivocal, such that myocardial ischemia cannot be adequately excluded
    - It is not appropriate to perform MPI on patients who have had a recent normal or abnormal stress echocardiogram
    - A stress echocardiogram is deemed to be abnormal when there are echocardiographic abnormalities. Electrocardiographic abnormalities without echocardiographic evidence of ischemia are considered to be normal studies

Patients with abnormal findings on cardiac CT / coronary CTA

Symptomatic Patients:

- With coronary artery calcium score > 400 Agatston units; **OR**
- Intermediate severity coronary stenosis on coronary CTA

Note: *If symptoms are typical of myocardial ischemia cardiac catheterization may be more appropriate than MPI*

Asymptomatic patients who have not had MPI, stress echo, cardiac PET or cardiac catheterization within the preceding three (3) years:

- With coronary artery calcium score > 400 Agatston units; **OR**
- Intermediate severity coronary stenosis coronary CTA

Patients with abnormal findings on cardiac catheterization

- To determine flow limiting significance of intermediate coronary stenosis

Common Diagnostic Indications

Myocardial viability evaluation

MPI may be used to evaluate myocardial viability in patients who

- Have established coronary artery disease; **AND**
- Have left ventricular systolic dysfunction (Left Ventricular Ejection Fraction <55%); **AND**
- Are candidates for revascularization

Note: *Pharmacologic stress echocardiography with a drug such as dobutamine that increases myocardial contractility is the preferred protocol*

Pre-operative cardiac evaluation of patients undergoing non-cardiac surgery

This guideline applies to patients undergoing non-emergency surgery

It is assumed that those who require emergency surgery will undergo inpatient pre-operative evaluation

- Patients with active cardiac conditions such as unstable coronary syndromes (unstable angina), decompensated heart failure (NYHA function of class IV, worsening or new onset heart failure), significant arrhythmias (third degree AV block Mobitz II AV block, uncontrolled supraventricular arrhythmia, symptomatic ventricular arrhythmias, ventricular tachycardia), symptomatic bradycardia or severe stenotic valvular lesions. It is recommended that these conditions be evaluated and managed per ACC/AHA guidelines prior to considering elective surgery. That evaluation may include MPI

Low-risk surgery (endoscopic procedures, superficial procedures, cataract surgery, breast surgery, ambulatory surgery)

- Provided that there are no active cardiac conditions (as outlined above), MPI prior to low-risk surgery is considered not medically necessary

Intermediate risk surgery (including but not limited to intraperitoneal and intrathoracic surgery, carotid endarterectomy, head and neck surgery, orthopedic surgery, prostate surgery, gastric bypass surgery) or **High-risk surgery** (including but not limited to aortic and other major vascular surgery, peripheral vascular surgery) when

- The patient has not had a normal coronary angiogram, SE, MPI, CCTA, Cardiac PET perfusion study or revascularization procedure within the previous one (1) year; **AND**
- At least one of the following applies:
  - Patient has established CAD (prior MI, prior PTCA, stent, or CABG) or presumed CAD (Q waves on EKG, abnormal MPI, SE or cardiac PET); **OR**
  - Patient has compensated heart failure or prior history of heart failure (CHF); **OR**
  - Patient has diabetes mellitus; **OR**
  - Patient has chronic renal insufficiency or renal failure; **OR**
  - Patient has a history of cerebrovascular disease (TIA, CVA or documented carotid stenosis requiring carotid endarterectomy); **OR**
  - Patient is unable to walk on a treadmill for reasons other than obesity

Abnormal EKG findings

Some patients have resting EKG findings which would render the interpretation of an exercise EKG test difficult or impossible. In these situations patients who, in the absence of the EKG abnormality, would not meet approval criteria for MPI, may be approved for MPI because exercise EKG testing without imaging would provide little clinically useful data. Patients with the following resting EKG abnormalities are included this category:

- Left bundle branch block; **OR**
- Ventricular paced rhythm; **OR**
- Left ventricular hypertrophy with repolarization abnormality; **OR**
- Digoxin effect; **OR**
- 1 mm ST depression or more on a recent EKG (within the past 30 days); **OR**
- Pre-excitation syndromes (E.G. WPW syndrome)

Unable to walk on a treadmill for reasons other than obesity

Nuclear Cardiology: Cardiac Blood Pool Imaging Blood Pool Imaging includes MUGA (Multi-Gated Acquisition) & First Pass Radionuclide Ventriculography

CPT Codes

78472..... Gated equilibrium; planar, single study, wall motion plus ejection fraction

78473..... Gated equilibrium; planar, multiple studies, wall motion study plus ejection fraction

78481..... First pass technique; single study, wall motion study plus ejection fraction

78483..... First pass technique; multiple studies, wall motion study plus ejection fraction

78494..... Gated equilibrium: SPECT, at rest, wall motion study plus ejection fraction

78496..... This code is an add-on code to be used in conjunction with 78472. As such, this code does not require separate review.

Commonly Used Radiopharmaceuticals

- Technetium-99m

Imaging Considerations

- Primarily used to evaluate global and regional ventricular function and to determine ejection fraction(s)
- May be used in the evaluation of intracardiac shunting or diastolic function
- First-pass studies display initial transit of the radiotracer bolus passing through the cardiopulmonary and central systemic circulations. Right and/or left ventricular function may be evaluated.
- Equilibrium studies display gated data (MUGA) which is acquired over many cardiac cycles, using a blood pool radiotracer. Both right and left ventricles may be evaluated.
- First pass studies should be acquired on a high count-rate camera in order that images have sufficient temporal resolution. High count-rate cameras are not required for MUGA.
- Studies may be performed at rest and/or during exercise.
- MUGA studies are technically more difficult in patients with irregular heart rhythms. Imaging times may have to be prolonged to acquire adequate data.
- Selection of the optimal diagnostic imaging for cardiac evaluation should be made within the context of other available studies (which include transthoracic echocardiography, transesophageal echocardiography, stress myocardial perfusion imaging, stress echocardiography, cardiac MRI, cardiac CT, cardiac PET imaging and invasive cardiac/coronary angiography), so that the resulting information facilitates patient management decisions and does not merely add a new layer of testing.
- Some disease states and medications interfere with red blood cell labeling. These should be taken into account when selecting the optimal imaging modality.
- In interpretation of this document, the term “clinically stable” is taken to mean that the patient has no new or worsening cardiac symptoms and there are no changes on cardiovascular examination.

Common Diagnostic Indications

Evaluation of left ventricular function

Note: *It is assumed that left ventricular function will be evaluated using a single imaging modality. Thus, if left ventricular function has been evaluated recently by echocardiography reevaluation using blood pool imaging is not necessary*

- Initial evaluation of known or suspected heart failure; **OR**
- Reevaluation of patients with known LV dysfunction (systolic or diastolic) in a patient with a deterioration in clinical status; OR
- Evaluation of patients with resting EKG abnormalities (LBBB, RBBB with left anterior or posterior hemiblock, LVH, RVH, Q waves suggestive of prior infarction); **OR**
- Reevaluation of patients with known heart failure (systolic or diastolic) in a patient with a change in clinical status; **OR**
- Baseline and serial reevaluation in patients undergoing, planning to undergo or who have undergone therapy with cardiotoxic agents (examples including but not limited to some chemotherapeutic agents for cancer, Novantrone [mitoxantrone] for multiple sclerosis); **OR**
- Screening study for left ventricular dysfunction every two (2) years in clinically stable and first-degree relatives of patients with inherited cardiomyopathy; **OR**
- Evaluation of suspected restrictive, infiltrative or genetic cardiomyopathy; **OR**
- Evaluation of patients with diagnosed or suspected myocarditis; **OR**
- Evaluation of LV function in a patient with known cardiomyopathy being considered for cardiac resynchronization therapy (CRT), implantable defibrillator (AICD) or ventricular assist device (VAD); **OR**
- Initial evaluation for cardiac resynchronization therapy (CRT) device optimization following implantation; **OR**
- Evaluation of a patient being treated with cardiac resynchronization therapy (CRT) with new or persistent signs or symptoms of heart failure for device optimization; **OR**
- Blood pool imaging is indicated for optimization of device settings in patients with ventricular assist device (VAD); **OR**
- When left ventricular dysfunction is suggested by other testing (chest x-ray, elevated BNP) and LV function has not been evaluated by another modality since that testing was performed; **OR**
- Where a clinically significant discrepancy that might influence patient management exists in the evaluation of left ventricular dysfunction by two other imaging modalities, MUGA/First Pass can be used as an arbiter; **OR**
- Pre and post cardiac transplantation

Evaluation of right ventricular function

- In patients suspected of having right ventricular dysfunction based on history and/or physical examination; **OR**
- Reevaluation of patients with established right ventricular dysfunction in patients with a change in clinical status; **OR**
- Evaluation of right ventricular function in patients with pulmonary hypertension; **OR**
- Evaluation of right ventricular function in patients with diagnoses known to cause right ventricular dysfunction including but not limited to coronary artery disease, valvular heart disease, left ventricular dysfunction, congenital heart disease, morbid obesity, sleep apnea syndrome, advanced lung disease, pulmonary thromboembolic disease, and right ventricular dysplasia; **OR**
- Evaluation of right ventricular function in patients with myocardial infarction where right ventricular involvement is suspected; **OR**
- Evaluation of right ventricular function in patients who are being evaluated for or have undergone cardiac or lung transplantation

Common Diagnostic Indications

Coronary artery disease (CAD) (applies to patients with established coronary artery disease)

- Recent (less than 3 weeks) acute coronary syndrome (myocardial infarction or unstable angina) for initial assessment of LV function
  - This study is usually done prior to discharge
  - Not required if left ventricular function has been assessed using another imaging modality; **OR**
- Prior acute coronary syndrome (myocardial infarction or unstable angina) for reevaluation of ventricular function during recovery phase (up to six [6] months following acute coronary syndrome); **OR**
- Prior acute coronary syndrome (myocardial infarction or unstable angina) for reevaluation of ventricular function after the recovery phase (more than six [6] months) in patients who develop new signs or symptoms suggestive of heart failure; **OR**
- Prior myocardial infarction for reevaluation of LV function in patients being considered for AICD or cardiac resynchronization therapy (CRT)

Congenital heart disease

- For detection and localization of shunts (ventricular septal defect [VSD], atrial septal defect [ASD], patent ductus arteriosus [PDA], anomalous pulmonary venous drainage)
  - Echocardiography is generally considered to be a preferable imaging modality in this clinical situation
- For evaluation of RV and/or LV function in a patient with established complex congenital heart disease

Valvular heart disease

- Established valvular heart disease in patients with new or worsening signs or symptoms
  - In patients with suspected valvular heart disease echocardiography is the appropriate initial imaging modality; **OR**
- Patients with severe asymptomatic aortic regurgitation to assist in optimal timing of aortic valve replacement
  - Rest and stress studies are appropriate in this clinical situation

Nuclear Cardiology
Infarct Imaging

CPT Codes

78466..... Planar, infarct avid; qualitative or quantitative

78468..... Planar, infarct avid; with ejection fraction by first pass technique

78469..... SPECT, infarct avid; with or without quantification

Radiopharmaceuticals

- Technetium-99m Pyrophosphate

Imaging Considerations

- Infarct imaging is typically optimal at 48-72 hours post-event
- False positive findings have been attributed to the following conditions:
  - Amyloidosis
  - Cardiac valvular and pericardial calcification
  - Cardiomyopathy
  - Doxorubicin (Adriamycin) Treatment
  - Myocarditis and Pericarditis
  - Prior myocardial infarction, that remains persistently positive
  - Radiation Therapy
  - Ventricular aneurysm
- Selection of the optimal diagnostic imaging for cardiac evaluation should be made within the context of other available studies (which include treadmill stress test, stress myocardial perfusion imaging, stress echocardiography, cardiac MRI, cardiac PET imaging and invasive cardiac/coronary angiography), so that the resulting information facilitates patient management decisions and does not merely add a new layer of testing.

Common Diagnostic Indications

Suspected acute myocardial infarction, which likely occurred within the last 7 days

- Including interrogation of the following:
  - Negative (past expected peak) cardiac enzymes
  - Abnormal baseline ECG, due to prior myocardial infarction
  - Left bundle branch block

Differentiation of subendocardial (non-Q-wave) infarction versus ischemia

Post-cardioversion

Following significant chest trauma or major surgical procedure, with chest pain

Cardiac Echocardiography
Stress Echocardiography (SE)

CPT Codes

93350..... Echocardiography, transthoracic during rest and cardiovascular stress test using treadmill, bicycle exercise and/or pharmacologically induced stress, with interpretation and report

93351..... Echocardiography, transthoracic during rest and cardiovascular stress test using treadmill, bicycle exercise and/or pharmacologically induced stress, with interpretation and report; including performance of continuous electrocardiographic monitoring with physician supervision

93320..... This code is an add-on code to be used in conjunction with 93350, 93351. As such, this code does not require separate review

93321..... This code is an add-on code to be used in conjunction with 93350, 93351. As such, this code does not require separate review

93325..... This code is an add-on code to be used in conjunction with 93350, 93351. As such, this code does not require separate review

93352..... This code is an add-on code to be used in conjunction with 93350, 93351. As such, this code does not require separate review

Uses of Stress Echocardiography (SE)

- The primary use of SE is in the diagnosis or exclusion of obstructive coronary artery disease (CAD).
- SE is also used for management of established coronary artery disease.
- SE may be used for assessment of myocardial viability in patients who have had myocardial infarction.
- SE is occasionally used in the evaluation of valvular heart disease, and for the detection and management of occult pulmonary hypertension.

Imaging Considerations

- A recent EKG is strongly recommended, preferably within 7 days of request for stress echocardiogram. The findings on the resting EKG may help to determine the need for imaging and may also show evidence of ischemia at rest or interval myocardial infarction.
- Unlike MPI, stress echocardiography does not expose the patient to ionizing radiation.
- Age, gender and the character of the chest pain provide useful predictors of CAD, as stratified in Table 1 below.

Table 1*: Pre-Test Probability of Coronary Artery Disease by Age, Gender and Symptoms

Very Low < 5% Low Probability < 10%	Intermediate probability 10-90% High Probability > 90%

*Reference for Table 1: Gibbons RJ, Balady GJ, Beasley JW, et al. ACC/AHA Guidelines for Exercise Testing: Executive Summary. Circulation. 1997;96:345-354.

Age (yr)	Gender	Typical/Definite Angina Pectoris	Atypical/Probable Angina Pectoris	Non-Anginal Chest Pain	Asymptomatic
30-39	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
60-69	Men	High	Intermediate	Intermediate	Low
	Women	High	Intermediate	Intermediate	Low

Imaging Considerations

Myocardial Perfusion Imaging and Stress Echocardiography may provide useful information on Coronary Heart Disease. Comparison data on Sensitivity and Specificity are provided in Table 2 below. Due to regional variation in technical expertise and interpretive proficiency, the clinician should use the diagnostic imaging modality that has been proven most accurate in his/her practices.

Table 2**: Comparison of Non-Invasive Diagnostic Imaging

** Reference for Table 2: Zaret BL, Bellar GA. *Clinical Nuclear Cardiology*. 3rd Edition. Philadelphia: Elsevier Mosby Publishers; 2005, page 539

	Nuclear Imaging Sensitivity (%)	Stress Echo Sensitivity (%)	Nuclear Imaging Specificity (%)	Stress Echo Specificity (%)
Exercise (7 studies)	83%	78%	83%	91%
Dobutamine (8 studies)	86%	80%	73%	86%
Adenosine (3 studies)	89%	63%	73%	86%
Dipyridamole (4 studies)	83%	68%	88%	89%

Several clinical indications listed for Stress Echo include standard methods of risk assessment, such as the SCORE (Systematic Coronary Risk Evaluation) or the Framingham risk score calculation. These risk calculation systems include consideration of the following factors:

Age	Sex
Abnormal Lipid Profile	Hypertension
Diabetes Mellitus (always = high risk)	Cigarette Smoking

Other coronary risk factors such as family history of premature CAD, coronary artery calcification, C reactive protein levels, obesity etc. are not included in the standard methods of risk assessment but are thought to contribute to coronary artery disease risk.

- Selection of the optimal diagnostic work-up for evaluation or exclusion of coronary artery disease should be made within the context of available studies (which include treadmill stress test, stress myocardial perfusion imaging, stress echocardiography, cardiac PET imaging and invasive cardiac/coronary angiography), so that the resulting information facilitates patient management decisions and does not merely add a new layer of testing.
- Occasionally it may be appropriate to do a second non-invasive test for diagnosis or exclusion of CAD when the initially selected test is technically suboptimal and the diagnosis of CAD cannot be established or excluded.
- SE may be performed using either physical or pharmacologic stress. If physical stress is used, the choice rests between treadmill exercise test and bicycle exercise test. While it is possible to acquire images during exercise in patients undergoing bicycle exercise testing, image quality during treadmill exercise is suboptimal. In this situation, the “stress” images are actually acquired immediately following peak exercise. Thus, the laboratory must be set up in a manner that allows imaging to be completed within 45 to 60 seconds after peak exercise.
- Some patients may not be suitable candidates for SE. Image quality is frequently suboptimal in morbidly obese patients and in those with advanced lung disease. If image quality at rest is inadequate, the test should be canceled and consideration given to an alternative imaging modality.
- For patients who are unable to walk on a treadmill for non-cardiac reasons (orthopedic limitations, claudication, neurological conditions, advanced lung disease, etc. exercise stress testing is not an option. These patients will require pharmacological testing with echo or nuclear imaging.
- It is anticipated that the evaluation of patients with acute chest pain will occur in the emergency room or in an inpatient setting and stress echo performed in these locations is not included in the AIM preauthorization program.

