

National Imaging Associates, Inc.*	
Clinical guidelines HEART CATHETERIZATION	Original Date: February 2010
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Guideline Number: NIA_CG_065	Implementation Date: January 202 32

GENERAL INFORMATION

It is an expectation that all patients receive care/services from a licensed clinician. All appropriate supporting documentation, including recent pertinent office visit notes, laboratory data, and results of any special testing must be provided. All prior relevant imaging results and the reason that alternative imaging cannot be performed must be included in the documentation submitted.

INDICATIONS FOR INVASIVE CORONARY ARTERIOGRAPHY¹⁻⁵

(Fihn, 2012, 2014; Patel, 2012, 2017; Wolk, 2014)

General

- New onset or worsening of the patient's previously known anginal symptoms in a patient with a history of CABG or PCI
- Symptomatic patients with a high pretest probability
- Unheralded syncope (not near syncope), where the etiology is unclear

Stable Ischemic Heart Disease

- Exercise electrocardiogram (ECG) stress test with high-risk findings, such as Duke Score ≤ -11 , ST segment elevation, hypotension, exercise-induced ventricular tachycardia (VT), or several minutes of ST segment depression post exercise³ (Patel, 2012)
- Stress imaging with high-risk findings (see Overview-Background section)
- Stress imaging with intermediate risk findings (see Overview-Background section) in a patient with one of the following:
 - Symptoms consistent with ischemia³ (Patel, 2012)
 - Unsatisfactory quality of life due to angina² (Fihn, 2012)
 - Ejection fraction (EF) $< 50\%$ ² (Fihn, 2012)

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1— Heart Catheterization

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- Non-invasive test with ~~low risk~~low-risk findings with new, worsening, or limiting symptoms with reasonable suspicion of cardiac origin despite optimal medical therapy (OMT) or inability to tolerate OMT¹⁻³ ~~(Fihn, 2012, 2014; Patel, 2012)~~
- New, worsening, or limiting symptoms, with known unrevascularized obstructive coronary artery disease (CAD), in a patient eligible for revascularization^{1, 2} ~~(Fihn, 2012, 2014)~~
- Discordant, equivocal, or inconclusive non-invasive evaluation in patients with suspected symptomatic stable ischemic heart disease, including the following^{3, 5, 6} ~~(Montalescot, 2013; Patel, 2012; Wolk, 2014)~~:
 - Low risk stress imaging with ~~high risk~~high-risk stress ECG response or stress induced typical angina³ ~~(Patel, 2012)~~
 - Equivocal, uninterpretable, or inconclusive stress imaging due to issues of attenuation or other problems with interpretability^{2, 3} ~~(Fihn, 2012; Patel, 2012)~~

CCTA Abnormalities

- Symptomatic patient with one of the following²⁻⁴ ~~(Fihn, 2012; Patel, 2012, 2017)~~:
 - One vessel ~~CAD~~ with ~~≥ 50-70%~~ stenosis
 - A stenosis of 40-90% and FFR-CT ≤ 0.8⁷
 - ~~Any patient with evidence of~~ ≥ 50% left main stenosis, **even if asymptomatic**

Heart Failure with Left Ventricular Dysfunction

- New heart failure, cardiomyopathy, or wall motion abnormality in patients who are candidates for coronary revascularization; including one of the following^{2, 3, 5, 8, 9} ~~(Fihn, 2012; Patel, 2012, 2013; Wolk, 2014; Yancy, 2013)~~:
 - Newly recognized ~~reduction in EF to ≤ 50%, with intermediate-risk findings on noninvasive testing and symptoms or signs of ischemia~~**heart failure in patients with known or suspected CAD**
 - Symptomatic heart failure or ischemia with new, unexplained wall motion abnormality^{2, 3} ~~(Fihn, 2012; Patel, 2012)~~
 - Structural abnormality (severe mitral regurgitation or ventricular septal defect) with reason to suspect ischemic origin
 - Deterioration in clinical status of heart failure or cardiomyopathy requiring invasive evaluation for guidance or alteration in therapy
 - Clarification of the diagnosis of myocarditis versus acute coronary syndrome¹⁰ ~~(Sarda, 2001)~~

Ventricular Arrhythmias

- Ventricular arrhythmias, without identified non-cardiac cause:
 - Following recovery