Common Diagnostic Indications

Suspected coronary artery disease in asymptomatic patients

- Patients with high-risk of CAD (SCORE) who have not had evaluation of coronary artery disease (MPI, stress echo, cardiac PET, coronary CTA or cardiac catheterization) within the preceding three (3) years; **OR**
- Patients with moderate or high risk of CAD (SCORE) who have a high risk occupation that would endanger others in the event of a myocardial infarction (for example: airline pilot, law-enforcement officer, firefighter, mass transit operator, bus driver) who have not had evaluation of coronary artery disease (MPI, stress echo, cardiac PET, coronary CTA or cardiac catheterization) within the preceding three (3) years; **OR**
- Patients with diseases/conditions with which coronary artery disease commonly coexists and who have not had evaluation of coronary artery disease (MPI, stress echo, cardiac PET, coronary CTA or cardiac catheterization) within the preceding three (3) years:
  - Diabetes mellitus; **OR**
  - Abdominal aortic aneurysm; **OR**
  - Established and symptomatic peripheral vascular disease; **OR**
  - Prior history of cerebrovascular accident (CVA), transient ischemic attack (TIA) or carotid endarterectomy (CEA) or high grade carotid stenosis (>70%); **OR**
  - Chronic renal insufficiency; **OR**
- Patients who have undergone cardiac transplantation and have had no evaluation for coronary artery disease within the preceding one (1) year; **OR**
- Patients in whom a decision has been made to treat with Interleukin 2; **OR**
- Patients awaiting solid organ transplantation who have not undergone evaluation for coronary artery disease within the preceding one (1) year

Suspected coronary artery disease in symptomatic patients who have not had evaluation of coronary artery disease (MPI, stress echo, cardiac PET, coronary CTA or cardiac catheterization) within the preceding sixty (60) days

- Chest pain
  - With intermediate or high pretest probability of CAD (Table 1); **OR**
  - With low or very low pretest probability of CAD (Table 1) and high risk of CAD (SCORE)
- Atypical symptoms: syncope, shortness of breath (dyspnea), neck, jaw, arm, epigastric or back pain, sweating (diaphoresis)
  - With moderate or high risk of CAD (SCORE)
- Other symptoms: palpitation, dizziness, lightheadedness, near syncope, nausea, vomiting, anxiety, weakness, fatigue, etc.
  - With high risk of CAD (SCORE)
- Patients with any cardiac symptom who have diseases/conditions with which coronary artery disease commonly coexists such as:
  - Diabetes mellitus; **OR**
  - Abdominal aortic aneurysm; **OR**
  - Established and symptomatic peripheral vascular disease; **OR**
  - Prior history of cerebrovascular accident (CVA), transient ischemic attack (TIA) or carotid endarterectomy (CEA) or high grade carotid stenosis (>70%); **OR**
  - Chronic renal insufficiency or renal failure; **OR**
- Patients who have undergone cardiac transplantation; **OR**
- Patients in whom a decision has been made to treat with Interleukin 2; **OR**
- Patients awaiting solid organ transplantation

Established coronary artery disease in asymptomatic patients

- Patients awaiting solid organ transplantation who have not undergone evaluation for coronary artery disease within the preceding one (1) year

Common Diagnostic Indications

Established coronary artery disease (diagnosed by previous cardiac catheterization, MPI, cardiac PET, or stress echo) in patients who have new or worsening symptoms

Note: *If symptoms are typical of myocardial ischemia cardiac catheterization may be more appropriate than SE*

Established coronary artery disease (diagnosed by previous cardiac catheterization, MPI, cardiac PET, or stress echo) in patients who have not undergone revascularization and have no symptoms or stable symptoms

- No evaluation of CAD (MPI, stress echo, cardiac PET, coronary CTA or cardiac catheterization) within the preceding three (3) years
- No evaluation of CAD (MPI, cardiac PET, stress echo, coronary CTA or cardiac catheterization) within the preceding one (1) year in a patient who has undergone cardiac transplantation and has been found to have CAD since transplantation

Established coronary artery disease in patients who have undergone revascularization

- For evaluation of new or worsening cardiac symptoms
  - If symptoms are typical of myocardial ischemia cardiac catheterization may be more appropriate than SE; **OR**
- For evaluation of stable patients who have undergone coronary artery bypass grafting more than five (5) years previously and who have not had an evaluation for coronary artery disease (MPI, stress echo, cardiac PET, coronary CTA or cardiac catheterization) within the past two (2) years
  - Stable patients whose revascularization has been incomplete may undergo SE three (3) years following the procedure and every three (3) years thereafter; **OR**
- For evaluation of stable patients who have undergone percutaneous coronary intervention(PCI) more than three (3) years previously and who have not had an evaluation for coronary artery disease (MPI, stress echo, cardiac PET, coronary CTA or cardiac catheterization) within the past three (3) years when **any of the following** applies
  - The patient has undergone PCI of the left main (LM) coronary artery or the proximal left anterior descending (LAD) coronary artery
  - The patient has undergone PCI of more than one coronary artery
  - The patient has chronic total occlusion of a coronary artery and the vessel on which PCI was performed is supplying collateral flow to the occluded vessel
  - The patient is known to have only one patent coronary artery.
  - Left ventricular ejection fraction LVEF is <35%

Established coronary artery disease in patients who have had myocardial infarction (ST elevation or non-ST elevation) or unstable angina within the preceding ninety (90) days provided that

- The patient did not undergo coronary angiography at the time of the acute event; **AND**
- The patient is currently clinically stable

Established Kawasaki Disease with Coronary Artery Involvement

- Every two year evaluation for confirmed small to medium coronary artery aneurysm
- Annual evaluation for confirmed large (giant) coronary artery aneurysm, multiple or complex aneurysms or coronary artery obstruction confirmed by angiography

Common Diagnostic Indications

Patients with new onset arrhythmias (patient can be symptomatic or asymptomatic)

This guideline applies to patients with suspected or established CAD

- Patients with sustained (lasting more than 30 seconds) or non-sustained (more than 3 beats but terminating within 30 seconds) ventricular tachycardia; **OR**
- Patients with atrial fibrillation or flutter and high or moderate risk of CAD (SCORE); **OR**
- Patients with atrial fibrillation or flutter and established CAD; **OR**
- Patients who have frequent premature ventricular contractions (PVC) defined as more than thirty (30) PVCs per hour on ambulatory EKG (Holter) monitoring
    - It is not appropriate to perform stress echocardiography for evaluation of infrequent premature atrial or ventricular depolarizations

Patients with new onset congestive heart failure or recently recognized left ventricular systolic dysfunction (patient can be symptomatic or asymptomatic)

This guideline applies to patients with suspected or established CAD

For patients in this category whose CAD risk (SCORE) is high, cardiac catheterization may be more appropriate than non-invasive evaluation

- Provided that new or worsening CAD has not been excluded as the cause of LV dysfunction/ CHF by any of the following tests: MPI, stress echo, cardiac PET, coronary CTA or cardiac catheterization

Patients with abnormal exercise treadmill test (performed without imaging)

This guideline applies to patients with suspected or established CAD

- Abnormal findings on an exercise treadmill test include (chest pain, ST segment change, abnormal BP response or complex ventricular arrhythmias)

Patients who have undergone recent (within the past 60 days) myocardial perfusion imaging (MPI)

- When the MPI is technically suboptimal, technically limited, inconclusive, indeterminate, or equivocal, such that myocardial ischemia cannot be adequately excluded
    - It is not appropriate to perform SE on patients who have had a recent normal or abnormal MPI
    - An MPI is deemed to be abnormal when there are abnormalities on the nuclear imaging portion of the test. Electrocardiographic abnormalities without evidence of ischemia on the nuclear imaging portion of the test are considered to be normal studies

Patients with abnormal findings on cardiac CT / coronary CTA

Symptomatic Patients:

- With coronary artery calcium score > 400 Agatston units; **OR**
- Intermediate severity coronary stenosis on coronary CTA

Note: *If symptoms are typical of myocardial ischemia, cardiac catheterization may be more appropriate than stress echo*

Asymptomatic patients who have not had MPI, stress echo, cardiac PET or cardiac catheterization within the preceding three (3) years:

- With coronary artery calcium score > 400 Agatston units; **OR**
- Intermediate severity coronary stenosis coronary CTA

Patients with abnormal findings on cardiac catheterization

- To determine flow limiting significance of intermediate coronary stenosis

Common Diagnostic Indications

Myocardial viability evaluation

Stress Echo may be used to evaluate myocardial viability in patients who

- Have established coronary artery disease; **AND**
- Have left ventricular systolic dysfunction (Left Ventricular Ejection Fraction <55%); **AND**
- Are candidates for revascularization

Note: *Pharmacologic stress echocardiography with a drug such as dobutamine that increases myocardial contractility is the preferred protocol*

Pre-operative cardiac evaluation of patients undergoing non-cardiac surgery

This guideline applies to patients undergoing non-emergency surgery

It is assumed that those who require emergency surgery will undergo in-patient pre-operative evaluation

- Patients with active cardiac conditions such as unstable coronary syndromes (unstable angina), decompensated heart failure (NYHA function of class IV, worsening or new onset heart failure), significant arrhythmias (third degree AV block Mobitz II AV block, uncontrolled supraventricular arrhythmia, symptomatic ventricular arrhythmias, ventricular tachycardia), symptomatic bradycardia or severe stenotic valvular lesions. It is recommended that these conditions be evaluated and managed per ACC/AHA guidelines prior to considering elective surgery. That evaluation may include Stress Echo

Low-risk surgery (endoscopic procedures, superficial procedures, cataract surgery, breast surgery, ambulatory surgery)

- Provided that there are no active cardiac conditions (as outlined above) Stress Echo prior to low-risk surgery is considered not medically necessary

Intermediate risk surgery (including but not limited to intraperitoneal and intrathoracic surgery, carotid endarterectomy, head and neck surgery, orthopedic surgery, prostate surgery, gastric bypass surgery) or **High-risk surgery** (including but not limited to aortic and other major vascular surgery, peripheral vascular surgery) when

- The patient has not had a normal coronary angiogram, SE, MPI, CCTA, Cardiac PET perfusion study or revascularization procedure within the previous one (1) year; **AND**
- At least one of the following applies:
  - Patient has established CAD (prior MI, prior PTCA, stent, or CABG) or presumed CAD (Q waves on EKG, abnormal MPI, SE or cardiac PET); **OR**
  - Patient has compensated heart failure or prior history of heart failure (CHF); **OR**
  - Patient has diabetes mellitus; **OR**
  - Patient has chronic renal insufficiency or renal failure; **OR**
  - Patient has a history of cerebrovascular disease (TIA, CVA or documented carotid stenosis requiring carotid endarterectomy); **OR**
  - Patient is unable to walk on a treadmill for reasons other than obesity

Common Diagnostic Indications

Valvular heart disease

- Stress echocardiography may be used in evaluation of asymptomatic patients with any of the following valvular lesions
  - Severe aortic stenosis
  - Severe aortic regurgitation with normal left ventricular size and function
  - Severe mitral stenosis
  - Severe mitral regurgitation with normal left ventricular size and function; **OR**
- Stress echocardiography may be used in evaluation of symptomatic patients with any of the following valvular lesions
  - Aortic stenosis of uncertain degree (due to the presence of co-existent severe left ventricular systolic dysfunction). Pharmacologic stress echocardiography with a drug such as dobutamine that increases myocardial contractility is the preferred protocol
  - Moderate mitral stenosis
  - Moderate mitral regurgitation

Pulmonary hypertension

- For evaluation of patients with suspected pulmonary hypertension whose resting echocardiogram fails to confirm that diagnosis, such that exercise induced pulmonary hypertension needs to be excluded; **OR**
- For evaluation of right and/or left ventricular function during exercise in patients with established exercised induced pulmonary hypertension

Hypertrophic obstructive cardiomyopathy

- For the evaluation of dynamic changes during exercise in patients with an established diagnosis of hypertrophic obstructive cardiomyopathy who do not have a resting outflow tract gradient of 50 mm Hg or more

Abnormal EKG findings

Some patients have resting EKG findings which would render the interpretation of an exercise EKG test difficult or impossible. In these situations patients who, in the absence of the EKG abnormality, would not meet approval criteria for SE, may be approved for SE because exercise EKG testing without imaging would provide little clinically useful data. Patients with the following resting EKG abnormalities are included in this category:

- Left bundle branch block; **OR**
- Ventricular paced rhythm; **OR**
- Left ventricular hypertrophy with repolarization abnormality; **OR**
- Digoxin effect; **OR**
- 1 mm ST depression or more on a recent EKG (within the past 30 days); **OR**
- Pre-excitation syndromes (e.g. WPW syndrome)

Unable to walk on a treadmill for reasons other than obesity

Transesophageal Echocardiography (TEE)

CPT Codes

93312..... TEE real-time with image documentation (2-D) (with or without M-mode recording)
93313..... Placement of transesophageal probe only
93314..... Image acquisition, interpretation and report only
93315..... TEE for congenital cardiac anomalies
93316..... Placement of transesophageal probe only (congenital cardiac anomalies)
93317..... Image acquisition, interpretation and report only (congenital cardiac anomalies)
93320..... This code is an add-on code to be used in conjunction with 93312, 93314, 93315, 93317. As such, this code does not require separate review
93321..... This code is an add-on code to be used in conjunction with 93312, 93314, 93315, 93317. As such, this code does not require separate review
93325..... This code is an add-on code to be used in conjunction with 93312, 93314, 93315, 93317. As such, this code does not require separate review

Standard Anatomic Coverage

- Heart, proximal great vessels, pericardium

Imaging Considerations

- In general, it is assumed that TEE is appropriately used as an adjunct or subsequent test to transthoracic echocardiography (TTE) when suboptimal TTE images preclude obtaining a diagnostic study.
- There are some clinical situations for which TEE is a more appropriate initial imaging test than TTE. These situations are outlined below under Common Diagnostic Indications for TEE.
- Since TEE requires conscious sedation, it should only be performed at locations where cardiac monitoring and appropriate equipment for cardiopulmonary resuscitation are readily available.
- Patients with oropharyngeal or esophageal pathology which contraindicates intubation of the esophagus are not suitable candidates for TEE.
- Intraoperative TEE (93318) is beyond the scope of AIMs diagnostic imaging management program and will not be addressed in this document.

Common Diagnostic Indications

In patients who have had, or are likely to have suboptimal transthoracic imaging

- When image quality is suboptimal such that the clinical question(s) prompting the TEE has/have not been adequately answered; **OR**
- When it is likely that transthoracic imaging will be suboptimal in the following situations:
  - Previous transthoracic echocardiograms were of suboptimal quality
  - In patients with severe abnormalities of thoracic contour (pectus deformities, severe kyphoscoliosis)
  - In patients who have recently had thoracic surgery where post-operative tenderness or the location of dressings or incisions would preclude imaging from the usual transthoracic locations
  - Following severe chest trauma
  - Following extensive burns to the thorax
  - In patients with a cardiac diagnosis made by TEE who require reevaluation, the results of which would lead to a change in therapy (e.g. resolution of an intracardiac thrombus following anticoagulation)

Common Diagnostic Indications

In patients whose clinical situation suggests that TEE may be preferable to transthoracic echocardiography

- In evaluation of suspected acute aortic pathology; **OR**
- In evaluation of valvular structure and function to assess suitability for and assist in planning of surgical or catheter based valvular intervention; **OR**
- To diagnose/manage endocarditis with a moderate or high pretest probability (e.g. bacteremia, especially staph bacteremia or fungemia); **OR**
- To diagnose/manage endocarditis involving prosthetic heart valves; **OR**
- In evaluation of persistent fever in a patient with an intracardiac device to exclude endocarditis; **OR**
- In evaluation of a patient with atrial fibrillation/flutter to facilitate clinical decision-making with regards to anticoagulation and/or cardioversion and/or ablation
    - TEE is not required when the decision has been made to anticoagulate the patient and not perform cardioversion; **OR**
- In evaluation of a patient who has undergone surgical correction of complex congenital heart disease for the exclusion of intracardiac thrombus; **OR**
- In evaluation for cardiovascular source of embolic event when no non-cardiac source has been identified

Resting Transthoracic Echocardiography (TTE)

CPT Codes

93303..... Transthoracic echocardiography or congenital cardiac anomalies; complete

93304..... Transthoracic echocardiography or congenital cardiac anomalies; follow-up or limited study

93306..... Echocardiography, transthoracic, real-time with image documentation (2D), includes M-mode recording, when performed, complete, with spectral Doppler echocardiography, and with color flow Doppler echocardiography

93307..... Transthoracic echocardiography; complete, without spectral Doppler echocardiography, or color flow Doppler echocardiography

93308..... Transthoracic echocardiography; complete, without spectral Doppler echocardiography, or color flow Doppler echocardiography follow-up or limited study

93320..... This code is an add-on code to be used in conjunction with 93303, 93304. As such, this code does not require separate review

93321..... This code is an add-on code to be used in conjunction with 93303, 93304, 93308. As such, this code does not require separate review

93325..... This code is an add-on code to be used in conjunction with 93303, 93304, 93308. As such, this code does require separate review

Standard Anatomic Coverage

- Heart, proximal great vessels, pericardium

Imaging Considerations

Advantages of transthoracic echocardiography:

- No risk to the patient
- Minimal patient discomfort
- Widely available
- Extremely portable
- No exposure to ionizing radiation

Disadvantages of transthoracic echocardiography:

- Image quality suboptimal in some patients
- Less sensitive than transesophageal echocardiography in some clinical situations

Ordering Issues:

- Transthoracic echocardiography should only be acquired on equipment which has the capability to perform Doppler echocardiography (pulsed-wave and continuous wave with spectral display) and color flow velocity mapping.
- In interpretation of this document, the term “clinically stable” is taken to mean that the patient has no new or worsening cardiac symptoms and there are no changes on cardiovascular examination.

Common Diagnostic Indications

Suspected valvular heart disease

- Evaluation of cardiac murmurs when the diagnosis of valvular heart disease has not been established
  - After the diagnosis of valvular heart disease has been established, follow the guidelines for the specific valvular lesion (eg, established aortic stenosis)
- Initial evaluation for mitral valve prolapse when signs or symptoms of mitral valve prolapse are present
- Initial evaluation for bicuspid aortic valve when there is a family history (established diagnosis in a first-degree relative)

Established native valvular stenosis (does not apply to congenital valvular stenosis)

- Changing signs or symptoms; **OR**
- Reevaluation of clinically stable patients with moderate or severe stenosis annually; **OR**
- Reevaluation of clinically stable patients with mild stenosis every three (3) years; **OR**
- Assessment of changes in hemodynamic severity and left ventricular function in patients with known aortic stenosis during pregnancy

Established native valvular regurgitation

- Changing signs or symptoms; **OR**
- Reevaluation of clinically stable patients with moderate or severe regurgitation annually; **OR**
- Reevaluation of clinically stable patients with mild regurgitation every three (3) years

Established bicuspid aortic valve

- Changing signs or symptoms suggesting the development of aortic valve dysfunction; **OR**
- Bicuspid aortic valve and dilated aortic root on prior echo (annual echocardiography is indicated); **OR**
- Bicuspid aortic valve and normal aortic root on prior echo [echo at three (3) yearly intervals is indicated]

Established mitral valve prolapse

- Changing signs or symptoms

Prosthetic cardiac valves (mechanical or bioprosthetic) and patients who have undergone valve repair

This guideline does not apply to valve replacement or repair for correction of congenital heart disease in childhood – see indication **Evaluation of patients with congenital heart disease**.

- Initial post-operative evaluation of valve function (baseline study); **OR**
- Signs and/or symptoms suggesting dysfunction of a repaired or replaced valve; **OR**
- Annual reevaluation of a patient with a prosthetic or repaired heart valve noted on prior imaging study to have moderate or severe dysfunction (stenosis or regurgitation); **OR**
- Evaluation at three (3) yearly intervals of a patient with a prosthetic or repaired heart valve noted on prior imaging study to have mild dysfunction (stenosis or regurgitation); **OR**
- Annual reevaluation of clinically stable adults (age 19 years or older) who have undergone valve repair or implantation of a bioprosthetic valve more than seven (7) years previously
  - This guideline does not apply to patients with a mechanical valve prosthesis; **OR**
- Following transcatheter aortic valve implantation/replacement (TAVI or TAVR), TTE is appropriate in clinically stable patients on one (1) occasion within the first three (3) months, at one (1) year, and annually thereafter.

Common Diagnostic Indications

Evaluation of patients with congenital heart disease

- Evaluation of patients in whom congenital heart disease is suspected based on signs and symptoms (including murmur, cyanosis, unexplained arterial desaturation, abnormal arterial pulses) abnormal EKG, abnormal chest x-ray; **OR**
- Patients with chromosomal abnormalities or major extra cardiac abnormality associated with a high incidence of coexisting cardiac abnormality; **OR**
- Patients with established congenital heart disease (repaired or unrepaired) in whom there is a change in clinical status; **OR**
- Adult patients with a childhood history of congenital heart disease (with or without prior surgical repair) in whom the original diagnosis is uncertain or when the precise nature of the structural abnormalities or hemodynamics is unclear; **OR**
- Annual echocardiography is appropriate in clinically stable patients age six (6) years or older with established complex congenital heart disease (with or without prior surgical repair) in whom surveillance for ventricular function, valvular function or pulmonary artery pressure is important in clinical decision-making
    - This does not include patients with successfully repaired patent ductus arteriosus, small atrial or ventricular septal defects, bicuspid aortic valve or mitral valve prolapse; **OR**
- Echocardiography is appropriate in clinically stable patients age five (5) years or younger with established congenital heart disease (with or without prior surgical repair) in whom surveillance for ventricular function, AV valvular regurgitation or pulmonary artery pressure is important in clinical decision-making; **OR**
- Initial outpatient post-operative evaluation of patients who have undergone surgical or catheter-based procedures to correct congenital heart disease (within 60 days of the procedure); **OR**
- TTE is appropriate every three (3) years in the follow up of patients who have undergone catheter-based closure of atrial or ventricular septal defects; **OR**
- Non adult patients (less than or equal to 18 years old) who are undergoing staged surgical correction of congenital heart disease; **OR**
- Patients in whom a decision to perform surgical or catheter based repair of congenital heart disease has been made and in whom echocardiography will be used to assist with procedural planning

Common Diagnostic Indications

Evaluation of ventricular function

Note: *It is assumed that left ventricular function will be evaluated using a single imaging modality. Thus, if left ventricular function has been evaluated recently by blood pool imaging reevaluation using echocardiography is not necessary.*

Hypertension

- Initial evaluation of patients with an established diagnosis of hypertension; **OR**
- Annual evaluation of non-adult patients (less than or equal to 18 years old) with an established diagnosis of hypertension

Heart Failure / Cardiomyopathy / Left Ventricular Dysfunction

- Initial evaluation of known or suspected heart failure; **OR**
- Reevaluation of patients with known heart failure (systolic or diastolic) in a patient with a deterioration in clinical status; **OR**
- Reevaluation of patients with known LV dysfunction (systolic or diastolic) in a patient with a deterioration in clinical status; **OR**
- Reevaluation of clinically stable non-adult (age 18 years or younger) patients with left ventricular systolic dysfunction (Left Ventricular ejection fraction <60%) at six (6) monthly intervals; **OR**
- Screening study every two (2) years in clinically stable first-degree relatives of patients with inherited cardiomyopathy {see specific indications for hypertrophic obstructive cardiomyopathy (HOCM) below}; **OR**
- Evaluation of suspected restrictive, infiltrative or genetic cardiomyopathy; **OR**
- Initial evaluation of suspected hypertrophic obstructive cardiomyopathy (HOCM) ; **OR**
- Reevaluation of known hypertrophic obstructive cardiomyopathy (HOCM) in a patient with a change in clinical status to guide or evaluate therapy; **OR**
- Annual reevaluation non-adult (age 18 years or younger) first-degree relatives of patients with established hypertrophic obstructive cardiomyopathy (HOCM); **OR**
- Evaluation every five (5) years of adult (age 19 years or older) first-degree relatives of patients with established hypertrophic obstructive cardiomyopathy (HOCM); **OR**
- Annual reevaluation of asymptomatic adult (age 19 years or older) patients with known hypertrophic obstructive cardiomyopathy (HOCM); **OR**
- Reevaluation of asymptomatic non-adult (age 18 years or younger) patients with known hypertrophic obstructive cardiomyopathy (HOCM) at six (6) monthly intervals

Implantable devices

- Evaluation of LV function in a patient with known cardiomyopathy being considered for cardiac resynchronization therapy (CRT), implantable defibrillator (AICD) or ventricular assist device (VAD); **OR**
- Initial evaluation for cardiac resynchronization therapy (CRT) device optimization following implantation; **OR**
- Evaluation of a patient being treated with cardiac resynchronization therapy (CRT) with new or persistent signs or symptoms of heart failure for device optimization; **OR**
- Echocardiography is indicated for optimization of device settings in patients with ventricular assist device (VAD); **OR**
- Echocardiography is indicated for evaluation of signs and/or symptoms suggestive of device related complications in patients with ventricular assist device (VAD)

Abnormalities on other testing

- Evaluation of patients with resting EKG abnormalities (LBBB, RBBB with left anterior or posterior hemiblock, LVH, RVH, Q waves suggestive of prior infarction); **OR**
- When left ventricular dysfunction is suggested by other testing (chest imaging, elevated BNP) and LV function has not been evaluated by another modality since that testing was performed; **OR**
- Where a significant discrepancy (more than would be expected for the range of error of the methods) exists in the evaluation of left ventricular dysfunction by two other imaging modalities, echocardiography can be used as an arbiter

Common Diagnostic Indications

Other

- Pre and post cardiac transplant evaluation; **OR**
- Evaluation of known or suspected myocarditis; **OR**
- Echocardiography to evaluate right ventricular function in patients with disease likely to affect right ventricular function including but not limited to chronic lung diseases and sleep apnea syndrome; **OR**
- Baseline and serial reevaluation in patients undergoing, planning to undergo or who have undergone therapy with cardiotoxic agents (examples including but not limited to some chemotherapeutic agents for cancer, Novantrone® (mitoxantrone) for multiple sclerosis

Evaluation of patients with cardiac arrhythmias

- In patients who have sustained (lasting more than 30 seconds) or nonsustained (more than 3 beats but terminating within 30 seconds) ventricular tachycardia
- In patients who have sustained (lasting more than 30 seconds) or non-sustained (more than 3 beats but terminating within 30 seconds) supraventricular tachycardia (including but not limited to atrial fibrillation, atrial flutter, atrial tachycardia, AV node reentrant tachycardia, etc.
- In patients who have frequent premature ventricular contractions (PVC) defined as more than thirty (30) PVCs per hour on ambulatory EKG (Holter) monitoring
    - It is not clinically indicated to perform echocardiography for evaluation of infrequent premature atrial or ventricular depolarizations

Evaluation of infective endocarditis (native or prosthetic valves)

- Patients with suspected endocarditis (positive blood cultures and/or a new murmur on physical examination)
- Reevaluation of patients with established endocarditis who have any of the following
    - Virulent organism; **OR**
    - Severe hemodynamic lesion; **OR**
    - Aortic involvement; **OR**
    - Persistent bacteremia; **OR**
    - Clinical deterioration

Evaluation of patients with suspected coronary artery disease

- Chest pain
    - Resting echocardiography may suggest a cause for the chest pain other than myocardial ischemia (mitral valve prolapse) and is therefore a reasonable imaging procedure in patients with chest pain
    - If coronary artery disease is a likely diagnosis and if a resting echocardiogram cannot be performed while the patient is experiencing the pain, a provocative test (exercise or pharmacological stress test with or without imaging as appropriate) is preferable
    - Resting echocardiography has no role in screening for coronary artery disease in asymptomatic patients; **OR**
- Echocardiography is appropriate in the evaluation of patients with suspected aberrant or anomalous coronary origins or coronary artery fistula

Common Diagnostic Indications

Evaluation of patients with known coronary artery disease

- Recent (< 3 weeks) acute coronary syndrome (myocardial infarction or unstable angina) and hemodynamic instability or signs or symptoms suggesting a complication of myocardial infarction including but not limited to acute mitral regurgitation, hypoxemia, abnormal chest x-ray, acute ventricular septal rupture, free wall rupture / tamponade, shock, right ventricular involvement, heart failure, or thrombus
  - This study is usually requested on an inpatient; **OR**
- Recent (< 3 weeks) acute coronary syndrome (myocardial infarction or unstable angina) for initial assessment of LV function
  - This study is usually done prior to discharge
  - Not required if left ventricular function has been assessed using a different imaging modality; **OR**
- Prior acute coronary syndrome (myocardial infarction or unstable angina) for reevaluation of ventricular function during recovery phase {up to six (6) months following acute coronary syndrome}; **OR**
- Prior acute coronary syndrome (myocardial infarction or unstable angina) for reevaluation of ventricular function after the recovery phase {more than six (6) months} in patients who develop new symptoms or signs suggestive of heart failure; **OR**
- Prior myocardial infarction for reevaluation of LV function in patients being considered for AICD or cardiac resynchronization therapy (CRT); **OR**
- Annual echocardiography is appropriate in non-adult patients (less than or equal to 18 years old) with an established diagnosis of aberrant or anomalous coronary origins or coronary artery fistula if the findings on echocardiography will impact clinical decision making; **OR**

Evaluation of Kawasaki disease

- Echocardiography is appropriate in the evaluation of patients with suspected Kawasaki disease; **OR**
- Echocardiography is appropriate in patients with an established diagnosis of Kawasaki disease at 2–4 weeks and again at 6-8 weeks following diagnosis whether or not there was coronary artery involvement; **OR**
- Echocardiography is appropriate for periodic surveillance up to one year following diagnosis of Kawasaki disease in patients with persistent fever; **OR**
- Echocardiography is appropriate for periodic surveillance up to one year following diagnosis of Kawasaki disease when previous echocardiograms reveal any of the following:
  - Coronary abnormalities
  - Left ventricular dysfunction
  - Pericardial effusion
  - Valvular regurgitation (other than trace or trivial regurgitation)
  - Aortic dilation; **OR**
- Annual echocardiography is appropriate in patients with an established diagnosis of Kawasaki disease who have small or medium sized coronary artery aneurysms; **OR**
- Semiannual (every six months) echocardiography is appropriate in patients with an established diagnosis of Kawasaki disease who have large or giant coronary artery aneurysms or coronary artery obstruction

Common Diagnostic Indications

Evaluation of signs, symptoms or abnormal testing

- Echocardiography is appropriate in the evaluation of the following newly recognized symptoms {dyspnea, lightheadedness, syncope, palpitations, reduced functional capacity, orthopnea, paroxysmal nocturnal dyspnea, transient ischemic attack (TIA) or cerebrovascular attack (CVA)}; **OR**
- Echocardiography is appropriate in the evaluation of chest pain not thought to be due to myocardial ischemia or infarction. If myocardial ischemia or infarction is thought to be the cause, resting outpatient echocardiography is not appropriate; **OR**
- Echocardiography is appropriate in the evaluation of the following newly recognized signs suggesting structural heart disease (murmur, cyanosis, ankle edema, ascites, elevation of jugular venous pressure, unexplained weight gain, tachycardia, tachypnea, audible third heart sound, lung crackles suggestive of pulmonary edema); **OR**
- Echocardiography is appropriate in the evaluation of patients who are hemodynamically unstable or hypotensive for unknown reasons; **OR**
- Echocardiography is appropriate in further evaluation of abnormal results from other testing which suggests underlying cardiac disease {abnormal chest imaging suggesting cardiac chamber enlargement, valvular or congenital heart disease or congestive heart failure, abnormal EKG suggesting chamber hypertrophy, valvular or congenital heart disease (LBBB, RBBB with anterior or posterior hemiblock, left or right ventricular hypertrophy or Q waves suggestive of prior infarction) or abnormal laboratory results suggesting congestive heart failure such as elevated B-type natriuretic peptide (BNP)}
    - When other cardiac testing raises concerns of underlying coronary artery disease, provocative testing is recommended over resting echocardiography; **OR**
- Echocardiography is appropriate in the evaluation of respiratory failure of unknown cause; **OR**
- Echocardiography is appropriate annually in the evaluation of patients with syndromes which place them at increased risk for the development of acquired myocardial or aortic diseases (for example, Marfan Syndrome, Ehlers-Danlos Syndrome, Turner Syndrome, etc.); **OR**
- Echocardiography is appropriate in the evaluation of suspected acute rheumatic fever

Evaluation of patients with pulmonary embolus

- In patients with known acute pulmonary embolus, echocardiography may be performed as it is useful in guiding initial decision making (thrombectomy, thrombolysis)
    - Echocardiography is not indicated in the initial evaluation of a patient with suspected pulmonary embolism in order to establish the diagnosis; **OR**
- In patients who have had a pulmonary embolus, echocardiography may be performed to evaluate right ventricular function and pulmonary artery pressure. If right ventricular function and pulmonary artery pressure are normal, repeated studies are not necessary

Evaluation of patients with pulmonary hypertension

- Echocardiography is indicated for evaluation of suspected pulmonary hypertension; **OR**
- Echocardiography is indicated in follow-up of pulmonary arterial pressures in patients with pulmonary hypertension to evaluate response to treatment; **OR**
- Echocardiography may be performed annually in clinically stable patients with an established diagnosis of pulmonary hypertension; **OR**
- Echocardiography may be performed to evaluate signs or symptoms which may be attributable to worsened pulmonary hypertension

Common Diagnostic Indications

Evaluation of aortic disease

- Echocardiography is appropriate on one occasion when ascending aortic aneurysm / dilation or dissection is suspected based on symptoms of chest pain or shortness of breath or abnormal physical findings suggesting these diagnoses
  - Although some providers will use transthoracic echocardiography in evaluation of diseases of the thoracic aorta, transesophageal echocardiography (TEE) is often preferable in this situation
- Echocardiography is indicated annually when pathology of the ascending aorta (aneurysm / dilation or dissection) is suspected because the patient has an established diagnosis of a connective tissue disease or genetic condition which predisposes to ascending aortic pathology including but not limited to Marfan syndrome, Ehlers-Danlos syndrome and familial aortic dilation (this guideline does not apply to surveillance of patients with bicuspid aortic valve – see separate guideline for this condition above)
- Echocardiography is appropriate for evaluation of the ascending aorta in patients with a suspected connective tissue disease or genetic condition which predisposes to ascending aortic pathology including but not limited to Marfan syndrome, Ehlers-Danlos syndrome and familial aortic dilation
- Annual echocardiography is appropriate in patients with an established diagnosis of ascending aortic aneurysm or dissection
  - Annual echocardiographic evaluation is usually sufficient in clinically stable patients but more frequent testing may be appropriate in some situations (e.g. in longitudinal follow-up of large or enlarging thoracic aneurysms, in follow-up of recently diagnosed thoracic aneurysms until stability is established)
- Echocardiography is appropriate in patients with an established diagnosis of ascending aortic aneurysm or dissection who develop new symptoms or signs of aortic aneurysm or dissection.

Evaluation of pericardial diseases

- Echocardiography is indicated in the evaluation of suspected pericardial conditions including but not limited to pericardial effusion, pericardial mass, constrictive pericarditis, effusive-constrictive conditions, patients post cardiac surgery or suspected pericardial tamponade
- Echocardiography is indicated in the evaluation of established pericardial conditions including but not limited to moderate and large pericardial effusion, pericardial mass, constrictive pericarditis, effusive-constrictive conditions, patients post cardiac surgery or suspected pericardial tamponade
  - Routine surveillance of known small pericardial effusions with no change in clinical status is not appropriate

Evaluation of cardiac masses or cardiac source of embolus

- Echocardiography is indicated in the diagnosis or exclusion of a cardiac source of embolus in a patient who has had or appears to have had a systemic embolic event (although transesophageal echocardiography (TEE) is often preferable in this situation)
- Echocardiography is indicated in the pre- and post-treatment evaluation of cardiac masses (tumor or thrombus)
  - Annual echocardiographic evaluation is usually sufficient in clinically stable patients with cardiac masses (tumors or thrombus) but more frequent testing may be appropriate in some situations (e.g. in longitudinal follow-up of enlarging masses or in follow-up of recently diagnosed masses until stability is established)

Computed Tomography (CT) Cardiac (Structure)

CPT Codes

75572..... Computed tomography, heart, with contrast material, for evaluation of cardiac structure and morphology (including 3-D image post-processing, assessment of cardiac function, and evaluation of venous structures if performed)

75573..... Computed tomography, heart, with contrast material, for evaluation of cardiac structure and morphology in the setting of congenital heart disease (including 3-D post-processing, assessment of left ventricular cardiac function, right ventricular structure and function and evaluation of venous structures, if performed)

Standard Anatomic Coverage

- Heart and great vessels within the thorax

Imaging Considerations

Advantages of Cardiac CT:

- Rapidly acquired exams, with excellent anatomic detail afforded by most multi-detector CT scanners with 64 or more active detector rows

Disadvantages of Cardiac CT include:

- Potential complications from use of intravascular iodinated contrast administration (see biosafety issues, below)
- Exposure to ionizing radiation
- Potential factors that may limit the image quality during acquisition of Cardiac CT such as:
  - Uncontrolled atrial or ventricular arrhythmias
  - Inability to image at a desired heart rate, which may occur despite beta blocker administration
  - Inability of the patient to comply with the requirements of scanning (patient motion during image acquisition, inability to comply with breath hold requirements, inability to lie supine, claustrophobia)
  - Because of the radiation exposure issues careful consideration should be given to other imaging modalities in pregnant women and children

Biosafety Issues:

- Ordering and imaging providers are responsible for considering safety issues prior to the cardiac CT exam. One of the most significant considerations is the requirement for intravascular iodinated contrast material, which may have an adverse effect on patients with a history of documented allergic contrast reactions or atopy, as well as on individuals with renal impairment, who are at greater risk for contrast-induced nephropathy. In addition, radiation safety issues including cumulative exposure to ionizing radiation should be considered.

Ordering Issues:

- This guideline does not apply to coronary CT angiography (CPT 75574).
- This guideline does not apply to Cardiac CT for quantitation of coronary artery calcification (CPT 75571).
- Selection of the optimal diagnostic work-up for cardiac evaluation should be made within the context of other available studies (which include transthoracic and transesophageal echocardiography and cardiac MRI), so that the resulting information facilitates patient management decisions and does not merely add a new layer of testing.
- There are uncommon circumstances when both Cardiac CT and Cardiac MRI should be ordered for the same clinical presentation. The specific rationale must be delineated at the time of request.
- In general, follow-up Cardiac CT exams should be performed only when there is a clinical change, with new signs or symptoms, or specific finding(s) requiring imaging surveillance.

Common Diagnostic Indications

Congenital heart disease

- For evaluation of suspected or established congenital heart disease in patients whose echocardiogram is technically limited or non-diagnostic; **OR**
- For further evaluation of patients whose echocardiogram suggests a new diagnosis of complex congenital heart disease; **OR**
- For evaluation of complex congenital heart disease in patients who are less than one year post surgical correction; **OR**
- For evaluation of complex congenital heart disease in patients who have new or worsening symptoms and/or a change in physical examination; **OR**
- To assist in surgical planning for patients with complex congenital heart disease; **OR**
- For surveillance in asymptomatic patients with complex congenital heart disease who have not had cardiac MRI or cardiac CT within the preceding year
    - Cardiac MRI or transesophageal echocardiography may be preferable to cardiac CT in order to avoid radiation exposure

Cardiomyopathy

- Evaluation of patients with suspected arrhythmogenic right ventricular dysplasia; **OR**
- To assess LV function in patients with suspected or established cardiomyopathy when all other non-invasive imaging is not feasible or technically suboptimal
    - Other modalities providing non-invasive evaluation of LV function include transthoracic and transesophageal echocardiography, blood pool imaging (MUGA or First pass) and cardiac MRI; **OR**
- To assess RV function in patients with suspected RV dysfunction when all other non-invasive imaging is not feasible or technically suboptimal
    - Other modalities providing non-invasive evaluation of RV function include transthoracic and transesophageal echocardiography, blood pool imaging (MUGA or First pass) and cardiac MRI

Valvular heart disease

- Evaluation of suspected dysfunction of native or prosthetic cardiac valves when all other cardiac imaging options are not feasible or technically suboptimal
    - Other modalities providing non-invasive evaluation of native or prosthetic valves include transthoracic and transesophageal echocardiography, and cardiac MRI
- Evaluation of established dysfunction of native or prosthetic cardiac valves when all other cardiac imaging options are not feasible or technically suboptimal
    - Other modalities providing non-invasive evaluation of native or prosthetic valves include transthoracic and transesophageal echocardiography, and cardiac MRI

Evaluation of patients with established coronary artery disease

- Non-invasive localization of coronary bypass grafts or potential grafts (including internal mammary artery) and/or evaluation of retrosternal anatomy in patients undergoing repeat surgical revascularization

Intra-cardiac and para-cardiac masses and tumors

- In patients with a suspected cardiac or para-cardiac mass (thrombus, tumor, etc.) suggested by transthoracic echocardiography, transesophageal echocardiography, blood pool imaging or contrast ventriculography who have not undergone cardiac CT or cardiac MRI within the preceding 60 days; **OR**
- In patients with established cardiac or para-cardiac mass (thrombus, tumor, etc.) who are clinically unstable; **OR**
- In patients with established cardiac or para-cardiac mass (thrombus, tumor, etc.) who are clinically stable and have not undergone cardiac CT or cardiac MRI within the preceding year; **OR**
- In patients with established cardiac or para-cardiac mass (thrombus, tumor, etc.) who have undergone treatment (chemotherapy, radiation therapy, thrombolysis, anticoagulation or surgery) within the preceding year and have not had cardiac CT or cardiac MRI within the preceding 60 days

Common Diagnostic Indications

Cardiac aneurysm and pseudoaneurysm

Evaluation of pericardial conditions (pericardial effusion, constrictive pericarditis, or congenital pericardial diseases)

- In patients with suspected pericardial constriction; **OR**
- In patients with suspected congenital pericardial disease; **OR**
- In patients with suspected pericardial effusion who have undergone echocardiography deemed to be technically suboptimal in evaluation of the effusion; **OR**
- In patients whose echocardiogram shows a complex pericardial effusion (loculated, containing solid material)

Evaluation of cardiac venous anatomy

- For localization of the pulmonary veins in patients with chronic or paroxysmal atrial fibrillation/flutter who are being considered for ablation; **OR**
- Coronary venous localization prior to implantation of a biventricular pacemaker

Evaluation of the thoracic aorta

- In patients with suspected thoracic aortic aneurysm / dilation who have not undergone CT or MRI of the thoracic aorta within the preceding 60 days; **OR**
- In patients with confirmed thoracic aortic aneurysm / dilation with new or worsening signs/symptoms; **OR**
- For ongoing surveillance of stable patients with confirmed thoracic aortic aneurysm / dilation who have not undergone surgical repair and have not had imaging of the thoracic aorta within the preceding six months; **OR**
- In patients with suspected aortic dissection; **OR**
- In patients with confirmed aortic dissection who have new or worsening symptoms; **OR**
- In patients with confirmed aortic dissection in whom surgical repair is anticipated (to assist in preoperative planning); **OR**
- For ongoing surveillance of stable patients with confirmed aortic dissection who have not undergone imaging of the thoracic aorta within the preceding year; **OR**
- In patients with confirmed aortic dissection or thoracic aortic aneurysm / dilation who have undergone surgical repair within the preceding year and have not undergone imaging of the thoracic aorta within the preceding six months; **OR**
- In patients who have sustained blunt chest trauma, penetrating aortic trauma or iatrogenic trauma as a result of aortic instrumentation; **OR**
- In patients being evaluated for potential transcatheter aortic valve implantation/replacement (TAVI or TAVR) provided that the patient has not undergone cardiac CT or cardiac MRI within the preceding 60 days

Coronary CT Angiography (CCTA) and CT Derived Fractional Flow Reserve (FFR-CT)

CPT Codes

75574..... Computed tomographic angiography, heart, coronary arteries and bypass grafts (where present), with contrast material, including 3-D image post-processing (including evaluation of cardiac structure and morphology, assessment of cardiac function, and evaluation of venous structures, if performed)

0501T ..... Noninvasive estimated coronary fractional flow reserve (FFR) derived from coronary computed tomography angiography data using computation fluid dynamics physiologic simulation software analysis of functional data to assess the severity of coronary artery disease; data preparation and transmission, analysis of fluid dynamics and simulated maximal coronary hyperemia, generation of estimated FFR model, with anatomical data review in comparison with estimated FFR model to reconcile discordant data, interpretation and report

0502T ..... Data preparation and transmission

0503T ..... Analysis of fluid dynamics and simulated maximal coronary hyperemia, and generation of estimated FFR model

0504T ..... Anatomical data review in comparison with estimated FFR model to reconcile discordant data, interpretation and report

Note: Codes 0501T–0504T are effective January 1, 2018. These codes should be reported if FFR is estimated from CCTA data.

Scope of this Guideline

The guideline addresses the appropriate application of CCTA and FFR-CT in the evaluation and management of outpatients. It does not address the use of CCTA and FFR-CT in the emergency room or inpatient settings.

Guideline Interpretation

This guideline does not supersede the enrollee's health plan medical policy specific to CCTA and FFR-CT.

Preamble

CCTA provides direct images of the coronary arteries (anatomical imaging); as such, it differs from more established noninvasive approaches to evaluation of the coronary arteries. Both myocardial perfusion imaging (MPI) and stress echocardiography (SE), for example, do not directly image the coronary arteries, but instead evaluate a parameter which is thought to reflect coronary blood flow to the myocardium and thereby infer the presence (or absence) of coronary stenosis (physiological imaging). In the case of MPI, myocardial uptake of an isotope is evaluated; whereas, with SE, decreased myocardial contractile reserve is assumed to be ischemic and therefore indicative of coronary stenosis.

CCTA has been compared to SE and MPI and has been found to be non-inferior, or superior, depending on the study and the endpoints evaluated. CCTA offers advantages over older approaches including shorter patient throughput times and lower radiation exposure (in the case of MPI). Furthermore, the negative predictive value of CCTA is very high (93%–100%). CCTA also has limitations including the need to use iodinated contrast agents (which may limit use in patients with renal impairment) and the reduction of image quality in morbidly obese patients, those with heavy coronary calcium burdens and those with coronary stents. Beta blockers are frequently required to slow heart rate, and claustrophobic patients may have difficulty with scanning protocols.

The ability to measure fractional flow reserve by CT (FFR-CT) has the potential to expand the clinical application of CCTA. FFR-CT adds a physiological dimension to the CCTA such that coronary stenosis can be visualized anatomically and then evaluated for flow limiting significance. Thus, the availability of FFR-CT would be expected to assist with decisions regarding subsequent care including the need for coronary angiography, the likelihood of benefit from revascularization, etc. FFR-CT cannot be performed as a stand-alone service, but rather is available (if indicated) to patients who have undergone CCTA. Currently, FFR-CT calculations are performed at a location physically removed from the imaging site following electronic transmission of the imaging data. Results are usually available within 24 hours, but shorter turnaround times are feasible on request.

Recent literature comparing CCTA combined with FFR-CT to traditional noninvasive coronary artery disease (CAD) evaluation has signaled that the former approach is non-inferior in terms of clinical endpoints and may offer advantages in terms of cost of care and radiation exposure.

Common Diagnostic Indications

The use of CT Coronary Angiography (CCTA), with or without Fractional Flow Reserve assessed by CT (FFR-CT), may be covered when accompanied by pre-test considerations as well as supporting clinical data and prerequisite information based on the following diagnostic indications.

For purposes of this guideline, a patient is considered to be "symptomatic" when one of the following (1–4) applies:

1. Chest pain
   - With intermediate or high pretest probability of CAD; **OR**
   - With low or very low pretest probability of CAD and high risk of CAD (SCORE)
2. Atypical symptoms: syncope, shortness of breath (dyspnea), neck, jaw, arm, epigastric or back pain, or sweating (diaphoresis)
   - With moderate or high risk of CAD (SCORE)
3. Other symptoms: palpitation, dizziness, lightheadedness, near syncope, nausea, vomiting, anxiety, weakness, fatigue, etc.
   - With high risk of CAD (SCORE)
4. Patients with any cardiac symptom who have diseases/conditions with which CAD commonly coexists, such as:
   - Abdominal aortic aneurysm; **OR**
   - Chronic renal insufficiency or renal failure; **OR**
   - Diabetes mellitus; **OR**
   - Established and symptomatic peripheral vascular disease; **OR**
   - Prior history of cerebrovascular accident (CVA), transient ischemic attack (TIA) or carotid endarterectomy (CEA) or high grade carotid stenosis (>70%)

Indications where FFR-CT will not be required in conjunction with CCTA

Congenital coronary artery anomalies

- For evaluation of suspected congenital anomalies of the coronary arteries

Indications where FFR-CT may be appropriate but is not a required capability of the performing imaging facility

Congestive heart failure/cardiomyopathy/left ventricular dysfunction

- For exclusion of CAD in patients with left ventricular ejection fraction <55% and low to moderate coronary heart disease risk (using standard methods of risk assessment, such as the SCORE risk calculation) in whom CAD has not been excluded as the etiology of the cardiomyopathy
  - Patients with high coronary heart disease risk should undergo cardiac catheterization

Preoperative evaluation for patients undergoing non-coronary cardiac surgery

- Evaluation of symptomatic or asymptomatic patients at moderate coronary heart disease risk (using standard methods of risk assessment, such as the SCORE risk calculation) to avoid an invasive angiogram, where all the necessary preoperative information can be obtained using cardiac CT
  - Procedures include open and percutaneous valvular procedures or ascending aortic surgery

Suspected coronary artery disease in patients who have had abnormal exercise EKG test (performed without imaging) within the past 60 days

- When both of the following apply
  - Patient is symptomatic
  - During testing the patient had exercise-induced chest pain, ST segment change, abnormal BP response or complex ventricular arrhythmias

Common Diagnostic Indications

Suspected coronary artery disease in patients who have had equivocal MPI or SE within the past 60 days

- When both of the following apply
  - Patient is symptomatic
  - The imaging portion of the study is neither clearly normal nor clearly abnormal

Suspected coronary artery disease in patients who have had abnormal MPI or SE within the past 60 days

- When both of the following apply
  - Patient is symptomatic
  - The imaging portion of the study is abnormal

Indications where FFR-CT may be appropriate and is a required capability of the imaging facility

Suspected coronary artery disease in symptomatic patients who have abnormal resting EKG

- When resting EKG abnormalities (left bundle branch block, electronically paced ventricular rhythm, left ventricular hypertrophy with repolarization abnormalities, resting ST segment depression 1 mm or more, digoxin effect or pre-excitation syndrome) would render an exercise treadmill test (without imaging) uninterpretable

Suspected coronary artery disease in symptomatic patients who have not had recent CAD evaluation

- When no CAD imaging evaluation (MPI, cardiac PET, stress echo, CCTA or coronary angiography) has been performed within the preceding sixty (60) days

References

1. Budoff MJ, Dowe D, Jollis JG, et al. Diagnostic performance of 64-multidetector row coronary computed tomographic angiography for evaluation of coronary artery stenosis in individuals without known coronary artery disease: results from the prospective multicenter ACCURACY (Assessment by Coronary Computed Tomographic Angiography of Individuals Undergoing Invasive Coronary Angiography) trial. *J Am Coll Cardiol*. 2008;52(21):1724-32.
2. Chinnaiyan KM, Peyser P, Goraya T, et al. Impact of a continuous quality improvement initiative on appropriate use of coronary computed tomography angiography. Results from a multicenter, statewide registry, the Advanced Cardiovascular Imaging Consortium. *J Am Coll Cardiol.* 2012;60(13):1185-91.
3. Chinnaiyan KM, Raff GL, Goraya T, et al. Coronary computed tomography angiography after stress testing: results from a multicenter, statewide registry, ACIC (Advanced Cardiovascular Imaging Consortium). *J Am Coll Cardiol* 2012; 59(7):688-95.
4. Dewey M, Rief M, Martus P, et al. Evaluation of computed tomography in patients with atypical angina or chest pain clinically referred for invasive coronary angiography: randomised controlled trial. *BMJ*. 2016; 355:i5441.
5. Douglas PS, De Bruyne B, Pontone G, et al; PLATFORM Investigators. 1-Year Outcomes of FFRCT-Guided Care in Patients With Suspected Coronary Disease: The PLATFORM Study. *J Am Coll Cardiol*. 2016;68(5):435-45.
6. Douglas PS, Hoffmann U, Patel MR, et al; PROMISE Investigators. Outcomes of anatomical versus functional testing for coronary artery disease. *N Engl J Med*. 2015;372(14):1291-300.
7. Douglas PS, Pontone G, Hlatky MA, et al. Clinical outcomes of fractional flow reserve by computed tomographic angiography-guided diagnostic strategies vs. usual care in patients with suspected coronary artery disease: the prospective longitudinal trial of FFR(CT): outcome and resource impacts study. *Eur Heart J*. 2015;36(47):3359-67.
8. ECRI Institute. FFRct Software (HeartFlow, Inc.) for Evaluating Coronary Artery Disease. In: Service. HTAI, editor: ECRI Institute; 2017.
9. Graham TP Jr, Driscoll DJ, Gersony WM, Newburger JW, Rocchini A, Towbin JA. Task Force 2: congenital heart disease. *J Am Coll Cardiol*. 2005;45(8):1326-33.
10. Grani C, Buechel RR, Kaufmann PA, Kwong RY. Multimodality Imaging in Individuals With Anomalous Coronary Arteries.

JACC Cardiovasc Imaging. 2017;10(4):471-81.
11. Halpern EJ, Fischman D, Savage MP, Koka AR, DeCaro M, Levin DC. Decision analytic model for evaluation of suspected coronary disease with stress testing and coronary CT angiography. *Acad Radiol*. 2010;17(5):577-86.
12. Hamilton-Craig C, Fifoot A, Hansen M, et al. Diagnostic performance and cost of CT angiography versus stress ECG--a randomized prospective study of suspected acute coronary syndrome chest pain in the emergency department (CT-COMPARE). *Int J Cardiol.* 2014;177(3):867-73.
13. Hlatky MA, De Bruyne B, Pontone G, et al; PLATFORM Investigators. Quality-of-Life and Economic Outcomes of Assessing Fractional Flow Reserve With Computed Tomography Angiography: PLATFORM. *J Am Coll Cardiol*. 2015;66(21):2315-23.
14. Hoffmann U, Ferencik M, Udelson JE, et al. Prognostic Value of Noninvasive Cardiovascular Testing in Patients With Stable Chest Pain: Insights From the PROMISE Trial (Prospective Multicenter Imaging Study for Evaluation of Chest Pain). *Circulation*. 2017;135(24):2320-32.
15. Hoffmann U, Truong QA, Schoenfeld DA, et al; ROMICAT-II Investigators. Coronary CT angiography versus standard evaluation in acute chest pain. *N Engl J Med.* 2012;367(4):299-308.
16. Jorgensen ME, Andersson C, Norgaard BL, et al. Functional Testing or Coronary Computed Tomography Angiography in Patients With Stable Coronary Artery Disease. *J Am Coll Cardiol*. 2017;69(14):1761-70.
17. Koo BK, Erglis A, Doh JH, et al. Diagnosis of ischemia-causing coronary stenoses by noninvasive fractional flow reserve computed from coronary computed tomographic angiograms. Results from the prospective multicenter DISCOVER-FLOW (Diagnosis of Ischemia-Causing Stenoses Obtained Via Noninvasive Fractional Flow Reserve) study. *J Am Coll Cardiol*. 2011;58(19):1989-97.
18. Levin DC, Parker L, Halpern EJ, Julsrud PR, Rao VM. The lack of growth in use of coronary CT angiography: is it being appropriately used? *AJR Am J Roentgenol*. 2011;196(4):862-7.
19. Litt HI, Gatsonis C, Snyder B, et al. CT angiography for safe discharge of patients with possible acute coronary syndromes. *N Engl J Med.* 2012;366(15):1393-403.
20. Lubbers M, Dedic A, Coenen A, et al. Calcium imaging and selective computed tomography angiography in comparison to functional testing for suspected coronary artery disease: the multicentre, randomized CRESCENT trial. *Eur Heart J*. 2016;37(15):1232-43.
21. Mark DB, Berman DS, Budoff MJ, et al; American College of Cardiology Foundation Task Force on Expert Consensus Documents. ACCF/ACR/AHA/NASCI/SAIP/SCAI/SCCT 2010 expert consensus document on coronary computed tomographic angiography: a report of the American College of Cardiology Foundation Task Force on Expert Consensus Documents. *Catheter Cardiovasc Interv.* 2010;76(2):E1-42.
22. Marwick TH, Cho I, B OH, et al. Finding the Gatekeeper to the Cardiac Catheterization Laboratory: Coronary CT Angiography or Stress Testing? *J Am Coll Cardiol*. 2015;65(25):2747-56.
23. McEvoy JW, Blaha MJ, Nasir K, et al. Impact of coronary computed tomographic angiography results on patient and physician behavior in a low-risk population. *Arch Intern Med*. 2011;171(14):1260-8.
24. McKavanagh P, Lusk L, Ball PA, et al. A comparison of cardiac computerized tomography and exercise stress electrocardiogram test for the investigation of stable chest pain: the clinical results of the CAPP randomized prospective trial. *Eur Heart J Cardiovasc Imaging.* 2015;16(4):441-8.
25. Meijboom WB, Meijs MF, Schuijf JD, et al. Diagnostic accuracy of 64-slice computed tomography coronary angiography: a prospective, multicenter, multivendor study. *J Am Coll Cardiol*. 2008;52(25):2135-44.
26. Miller JM, Rochitte CE, Dewey M, et al. Diagnostic performance of coronary angiography by 64-row CT. *N Engl J Med*. 2008;359(22):2324-36.
27. Min JK, Leipsic J, Pencina MJ, et al. Diagnostic accuracy of fractional flow reserve from anatomic CT angiography. *JAMA*. 2012;308(12):1237-45.
28. Nagaraja V, Mamas M, Mahmoudi M, Rogers C, Curzen N. Change in angiogram-derived management strategy of patients with chest pain when some FFR data are available: How consistent is the effect? *Cardiovasc Revasc Med*. 2017;18(5):320-7.
29. Nakanishi R, Budoff MJ. Noninvasive FFR derived from coronary CT angiography in the management of coronary artery disease: technology and clinical update. *Vasc Health Risk Manag*. 2016;12:269-78.
30. Nakazato R, Park HB, Berman DS, et al. Noninvasive fractional flow reserve derived from computed tomography angiography for coronary lesions of intermediate stenosis severity: results from the DeFACTO study. *Circ Cardiovasc Imaging*. 2013;6(6):881-9.
31. National Institute for Health and Care Excellence (NICE). HeartFlow FFRct for estimating fractional flow reserve from

coronary CT angiography. Medical technology consultation document (MTG32). London: Royal College of Physicians (UK); National Clinical Guideline Centre; 2017. p. 28.

32. Nielsen LH, Ortner N, Norgaard BL, Achenbach S, Leipsic J, Abdulla J. The diagnostic accuracy and outcomes after coronary computed tomography angiography vs. conventional functional testing in patients with stable angina pectoris: a systematic review and meta-analysis. *Eur Heart J Cardiovasc Imaging*. 2014;15(9):961-71.
33. Norgaard BL, Leipsic J, Gaur S, et al; NXT Trial Study Group. Diagnostic performance of noninvasive fractional flow reserve derived from coronary computed tomography angiography in suspected coronary artery disease: the NXT trial (Analysis of Coronary Blood Flow Using CT Angiography: Next Steps). *J Am Coll Cardiol*. 2014;63(12):1145-55.
34. Patel MR, Peterson ED, Dai D, et al. Low diagnostic yield of elective coronary angiography. *N Engl J Med.* 2010;362(10):886-95.
35. Perk J, De Backer G, Gohlke H, et al. European Guidelines on cardiovascular disease prevention in clinical practice (version 2012). The Fifth Joint Task Force of the European Society of Cardiology and Other Societies on Cardiovascular Disease Prevention in Clinical Practice (constituted by representatives of nine societies and by invited experts). *Eur Heart J*. 2012;33(13):1635-701.
36. Rajani R, Webb J, Marciniak A, Preston R. Comparative efficacy testing - fractional flow reserve by coronary computed tomography for the evaluation of patients with stable chest pain. *Int J Cardiol*. 2015;183:173-7.
37. Rogers IS, Banerji D, Siegel EL, et al. Usefulness of comprehensive cardiothoracic computed tomography in the evaluation of acute undifferentiated chest discomfort in the emergency department (CAPTURE). *Am J Cardiol.* 2011;107(5):643-50.
38. Roifman I, Wijeysundera HC, Austin PC, et al. Comparison of Anatomic and Clinical Outcomes in Patients Undergoing Alternative Initial Noninvasive Testing Strategies for the Diagnosis of Stable Coronary Artery Disease. *J Am Heart Assoc*. 2017;6(7).
39. Ropers D, Moshage W, Daniel WG, Jessl J, Gottwik M, Achenbach S. Visualization of coronary artery anomalies and their anatomic course by contrast-enhanced electron beam tomography and three-dimensional reconstruction. *Am J Cardiol*. 2001;87(2):193-7.
40. SCOT-HEART Investigators. CT coronary angiography in patients with suspected angina due to coronary heart disease (SCOT-HEART): an open-label, parallel-group, multicentre trial. *Lancet*. 2015;385(9985):2383-91.
41. Shreibati JB, Baker LC, Hlatky MA. Association of coronary CT angiography or stress testing with subsequent utilization and spending among Medicare beneficiaries. *JAMA*. 2011;306(19):2128-36.
42. Tonino PA, De Bruyne B, Pijls NH, et al; FAME Study Investigators. Fractional flow reserve versus angiography for guiding percutaneous coronary intervention. *N Engl J Med*. 2009;360(3):213-24.
43. Williams MC, Hunter A, Shah ASV, et al; SCOT-HEART Investigators. Use of Coronary Computed Tomographic Angiography to Guide Management of Patients With Coronary Disease. *J Am Coll Cardiol*. 2016;67(15):1759-68.

Cardiac Computed Tomography (CT) for Quantitative Evaluation of Coronary Calcification

CPT Codes

75571..... Computed tomography, heart, without contrast material, with quantitative evaluation of coronary artery calcium

Standard Anatomic Coverage

- Coronary Artery Imaging

Imaging Considerations

Advantages of cardiac CT for quantitative evaluation of coronary artery calcification:

- Rapidly acquired exams
- Coronary artery calcification has been shown to correlate with the presence of atheromatous coronary artery disease

Disadvantages of cardiac CT for quantitative evaluation of coronary artery calcification:

- Exposure to ionizing radiation
- No role in the evaluation of patients with symptoms potentially due to coronary artery disease
- Not clear that risk stratification data provided by quantitative evaluation of coronary artery calcification impacts patient outcomes

Biosafety issues:

- Ordering and imaging providers are responsible for considering safety issues prior to performing quantitative evaluation of coronary artery calcification

Ordering issues:

- Cardiac CT for quantitative evaluation of coronary artery calcification is not covered by most healthcare insurers as a screening study.
- Selection of the optimal diagnostic work-up for cardiac evaluation should be made within the context of other available studies (which include treadmill stress test, stress myocardial perfusion imaging, stress echocardiography, cardiac MRI, cardiac PET imaging and invasive cardiac/coronary angiography), so that the resulting information facilitates patient management decisions and does not merely add a new layer of testing.
- This guideline pertains to cardiac CT for quantitative evaluation of coronary artery calcification using either Electron Beam CT (EBCT) or Multi-Detector CT (MDCT).
- This guideline does not apply to coronary CT angiography (CPT 75574).
- This guideline does not apply to cardiac CT for evaluation of cardiac structure and function (CPT 75572-75573).

Quantitative Evaluation of Coronary Artery Calcification

The use of cardiac CT for quantitative evaluation of coronary artery calcification has not been conclusively shown to impact patient outcomes and is therefore considered to be not medically necessary in all clinical situations

Magnetic Resonance Imaging (MRI) Cardiac

CPT Codes

75557..... Cardiac MRI for morphology and function, without contrast material
75559..... Cardiac MRI for morphology and function, without contrast material, with stress imaging
75561..... Cardiac MRI for morphology and function, without contrast material, followed by contrast material
75563..... Cardiac MRI for morphology and function, without contrast material, followed by contrast material with stress imaging
75565..... Add-on code to be used in conjunction with 75557, 75559, 75561, and 75563. As such, this code does not require separate review.

Coding Considerations

Only one procedure in the series 75557–75563 is appropriately reported per session.

Imaging Considerations

Patient Compatibility Issues:

- Gating Issues: As with other cardiac imaging modalities, the acquisition of images is frequently gated to the electrocardiogram. Thus, in patients with irregular heart rhythms, image quality may be suboptimal.

Biosafety Issues:

- Ordering and imaging providers are responsible for considering biosafety issues prior to MRI examination, to ensure patient safety. Among the generally recognized contraindications to MRI exam performance are permanent pacemakers (some newer models are MRI compatible) or implantable cardioverter-defibrillators (ICD), intracranial aneurysm surgical clips that are not compatible with MR imaging, as well as other devices considered unsafe in MRI scanners (including certain implanted materials in the patient as well as external equipment, such as portable oxygen tanks).
- Contrast utilization is at the discretion of the ordering and imaging providers.

Ordering Issues:

- Selection of the optimal diagnostic work-up for cardiac evaluation should be made within the context of other available studies (which include treadmill stress test, stress myocardial perfusion imaging, stress echocardiography, cardiac MRI, cardiac PET imaging and invasive cardiac/coronary angiography), so that the resulting information facilitates patient management decisions and does not merely add a new layer of testing.

Common Diagnostic Indications

Coronary artery disease

Patients who have had a myocardial infarction

- To assess viability of the infarcted myocardium utilizing delayed hyperenhancement (contrast studies) when other studies (myocardial perfusion imaging or stress echocardiography) have yielded equivocal or indeterminate results; **OR**
- To assess LV function post myocardial infarction when there is discordant information from other studies or when other studies are technically suboptimal; **OR**
- To assess mitral valve regurgitation post-myocardial infarction when echocardiography is technically suboptimal; **OR**
- To assess ventricular septal defects post-myocardial infarction when echocardiography is technically suboptimal; **OR**
- To delineate pericardial effusions associated with acute myocardial infarction when echocardiography is technically suboptimal

Patients with suspected coronary artery disease

- For evaluation of patients with suspected congenital coronary anomalies

Common Diagnostic Indications

Myocarditis

- For the evaluation of patients with suspected myocarditis; **OR**
- For follow-up evaluation LV function of patients with an established diagnosis of myocarditis whose transthoracic echocardiogram is technically suboptimal

Cardiomyopathy

- To assess LV function in symptomatic patients with suspected or established cardiomyopathy when there is discordant information from other studies or when other studies are technically suboptimal; **OR**
- Annual evaluation for suspected cardiomyopathy in clinically stable patients with an established diagnosis of a chronic and progressive disease (excluding CAD) which may result in cardiomyopathy when echocardiography fails to exclude cardiomyopathy. This guideline applies to infiltrative cardiomyopathies (e.g. sarcoidosis; amyloidosis; hemochromatosis), hypertrophic obstructive cardiomyopathy (HOCM) and non-compaction cardiomyopathy; **OR**
- Reevaluation of clinically stable patients with cardiomyopathy at yearly intervals when echocardiography is technically suboptimal; **OR**
- Evaluation of patients with suspected arrhythmogenic right ventricular dysplasia; **OR**
- For coronary vein mapping in patients with cardiomyopathy for whom cardiac resynchronization therapy (CRT) is planned

Cardiac aneurysm or pseudoaneurysm

Congenital heart disease

- For evaluation of suspected congenital anomalies of the coronary arteries; **OR**
- For evaluation of suspected or established congenital heart disease in patients whose echocardiogram is technically limited or nondiagnostic; **OR**
- For further evaluation of patients whose echocardiogram suggests a new diagnosis of complex congenital heart disease; **OR**
- For evaluation of complex congenital heart disease in patients who are less than one year post surgical correction; **OR**
- For evaluation of complex congenital heart disease in patients who have new or worsening symptoms and/or a change in physical examination; **OR**
- To assist in surgical planning for patients with complex congenital heart disease; **OR**
- For surveillance in asymptomatic patients with complex congenital heart disease who have not had cardiac MRI or cardiac CT within the preceding year

Valvular heart disease

- Following inconclusive echocardiography or when echocardiography is not feasible; **OR**
- When moderate or severe valvular disease diagnosed using other imaging modalities requires further definition and that information is likely to affect subsequent management of the patient
    - To assess valvular lesions and measure regurgitant volume, regurgitant fraction, ejection fraction and ventricular volumes
    - To help determine the timing for valvular surgery

Intra-cardiac and para-cardiac masses and tumors

- In patients with a suspected cardiac or para-cardiac mass (thrombus, tumor, etc.) suggested by transthoracic echocardiography, transesophageal echocardiography, blood pool imaging or contrast ventriculography who have not undergone cardiac MRI or cardiac CT within the preceding 60 days; **OR**
- In patients with established cardiac or para-cardiac mass (thrombus, tumor, etc.) who are clinically unstable; **OR**
- In patients with established cardiac or para-cardiac mass (thrombus, tumor, etc.) who are clinically stable and have not undergone cardiac MRI or cardiac CT within the preceding year; **OR**
- In patients with established cardiac or para-cardiac mass (thrombus, tumor, etc.) who have undergone treatment (chemotherapy, radiation therapy, thrombolysis, anticoagulation or surgery) within the preceding year and have not had cardiac MRI or cardiac CT within the preceding 60 days

Common Diagnostic Indications

Evaluation of cardiac venous anatomy

- For localization of the pulmonary veins in patients with chronic or paroxysmal atrial fibrillation/flutter who are being considered for ablation; **OR**
- Coronary venous localization prior to implantation of a biventricular pacemaker

Evaluation of pericardial conditions (pericardial effusion, constrictive pericarditis, or congenital pericardial diseases)

- In patients with suspected pericardial constriction; **OR**
- In patients with suspected congenital pericardial disease; **OR**
- In patients with suspected pericardial effusion (including hemopericardium) who have undergone echocardiography deemed to be technically suboptimal in evaluation of the effusion; **OR**
- In patients whose echocardiogram shows a complex pericardial effusion (loculated, containing solid material)

Evaluation of the thoracic aorta

- In patients with suspected thoracic aortic aneurysm / dilation who have not undergone CT or MRI of the thoracic aorta within the preceding 60 days; **OR**
- In patients with confirmed thoracic aortic aneurysm / dilation with new or worsening signs/symptoms; **OR**
- For ongoing surveillance of stable patients with confirmed thoracic aortic aneurysm / dilation who have not undergone imaging of the thoracic aorta within the preceding six months; **OR**
- In patients with suspected aortic dissection; **OR**
- In patients with confirmed aortic dissection who have new or worsening symptoms; **OR**
- In patients with confirmed aortic dissection in whom surgical repair is anticipated (to assist in pre-operative planning); **OR**
- For ongoing surveillance of stable patients with confirmed aortic dissection who have not undergone imaging of the thoracic aorta within the preceding year; **OR**
- In patients with confirmed aortic dissection or thoracic aortic aneurysm / dilation who have undergone surgical repair within the preceding year and have not undergone imaging of the thoracic aorta within the preceding six months; **OR**
- In patients who have sustained blunt chest trauma, penetrating aortic trauma or iatrogenic trauma as a result of aortic instrumentation; **OR**
- In patients being evaluated for potential transcatheter aortic valve implantation/replacement (TAVI or TAVR) provided that the patient has not undergone cardiac CT or cardiac MRI within the preceding 60 days

Positron Emission Tomography (PET) Myocardial Imaging

CPT Codes

78491..... PET myocardial perfusion, single study

78492..... PET myocardial perfusion, multiple studies

78459..... PET myocardial, metabolic evaluation

Commonly Used Radiopharmaceuticals

- Ammonia (13NH3)
- Rubidium Chloride (82 RbCl)
- 2-(18F) FLURO-2DEOXY-D-GLUCOSE (FDG)

Imaging Considerations

- Perfusion PET imaging, using ammonia or rubidium isotopes, is used to differentiate areas of myocardium with normal coronary blood flow from those with abnormal coronary blood flow.
- Rest and/or pharmacological stress perfusion PET imaging can be performed.
- When non-invasive imaging is required in morbidly obese patients (BMI > or = 40 kg/m2), with suspected or established CAD, perfusion PET imaging may be considered as the initial test (because of a higher likelihood of technically suboptimal image quality on nuclear stress testing and stress echocardiography in this patient subgroup).
- PET perfusion imaging may also be a preferable initial noninvasive test for other patients in whom conventional nuclear perfusion imaging is likely to be suboptimal including those with breast implants, previous mastectomy, pleural or pericardial effusion, chest wall deformity and those with suboptimal prior nuclear imaging due to attenuation artifact.
- Perfusion PET myocardial imaging is not appropriate for screening for coronary artery disease in asymptomatic low-risk patients regardless of age or body habitus. Whenever possible and clinically appropriate, exercise stress testing should be used in preference to pharmacological testing. However, for patients who are unable to exercise or who have baseline EKG abnormalities which make pharmacological testing preferable, PET imaging is preferable to conventional nuclear perfusion imaging or stress echocardiography.
- Metabolic evaluation (to determine myocardial viability) is performed using PET flurodeoxyglucose (FDG) imaging. Metabolic PET imaging has been shown to be useful in identification of patients who are likely to benefit from revascularization.
- PET metabolic imaging of the myocardium provides clinically useful information only when the myocardium is deemed to be nonviable using other imaging modalities (conventional nuclear perfusion imaging or echocardiography) or when such imaging modalities are inconclusive regarding the viability status of the myocardium.
- Perfusion PET imaging and metabolic PET imaging may occasionally be appropriate in the evaluation of myocardial pathologic processes other than coronary artery disease (e.g. sarcoidosis).
- Isotopes used in PET imaging require special handling arrangements because of their short half-lives.
- While rubidium may be produced in a commercially available on-site generator, ammonia requires cyclotron production.
- Cardiac PET perfusion imaging has higher temporal and special resolution than conventional nuclear perfusion imaging.
- Cardiac PET has the ability to quantify regional myocardial blood flow and myocardial flow reserve, and this information may be useful in determining optimal treatment.
- Prognostic information derived from cardiac PET perfusion imaging is enhanced by gated imaging used to provide LV function evaluation.

- Radiation exposure should be considered in selection of the optimal study for evaluation for cardiac disease.
- Selection of the optimal diagnostic imaging for cardiac evaluation should be made within the context of other available modalities (which include treadmill stress test, conventional nuclear perfusion imaging, stress echocardiography, cardiac CT, cardiac MRI and invasive cardiac/coronary angiography), so that the resulting information facilitates patient management decisions and does not merely add a new layer of testing.

Note: *For the purposes of interpretation of this guideline, the term "conventional nuclear perfusion imaging" refers to imaging using Thallium or Technetium isotopes.*

Common Diagnostic Indications for PET Perfusion Imaging

PET perfusion imaging is appropriate as the **initial** noninvasive stress imaging test for suspected or established CAD for patients who have a relative contraindication(s) to conventional nuclear perfusion imaging (Table 1) and/or a contraindication to exercise stress testing (Table 2) who meet any of the indications for stress testing outlined below.

Table 1. Relative contraindications to conventional nuclear perfusion imaging
Morbid obesity (BMI > or = 40 kg/m^2)
Breast implant(s) in situ
Previous suboptimal conventional nuclear perfusion imaging which was suboptimal due to attenuation artifact
Previous conventional nuclear imaging discordant with coronary angiographic findings
Known pericardial or pleural effusion
Prior mastectomy
Chest wall deformity
Table 2. Contraindications to exercise stress testing
1. Resting EKG abnormalities a. Complete left bundle branch block LBBB b. Electronically paced ventricular rhythm c. Resting ST depression > 1mm d. Left ventricular hypertrophy (LVH) with secondary repolarization abnormalities e. Digoxin effect f. Pre-excitation (e.g. Wolfe Parkinson White syndrome) g. Previous false positive EKG stress test
2. Conditions limiting exercise capacity such that target heart rate (HR) is unlikely to be achieved a. Orthopedic or neurological impairment b. Severe COPD c. Severe heart failure d. Severe claudication e. Prior failure to achieve target HR f. Use of negatively chronotropic medications which cannot be temporarily withheld for testing
3. Severe valvular stenosis
4. Presence of an implanted cardioverter-defibrillator (ICD)

Common Diagnostic Indications for PET Perfusion Imaging

Suspected coronary artery disease in asymptomatic patients

- Patients with high-risk of CAD (SCORE) who have not had evaluation of coronary artery disease (MPI, stress echo, cardiac PET, coronary CTA or cardiac catheterization) within the preceding three (3) years; **OR**
- Patients with moderate or high risk of CAD (SCORE) who have a high risk occupation that would endanger others in the event of a myocardial infarction, for example: airline pilot, law-enforcement officer, firefighter, mass transit operator, bus driver) who have not had evaluation of coronary artery disease (MPI, stress echo, cardiac PET, coronary CTA or cardiac catheterization) within the preceding three (3) years; **OR**
- Patients with diseases/conditions with which coronary artery disease commonly coexist and who have not had evaluation of coronary artery disease (MPI, stress echo, cardiac PET, coronary CTA or cardiac catheterization) within the preceding three (3) years:
  - Diabetes mellitus; **OR**
  - Abdominal aortic aneurysm; **OR**
  - Established and symptomatic peripheral vascular disease; **OR**
  - Prior history of cerebrovascular accident (CVA), transient ischemic attack (TIA) or carotid endarterectomy (CEA) or high grade carotid stenosis (>70%); **OR**
  - Chronic renal insufficiency or renal failure; **OR**
- Patients who have undergone cardiac transplantation and have had no evaluation for coronary artery disease within the preceding one (1) year; **OR**
- Patients in whom a decision has been made to treat with interleukin 2
- Patients awaiting solid organ transplantation who have not undergone evaluation for coronary artery disease within the preceding one (1) year

Suspected coronary artery disease in symptomatic patients who have not had evaluation of coronary artery disease (MPI, stress echo, cardiac PET, coronary CTA or cardiac catheterization) within the preceding sixty (60) days

- Chest pain
  - With intermediate or high pretest probability of CAD (Table 1); **OR**
  - With low or very low pretest probability of CAD (Table 1) and high risk of CAD (SCORE)
- Atypical symptoms: syncope, shortness of breath (dyspnea), neck, jaw, arm, epigastric or back pain, or sweating (diaphoresis)
  - With moderate or high risk of CAD (SCORE)
- Other symptoms; palpitation, dizziness, lightheadedness, near syncope, nausea, vomiting, anxiety, weakness, fatigue, etc.
  - With high risk of CAD (SCORE)
- Patients with any cardiac symptom who have diseases/conditions with which coronary artery disease commonly coexists such as:
  - Diabetes mellitus; **OR**
  - Abdominal aortic aneurysm; **OR**
  - Established and symptomatic peripheral vascular disease; **OR**
  - Prior history of cerebrovascular accident (CVA), transient ischemic attack (TIA) or carotid endarterectomy (CEA) or high grade carotid stenosis (>70%); **OR**
  - Chronic renal insufficiency or renal failure; **OR**
- Patients who have undergone cardiac transplantation; **OR**
- Patients in whom a decision has been made to treat with Interleukin 2; **OR**
- Patients awaiting solid organ transplantation

Established coronary artery disease in asymptomatic patients

- Patients awaiting solid organ transplantation who have not undergone evaluation for coronary artery disease within the preceding one (1) year

Common Diagnostic Indications for PET Perfusion Imaging

Established coronary artery disease (diagnosed by previous cardiac catheterization, MPI, cardiac PET, or stress echo) in patients who have new or worsening symptoms

Note: *If symptoms are typical of myocardial ischemia, cardiac catheterization may be more appropriate than perfusion PET imaging.*

Established coronary artery disease (diagnosed by previous cardiac catheterization, MPI, cardiac PET, or stress echo) in patients who have not undergone revascularization and have no symptoms or stable symptoms

- No evaluation of CAD (MPI, stress echo, cardiac PET, coronary CTA or cardiac catheterization) within the preceding three (3) years
- No evaluation of CAD (MPI, cardiac PET, stress echo, coronary CTA or cardiac catheterization) within the preceding one (1) year in a patient who has undergone cardiac transplantation and has been found to have CAD since transplantation

Established coronary artery disease in patients who have undergone revascularization

- For evaluation of new or worsening cardiac symptoms
  - If symptoms are typical of myocardial ischemia, cardiac catheterization may be more appropriate than MPI; **OR**
- For evaluation of stable patients who have undergone coronary artery bypass grafting more than five (5) years previously and who have not had an evaluation for coronary artery disease (MPI, stress echo, cardiac PET, coronary CTA or cardiac catheterization) within the past two (2) years
  - Stable patients whose revascularization has been incomplete may undergo MPI three (3) years following the procedure and every three (3) years thereafter; **OR**
- For evaluation of stable patients who have undergone percutaneous coronary intervention (PCI) more than three (3) years previously and who have not had an evaluation for coronary artery disease (MPI, stress echo, cardiac PET, coronary CTA or cardiac catheterization) within the past three (3) years when any of the following applies
  - The patient has undergone PCI of the left main (LM) coronary artery or the proximal left anterior descending (LAD) coronary artery
  - The patient has undergone PCI of more than one coronary artery
  - The patient has chronic total occlusion of a coronary artery and the vessel on which PCI was performed is supplying collateral flow to the occluded vessel
  - The patient is known to have only one patent coronary artery.
  - Left ventricular ejection fraction LVEF is <35%

Established coronary artery disease in patients who have had myocardial infarction (ST elevation or non-ST elevation) or unstable angina within the preceding ninety (90) days provided that:

- The patient did not undergo coronary angiography at the time of the acute event; **AND**
- The patient is currently clinically stable

Established Kawasaki disease with coronary artery involvement

- Every two-year evaluation for confirmed small to medium coronary artery aneurysm
- Annual evaluation for confirmed large (giant) coronary artery aneurysm, multiple or complex aneurysms or coronary artery obstruction confirmed by angiography

Common Diagnostic Indications for PET Perfusion Imaging

Patients with new onset arrhythmias (patient can be symptomatic or asymptomatic)

This guideline applies to patients with suspected or established CAD.

- Patients with sustained (lasting more than 30 seconds) or non-sustained (more than 3 beats but terminating within 30 seconds) ventricular tachycardia; **OR**
- Patients with atrial fibrillation or flutter and high or moderate risk of CAD (SCORE); **OR**
- Patients with atrial fibrillation or flutter and established CAD; **OR**
- Patients who have frequent premature ventricular contractions (PVC) defined as more than thirty (30) PVCs per hour on ambulatory EKG (Holter) monitoring
    - It is not clinically indicated to perform perfusion PET imaging for evaluation of infrequent premature atrial or ventricular depolarizations

Patients with new onset congestive heart failure or recently recognized left ventricular systolic dysfunction (patient can be symptomatic or asymptomatic)

This guideline applies to patients with suspected or established CAD.

For patients in this category whose CAD risk (SCORE) is high, cardiac catheterization may be more appropriate than non-invasive evaluation.

- Provided that new or worsening CAD has not been excluded as the cause of LV dysfunction/ CHF by any of the following tests: MPI, stress echo, cardiac PET, coronary CTA or cardiac catheterization

Patients with abnormal exercise treadmill test (performed without imaging)

This guideline applies to patients with suspected or established CAD.

- Abnormal findings on an exercise treadmill test include (chest pain, ST segment change, abnormal BP response or complex ventricular arrhythmias)

Patients with abnormal findings on cardiac CT / coronary CTA

Symptomatic Patients:

- With coronary artery calcium score > 400 Agatston units; **OR**
- Intermediate severity coronary stenosis on coronary CTA

Note: *If symptoms are typical of myocardial ischemia, cardiac catheterization may be more appropriate than MPI.*

Asymptomatic patients who have not had MPI, stress echo, cardiac PET or cardiac catheterization within the preceding three (3) years:

- With coronary artery calcium score > 400 Agatston units; **OR**
- Intermediate severity coronary stenosis coronary CTA

Patients with abnormal findings on cardiac catheterization

- To determine flow limiting significance of intermediate coronary stenosis

Common Diagnostic Indications for PET Perfusion Imaging

Pre-operative cardiac evaluation of patients undergoing non-cardiac surgery

This guideline applies to patients undergoing non-emergency surgery.

It is assumed that those who require emergency surgery will undergo inpatient preoperative evaluation.

- Patients with active cardiac conditions such as unstable coronary syndromes (unstable angina), decompensated heart failure (NYHA function of class IV, worsening or new onset heart failure), significant arrhythmias (third degree AV block Mobitz II AV block, uncontrolled supraventricular arrhythmia, symptomatic ventricular arrhythmias, ventricular tachycardia), symptomatic bradycardia or severe stenotic valvular lesions. It is recommended that these conditions be evaluated and managed per ACC/AHA guidelines prior to considering elective surgery. That evaluation may include MPI.

Low-risk surgery (endoscopic procedures, superficial procedures, cataract surgery, breast surgery, ambulatory surgery)

- Provided that there are no active cardiac conditions (as outlined above), MPI prior to low-risk surgery is considered not medically necessary.

Intermediate-risk surgery (including but not limited to intraperitoneal and intrathoracic surgery, carotid endarterectomy, head and neck surgery, orthopedic surgery, prostate surgery, gastric bypass surgery) or **High-risk surgery** (including but not limited to aortic and other major vascular surgery, peripheral vascular surgery) when

- The patient has not had a normal coronary angiogram, SE, MPI, CCTA, Cardiac PET perfusion study or revascularization procedure within the previous one (1) year; **AND**
- At least one of the following applies:
  - Patient has established CAD (prior MI, prior PTCA, stent, or CABG) or presumed CAD (Q waves on EKG, abnormal MPI, SE or cardiac PET); **OR**
  - Patient has compensated heart failure or prior history of heart failure (CHF); **OR**
  - Patient has diabetes mellitus; **OR**
  - Patient has chronic renal insufficiency or renal failure; **OR**
  - Patient has a history of cerebrovascular disease (TIA, CVA or documented carotid stenosis requiring carotid endarterectomy)

PET perfusion imaging is appropriate in follow up to other noninvasive stress imaging tests in the following situations:

Patients who have undergone recent (within the past 60 days) stress echocardiography or conventional nuclear perfusion imaging

- When the initial test is technically suboptimal, technically limited, inconclusive, indeterminate, or equivocal, such that myocardial ischemia cannot be adequately excluded
  - It is not appropriate to perform PET perfusion imaging on patients who have had a recent normal or abnormal stress echocardiogram or conventional nuclear perfusion imaging test.
  - An initial stress imaging test is deemed to be abnormal when there are echocardiographic or perfusion abnormalities. Studies with electrocardiographic abnormalities without echocardiographic or perfusion evidence of ischemia are considered to be normal studies.

PET perfusion imaging – sarcoidosis:

PET perfusion imaging is appropriate in the evaluation of patients with suspected or established cardiac sarcoidosis when performed in conjunction with metabolic PET imaging

Common Diagnostic Indications for Metabolic PET Imaging

Metabolic PET imaging for evaluation of myocardial viability – when all four of the following conditions are met:

- The patient has established coronary artery disease; **AND**
- Left ventricular systolic dysfunction; **AND**
- Viability status is not defined by other testing; **AND**
- Revascularization is being considered

Metabolic PET imaging for evaluation of non-coronary cardiac diseases

- Metabolic PET imaging (with or without perfusion imaging) may be used in the diagnosis or management of cardiac sarcoidosis

References

1. Akers SR, Panchal V, Ho VB, et al.; Expert Panel on Cardiac Imaging. ACR Appropriateness Criteria® Chronic Chest Pain-High Probability of Coronary Artery Disease. *J Am Coll Radiol.* 2017;14(5s):S71-S80.
2. Al Moudi M, Sun Z, Lenzo N. Diagnostic value of SPECT, PET and PET/CT in the diagnosis of coronary artery disease: A systematic review. *Biomed Imaging Interv J*. 2011;7(2):e9.
3. Bateman TM, Dilsizian V, Beanlands RS, DePuey EG, Heller GV, Wolinsky DA. American Society of Nuclear Cardiology and Society of Nuclear Medicine and Molecular Imaging Joint Position Statement on the Clinical Indications for Myocardial Perfusion PET. *J Nucl Med.* 2016;57(10):1654-1656.
4. Bateman TM, Heller GV, McGhie AI, et al. Diagnostic accuracy of rest/stress ECG-gated Rb-82 myocardial perfusion PET: comparison with ECG-gated Tc-99m sestamibi SPECT. *J Nucl Cardiol.* 2006;13(1):24-33.
5. Di Carli MF, Murthy VL. Cardiac PET/CT for the evaluation of known or suspected coronary artery disease. *Radiographics*. 2011;31(5):1239-54.
6. Dorbala S, Di Carli MF, Beanlands RS, et al. Prognostic value of stress myocardial perfusion positron emission tomography: results from a multicenter observational registry. *J Am Coll Cardiol.* 2013;61(2):176-84.
7. Heller GV, Beanlands R, Merlino DA, et al. ASNC model coverage policy: Cardiac positron emission tomographic imaging. *J Nucl Cardiol.* 2013;20(5):916-47.
8. Jaarsma C, Leiner T, Bekkers SC, et al. Diagnostic performance of noninvasive myocardial perfusion imaging using single-photon emission computed tomography, cardiac magnetic resonance, and positron emission tomography imaging for the detection of obstructive coronary artery disease: a meta-analysis. *J Am Coll Cardiol*. 2012;59(19):1719-28.
9. Lertsburapa K, Ahlberg AW, Bateman TM, et al. Independent and incremental prognostic value of left ventricular ejection fraction determined by stress gated rubidium 82 PET imaging in patients with known or suspected coronary artery disease. *J Nucl Cardiol.* 2008;15(6):745-53.
10. Machac J. Cardiac positron emission tomography imaging. *Semin Nucl Med*. 2005;35(1):17-36.
11. Mc Ardle BA, Dowsley TF, deKemp RA, Wells GA, Beanlands RS. Does rubidium-82 PET have superior accuracy to SPECT perfusion imaging for the diagnosis of obstructive coronary disease?: A systematic review and meta-analysis. *J Am Coll Cardiol.* 2012;60(18):1828-37.
12. Merhige ME, Breen WJ, Shelton V, Houston T, D'Arcy BJ, Perna AF. Impact of myocardial perfusion imaging with PET and (82)Rb on downstream invasive procedure utilization, costs, and outcomes in coronary disease management. *J Nucl Med*. 2007;48(7):1069-76.
13. Parker MW, Iskandar A, Limone B, et al. Diagnostic accuracy of cardiac positron emission tomography versus single photon emission computed tomography for coronary artery disease: a bivariate meta-analysis. *Circ Cardiovasc Imaging*. 2012;5(6):700-7.

Cardiac Bibliography

1. American College of Cardiology. *Choosing Wisely: Five Things Physicians and Patients Should Question*. Philadelphia, PA: ABIM Foundation; 2012. http://choosingwisely.org/wp-content/uploads/2012/04/5things_12_factsheet_Amer_Coll_Cardio.pdf. Accessed May 15, 2012.
2. American Society of Nuclear Cardiology. *Choosing Wisely: Five Things Physicians and Patients Should Question*. Philadelphia, PA: ABIM Foundation; 2012. http://choosingwisely.org/wp-content/uploads/2012/04/5things_12_factsheet_Amer_Soc_Nuc_Cardio.pdf. Accessed May 15, 2012.
3. Anderson JL, Adams CD, Antman EM, et al. ACC/AHA 2007 guidelines for the management of patients with unstable angina/non-ST-elevation myocardial infarction. *J Am Coll Cardiol*. 2007;50(7):e1-157.
4. Antman EM, Anbe DT, Armstrong PW, et al. ACC/AHA guidelines for the management of patients with ST-elevation myocardial infarction. *J Am Coll Cardiol*. 2004;44(3):671-719.
5. Armstrong W, Zoghbi W. Stress echocardiography-current methodology and clinical applications. *J Am Coll Cardiol*. 2005;45(11):1739-1747.
6. Bacharach SL, Bax JJ, et al. PET myocardial glucose metabolism and perfusion imaging: part 1—guidelines for patient preparation and data acquisition. *J Nucl Cardiol*. 2003;10(5):543-554.
7. Balady GJ, Larson MG, Vasan RS, et al. Usefulness of exercise testing in the prediction of coronary disease risk among asymptomatic persons as a function of the framingham risk score. *Circulation*. 2004:110(14):1920-1925.
8. Bengel FM, Higuchi T, Javadi MS, Lautamäki R. Cardiac positron emission tomography. *J Am Coll Cardiol*. 2009;54(1);1-15.
9. Bomma C, Dalal D, Tandri H, et al. Evolving role of multidetector computed tomography in evaluation of arrhythmogenic right ventricular dysplasia/cardiomyopathy. *Am J Cardiol*. 2007;100(1):99-105.
10. Bonow RO, Carabello BA, Chatterjee K, et al. ACC/AHA 2006 guidelines for the management of patients with valvular heart disease. *J Am Coll Cardiol*. 2006;48(3):e1-148.
11. Botvinick EH. Scintigraphic blood pool and phase image analysis: the optimal tool for evaluation of resynchronization therapy. *J Nucl Cardiol*. 2003;10(4):424-428.
12. Cheitline MD, Armstrong WF, Aurigemma GP, et al. ACC/AHA/ASE 2003 guideline update for the clinical application of echocardiography. *J Am Coll Cardiol*. 2003;42(5):954-970.
13. Chiles C, Carr JJ. Vascular Diseases of the Thorax: Evaluation with Multidetector CT. *Radiol Clin N Am*. 2005;43(3):543-569.
14. Conroy RM, Pyorala K, Fitzgerald AP, et al. Estimation of ten-year risk of fatal cardiovascular disease in Europe: the SCORE project. *Eur Heart J*. 2003;24(11):987-1003.
15. Crean A, Dutka D, Coulden R. Cardiac imaging using nuclear medicine and positron emission tomography. *Radiol Clin N Am*. 2004;42(3):619-634.
16. Datta J, White CS, Gikleson RC, et al. Anomalous coronary arteries in adults: depiction at multi-detector row CT angiography. *Radiology*. 2005;235(3):812-818.
17. Dembo LG, Shifrin RY, Wolff SD. MR imaging in ischemic heart disease. *Radiol Clin N Am*. 2004;42(3):651-673.
18. DePuey EG, Corbett JR, Friedman JD, et al. Imaging guidelines for nuclear cardiology procedures - a report of the American Society of Nuclear Cardiology Quality Assurance Committee. *J Nucl Cardiol*. 2006;13:e21-171.
19. DePuey EG, Port S, Wackers FJ, et al. Non-perfusion applications in nuclear cardiology. *J Nucl Cardiol*. 1998;5(2):218-231.
20. Detrano R, Guerci AD, Carr JJ, et al. Coronary calcium as a predictor of coronary events in four racial or ethnic groups. *N Engl J Med*. 2008;358(13):1336-1345.
21. DiBaise L, Fahmy TS, Wazni OM, et al. Pulmonary vein total occlusion following caheter ablation for atrial fibrillation : clinical implications after long-term follow-up. *J Am Coll Cardiol*. 2006;48(12):2493-2499.
22. DiCarli MF. CT coronary angiography: where does it fit? *J Nucl Med*. 2006;47:1397–1399.
23. Douglas PS, Garcia MJ, Haines DE, et al. ACCF/ASE/AHA/ASNC/HFSA/HRS/SCAI/SCCM/SCCT/SCMR 2011 appropriate use criteria for echocardiography. *J Am Coll Cardiol*. 2011;57(9):1126-1166.

24. Eagle KA, Berger PB, Calkins H, et al. ACC/AHA guideline update for perioperative cardiovascular evaluation for noncardiac surgery. *J Am Coll Cardiol*. 2002;39(3):542-553.
25. Edelman RR. Contrast-enhanced MR imaging of the heart: overview of the literature. *Radiology*. 2004;232(3):653-668.
26. Ehara M, Kawai M, Surmely JF et al. Diagnostic accuracy of coronary in-stent restenosis using 64-slice computed tomography. *J Am Coll Cardiol*. 2007;49:951-959.
27. Elhendy A, O'Leary E, Xie F, et al. Comparative accuracy of real-time myocardial contrast perfusion imaging and wall motion analysis during dobutamine stress echocardiography for the diagnosis or coronary artery disease. *J Am Coll Cardiol*. 2004:44(11):2185-2191.
28. Fihn SD, Gardin JM, Abrams J, et al. 2012 ACCF/AHA/ACP/AATS/PCNA/SCAI/STS guideline for the diagnosis and management of patients with stable ischemic heart disease: a report of the ACCF/AHA task force on practice guidelines. *Circulation*. 2012;126(25):e354-e471.
29. Fleischmann K, Hunink M, Kuntz K, Douglas PS. Exercise echocardiography or exercise SPECT imaging? *JAMA*. 1998;280(10):913-920.
30. Fleisher LA, Beckman JA, Brown KA, et al. ACC/AHA 2007 guidelines on perioperative cardiovascular evaluation and care for noncardiac surgery. executive summary. *J Am Coll Cardiol.* 2007;50(17):1707-1732.
31. Froelicher VF, Fearon WF, Ferguson CM, et al. Lessons learned from studies of the standard exercise ECG test. *Chest*. 1999;116(5):1442-1451.
32. Gersh BJ, Maron BJ, Bonow RO et al. 2011 ACCF/AHA guideline for the diagnosis and treatment of hypertrophic cardiomyopathy: a report of the American College of Cardiology Foundation/American Heart Association Task Force on Practice Guidelines. *J Am Coll Cardiol*. 2011;58:e212-e260.
33. Gibbons RJ, Balady GJ, Bricker JT, et al. ACC/AHA/ASNC guideline update for exercise testing: a report of the american college of cardiology/american heart association task force on practice guidelines, committee on exercise testing. *Circulation*. 2002;106(14):1883-1892.
34. Gibbons RJ, Carryer D, Liu H, et al. Use of echocardiography in Olmsted County outpatients with chest pain and normal resting electrocardiograms seen at Mayo Clinic Rochester. *Mayo Clin Proc*. 2015;90(11):1492-1498.
35. Gilkeson RC, Ciancibello L, Zahka K. Multidetector CT evaluation of congenital heart disease in pediatric and adult patients. *AJR Am J Roentgenol*. 2003;180(4):973-980.
36. Glockner JF, Johnston DL, McGee KP. Evaluation of Cardiac Valvular Disease with MR Imaging: Qualitative and Quantitative Techniques. *Radiographics*. 2003;23(1);e9.
37. Goo HW, Park IS, Ko JK, et al. CT of congenital heart disease: normal anatomy and typical pathologic conditions. *Radiographics*. 2003;23:S147-S165.
38. Grebenc M, Rosado de Christenson M, Burke A, Green CE, Galvin JR. Primary cardiac and pericardial neoplasms: radiologic-pathologic correlation. *Radiographics*. 2000;20(4):1073-1103.
39. Greenland P, Alpert JS, Beller GA, et al. 2010 ACCF /AHA guideline for assessment of cardiovascular risk in asymptomatic adults: executive summary. *J Am Coll Cardiol*. 2010;56(25):2182-2199.
40. Greenland P, Bonow RO, Brundage BH, et al. ACC/ AHA 2007 clinical expert consensus document on coronary artery calcium scoring by computed tomography in global cardiovascular risk assessment and in evaluation of patients with chest pain. *J Am Coll Cardiol*. 2007;49(3):378-402.
41. Grundy SM, Pasternak R, Greenland P, Smith S Jr, Fuster V. Assessment of cardiovascular risk using multiple-risk-factor assessment equations: a statement for healthcare professionals from the American Heart Association and the American College of Cardiology. *Circulation*. 1999;100(13):1481-1492.
42. Hachamovitch R, Hayes S, Friedman, J, Cohen I, Berman DS. Stress myocardial perfusion single-photon emission computed tomography is clinically effective and cost effective in risk stratification of patients with a high likelihood or coronary artery disease (CAD) but no known CAD. *J Am Coll Cardiol*. 2004;43(2):200-208.
43. Hachamovitch R, Hayes, Friedman J, et al. Determinants of risk and its temporal variation in patients with normal stress myocardial perfusion scans. *J Am Coll Cardiol*. 2003;41(8):1329-1340.
44. Hachamovitch R, Nutter B, Hlatky MA, et al. Patient management after noninvasive cardiac imaging results from SPARC (Study of myocardial perfusion and coronary anatomy imaging roles in coronary artery disease). *J Am Coll Cardiol*. 2012;59(5):462-474.
45. Hendel RC, Abbott BG, Bateman TM et al. The role of radionuclide myocardial perfusion imaging in asymptomatic individuals. *J Nucl Cardiol*. 2011;18(1):3-15.
46. Hendel RC, Berman DS, Di Carli MF, et al. ACCF/ASNC/ACR/ASE/SCCT/SNM 2009 appropriate use criteria for cardiac radionuclide imaging. *J Am Coll Cardiol*. 2009;53(23):2201-2229.

47. Hendel RC, Patel MR, Kramer CM, et al. ACCF/ACR/SCCT/SCMR/ASNC/NASCI/SCAI/SIR appropriateness criteria for cardiac computed tomography and cardiac magnetic resonance imaging. *J Am Coll Cardiol*. 2006;48(7):1475-1497.
48. Higgins CB, de Roos A. *MRI and CT of the Cardiovascular System*. Philadelphia, PA: Lippincott Williams & Wilkins; 2006.
49. Hiratzka LF, Bakris GL, Beckman JA, et al. 2010 ACCF/AHA/AATS/ACR/ASA/SCA/SCAI/SIR/STS/SVM guidelines for the diagnosis and management of patients with thoracic aortic disease. *J Am Coll Cardiol*. 2010;55(14):e27-e129.
50. Hiratzka LF, Bakris GL, Beckman JA, et al. 2010 ACCF/AHA/AATS/ACR/ASA/SCA/SCAI/SIR/STS/SVM guidelines for the diagnosis and management of patients with thoracic aortic disease. *J Am Coll Cardiol.* 2010; 55(14):1509-1544.
51. Holmes DR Jr, Mack MJ, Kaul S, et al. 2012 ACCF/AATS/SCAI/STS expert consensus document on transcatheter aortic valve replacement. *J Am Coll Cardiol*. 2012;59(13):1200-54.
52. Hundley WG, Bluemke DA, Finn JP, et al. ACCF/ACR/AHA/NASCI/SCMR 2010 expert consensus document on cardiovascular magnetic resonance. *J Am Coll Cardiol*. 2010;55(23);2614-2662.
53. Hunold P, Schlosser T, Vogt F, et al. Myocardial late enhancement in contrast-enhanced cardiac MRI: distinction between infarction scar and non-infarction-related disease. *AJR Am J Roentgenol*. 2005;184(5):1420-1426.
54. Hunt SA, Abraham WT, Chin MH, et al. 2009 Focused update incorporated into the ACC/AHA 2005 guidelines for the diagnosis and management of heart failure in adults. *J Am Coll Cardiol*, 2009;53(15):e1-90.
55. Kasirajan V, Hertzer NR, Beven EG, O'Hara PJ, Krajewski LP, Sullivan TM. Management of isolated common iliac artery aneurysms. *Cardiovasc Surg*. 1998;6(2):171.
56. Kim KP, Einstein AJ, Berrington de Gonzalez A. Coronary artery calcification screening–estimated radiation dose and cancer risk. *Arch Intern Med*. 2009;169(13):1188-1194.
57. Kim SC, Adams SC, Hendel RC. Role of nuclear cardiology in the evaluation of acute coronary syndromes. *Ann Emerg Med*. 1997;30(2):210-218.
58. Klein AL, Murray RD, Grimm RA. Role of transesophageal echocardiography-guided cardioversion of patients with atrial fibrillation. *J Am Coll Cardiol.* 2001;37(3):691-704.
59. Klocke FJ, Baird MG, Bateman TM, et al. ACC/AHA/ASNC guidelines for the clinical use of cardiac radionuclide imaging: a report of the American College of Cardiology/American Heart Association Task Force on Practice Guidelines, ACC/AHA/ASNC Committee To Revise the 1995 guideline for the clinical use of cardiac radionuclide imaging. *Circulation*. 2003;108(11):1404-1418.
60. Koh AS, Flores JL, Keng FY, Tan RS, Chua TS. Correlation between clinical outcomes and appropriateness grading for referral to myocardial perfusion imaging for preoperative evaluation prior to non-cardiac surgery. *J Nucl Cardiol*. 2012;19(2):277-284.
61. Kohli P, Gulati M. Exercise stress testing in women: going back to the basics. *Circulation*. 2010 Dec 14;122(24):2570-2580.
62. Krupski WC, Selzman CH, Floridia R, Strecker PK, Nehler MR, Whitehill TA. Contemporary management of isolated iliac aneurysms. *J Vasc Surg.* 1998;28(1):1.
63. Maganti K, Rigolin V. Stress echocardiography versus myocardial SPECT for risk stratification of patients with coronary artery disease. *Curr Opin Cardiol*. 200318(6):486-493.
64. Marcus FI, McKenna WJ, Sherrill D, et al. Diagnosis of arrhythmogenic right ventricular cardiomyopathy/dysplasia: proposed modification of the task force criteria. *Circulation*. 2010;121(13):1533-1541.
65. Mark DB, Berman DS, Budoff MJ, et al. ACCF/ACR/AHA/NASCI/SAIP/SCAI/SCCT 2010 expert consensus document on coronary computed tomographic angiography: a report of the American College of Cardiology Foundation Task Force on Expert Consensus Documents. *J Am Coll Cardiol*. 2010;55(23);2663-2699.
66. Marwick T, Williams MJ, Haluska B, et al. Exercise echocardiography is an accurate and cost-efficient technique for detection of coronary artery disease in women. *J Am Coll Cardiol*. 1995;26(2):355-341.
67. Marwick TH, Zuchowski C, Lauer MS, et al. Functional status and quality of life in patients with heart failure undergoing coronary bypass surgery after assessment of myocardial viability. *J Am Coll Cardiol*. 1999;33(3):750-758.
68. Mehta D, Lubitz SA, Frankel Z, et al. Cardiac involvement in patients with sarcoidosis: diagnostic and prognostic value of outpatient testing. *Chest*. 2008;133(6);1426-1435.
69. Meyer T, Martinoff S, Hadamitsky M, et al. Improved noninvasive assessment of coronary artery bypass grafts with 64-slice computed tomographic angiography in an unselected patient population. *J Am Coll Cardiol*. 2007;49:946-950.
70. Mieres JH, Shaw LJ, Arai A, et al. Role of noninvasive testing in the clinical evaluation of women with suspected coronary artery disease. *Circulation*. 2005;111(5);682-696.

71. Newberger JW, Takahashi M, Gerber MA, et al. Diagnosis, treatment, and long-term management of kawasaki disease a statement for health professionals from the Committee on Rheumatic Fever, Endocarditis and Kawasaki Disease, Council on Cardiovascular Disease in the Young, American Heart Association, endorsed by the American Academy of Pediatrics. *Circulation*. 2004;110(17):2747-2771.
72. Nishimura RA, Otto CM, Bonow RO, et al. 2014 AHA/ACC Guideline for the Management of Patients With Valvular Heart Disease: A Report of the American College of Cardiology/American Heart Association Task Force on Practice Guidelines. *J Am Coll Cardiol*. 2014;63(22):e57-e185.
73. Olmos L, Dakik H, Gordon R, et al. Long-term prognostic value of exercise echocardiography compared with exercise 201Tl, ECG, and clinical variables in patients evaluated for coronary artery disease. *Circulation*. 1998; 98(24):2679-2686.
74. Otto CM. Valvular aortic stenosis. disease severity and timing of Intervention. *J Am Coll Cardiol*. 2006;4(11)7:2141-2151.
75. Panjrath GS, Jain D. Monitoring chemotherapy induced cardiotoxicity: role of cardiac nuclear imaging. *J Nucl Cardiol.* 2006;13(3):415-426.
76. Patel MR, White RD, Abbara S, et al. 2013 ACCF/ACR/ASE/ASNC/SCCT/SCMR Appropriate Utilization of Cardiovascular Imaging in Heart Failure: A Joint Report of the American College of Radiology Appropriateness Criteria Committee and the American College of Cardiology Foundation Appropriate Use Criteria Task Force. *J Am Coll Cardiol*. 2013;61(21):2207-2231.
77. Pellikka, PA, Nagueh SF, Elhendy AA, Kuehl CA, Sawada SG. American Society of Echocardiography recommendations for performance, interpretation, and application of stress echocardiography. *J Am Soc Echocardiogr*. 2007;20(9):1021-1041.
78. Pennell D, Sechtem UP, Higgins CB, et al. Clinical indications for cardiovascular magnetic resonance (CMR): Consensus Panel report. *Eur Heart J*. 2004:25(21):1940-1965.
79. Phillips LM, Mieres JH. Noninvasive assessment of coronary artery disease in women: What's next? *Curr Cardiol Rep*. 2010;12(2):147-154.
80. Picano E, Pasanisi E, Brown J, Marwick TH. A gatekeeper for the gatekeeper: inappropriate referrals to stress echocardiography. *Am Heart J*. 2007;154(2):285-290.
81. Picano E, Pibarot P, Lancelotti P, Monin JL, Bonow RO. The Emerging Role of Exercise Testing and Stress Echocardiography in Valvular Heart Disease. *J Am Coll Cardiol*. 2009;54(24):2251-2260.
82. Poornima I, Miller T, Christian T, et al. Utility of Myocardial Perfusion Imaging in Patients with Low-Risk Treadmill Scores. *J Am Coll Cardiol*. 2004;43(2):194-199.
83. Qaseem A, Alguire P, Dallas P, et al. Appropriate use of screening and diagnostic tests to foster high-value, cost-conscious care. *Ann Intern Med*. 2012;156(2):147-149.
84. Rahimi AR, York M, Gheewala N, Markson L, Hauser TH, Manning WJ. Trends in outpatient transthoracic echocardiography: impact of appropriateness criteria publication. *Am J Med*. 2011;124(8):740-746.
85. Redberg RF, Walsh J. Pay now, benefits may follow—the case of cardiac computed tomographic angiography. *N Engl J Med*. 2008;359(22):2309-2311.
86. Richardson JW, Greenfield LJ. Natural history and management of iliac aneurysms. *J Vasc Surg*. 1988;8(2):165.
87. Rienmüller R, Gröll R, Lipton M. CT and MR imaging of pericardial disease. *Radiol Clin N Am*. 2004;42(3):587-601.
88. Santilli SM, Wernsing SE, Lee ES. Expansion rates and outcomes for iliac artery aneurysms. *J Vasc Surg.* 2000;31(1 Pt 1):114.
89. Sato H, Iwasaki T, et al. Prediction of functional recovery after revascularization in coronary artery disease using 18 FDG and 123I BMIPP SPECT. *Chest* 2000;117(1):65.
90. Schelbert HR, Beanlands R, Bengel F. PET myocardial perfusion and glucose metabolism imaging: Part 2—guidelines for interpretation and reporting. *J Nucl Cardiol*. 2003;10(5):557-571.
91. Schinkel, AFL, Bax, JJ, Geleijnse ML, et al. Noninvasive evaluation of ischaemic heart disease: myocardial perfusion imaging or stress echocardiography? *Eur Heart J*. 2003;24(9):789-800.
92. Senior R, Monaghan M, Becher H, et al. Stress echocardiography for the diagnosis and risk stratification of patients with suspected or known coronary artery disease: a critical appraisal. Supported by the British Society of Echocardiography. *Heart*. 2005;91(4):427-436.
93. Shaw LJ, Mieres JH, Hendel RH, et al. Comparative effectiveness of exercise electrocardiography with or without myocardial perfusion single photon emission computed tomography in women with suspected coronary artery disease: results from the What Is the Optimal Method for Ischemia Evaluation in Women (WOMEN) trial. *Circulation*. 2011;124(11):1239-1249.

94. Strauss HW, Miller DD, Wittry MD, et al. Society of Nuclear Medicine Procedure Guideline for Myocardial Perfusion Imaging 3.3. *J Nucl Med Technol*. 2008;36(3):155-161..
95. Taylor AJ, Cerqueira M, Hodgson JM, et al. ACCF/ SCCT/ACR/AHA/ASE/ASNC/SCAI/SCMR 2010 appropriate use criteria for cardiac computed tomography. *J Am Coll Cardiol*. 2010;56(22):1864-1894.
96. Thrall JH, Ziessman HA. *Nuclear Medicine: The Requisites*. 2nd edition. St. Louis: Elsevier Mosby Publishers; 2001:105-109.
97. Tops LF, Krishnan SC, Schuijf JD, Schalij MJ, Bax JJ. Noncoronary applications of cardiac multidetector row computed tomography. *JACC Cardiol Imaging*. 2008;1(1):94–106.
98. Travin MI, Bergmann SR. Assessment of myocardial viability. *Semin Nucl Med*. 2005;35(1):2-16.
99. Vahanian A, Baumgartner H, Bax J, et al. Guidelines on the management of valvular heart disease: the Task Force on the Management of Valvular Heart Disease of the European Society of Cardiology. *Eur Heart J*. 2007;28(2):230-268.
100. Vallejo E, Dione DP, Sinusas AJ, Wackers FJ. Assessment of left ventricular ejection fraction with quantitative gated SPECT: accuracy and correlation with first pass radionuclide angiography. *J Nucl Cardiol*. 2000;7(5):461-470.
101. Vavas E, Hong SN, Rosen SE, Mieres JH. Noninvasive diagnostic techniques for coronary disease in women. *Clin Cardiol*. 2012;35(3):149-155.
102. Wang ZF, Reddy GP, Gotway MB, et al. CT and MR imaging of pericardial disease. *Radiographics*. 2003;23:S167-S180.
103. Warnes CA, Williams RG, Bashore TM, et al. ACC/AHA 2008 guidelines for the management of adults with congenital heart disease. *J Am Coll Cardiol*. 2008;52(23):e143-e263.
104. Weinreb JC, Larson PA, Woodard PK, et al. American College of Radiology clinical statement on noninvasive cardiac imaging. *Radiology*. 2005;235(3):723-772.
105. Willens HJ, Kessler KM. Transesophageal echocardiography in the diagnosis of diseases of the thoracic aorta; part 1. aortic dissection, aortic intramural hematoma, and penetrating atherosclerotic ulcer of the aorta. *Chest*. 1999;116(6):1772-1779. Williams KA. A historical perspective on measurement of ventricular function with scintigraphic techniques: part II - ventricular function with gated techniques for blood pool and perfusion imaging. *J Nucl Cardiol*. 2005;12(2):208-15.
106. Williams KA. Measurement of ventricular function with scintigraphic techniques: part I - imaging hardware, radiopharmaceuticals, and first pass radionuclide angiography. *J Nucl Cardiol*. 2005;12(1):86-95.
107. Wolk MJ, Bailey SR, Doherty JU, et al. ACCF/AHA/ASE/ASNC/HFSA/HRS/SCAI/SCCT/SCMR/STS 2013 Multimodality Appropriate Use Criteria for the Detection and Risk Assessment of Stable Ischemic Heart Disease: A Report of the American College of Cardiology Foundation Appropriate Use Criteria Task Force, American Heart Association, American Society of Echocardiography, American Society of Nuclear Cardiology, Heart Failure Society of America, Heart Rhythm Society, Society for Cardiovascular Angiography and Interventions, Society of Cardiovascular Computed Tomography, Society for Cardiovascular Magnetic Resonance, and Society of Thoracic Surgeons. *J Am Coll Cardiol.* 2014;63(4):380-406.
108. Yancy CW, Jessup M, Bozkurt B, et al. 2013 ACCF/AHA Guideline for the Management of Heart Failure: Executive Summary: A Report of the American College of Cardiology Foundation/American Heart Association Task Force on Practice Guidelines. *J Am Coll Cardiol*. 2013;62(16):1495-1539.
109. Yao SS, Qureshi E, Sherrid M, Chaudhry FA. Practical applications in stress echocardiography: risk stratification and prognosis in patients with known or suspected ischemic heart disease. *J Am Coll Cardiol*. 2003;42(6):1084-1090.
110. Zaret BL, Bellar GA. *Clinical Nuclear Cardiology*. 3rd Edition. Philadelphia: Elsevier Mosby Publishers; 2005.
111. Zellweger MJ, Lewin HC, Lai S, et al. When to stress patients after coronary artery bypass surgery. *J Am Coll Cardiol*. 2001;37(1):144-152.
112. Zoghbi WA, Enriquez-Sarano M, Foster E, et al. Recommendations for evaluation of the severity of native valvular regurgitation with two-dimensional and Doppler echocardiography. *J Am Soc Echocardiogr*. 2003;16(7):777-802.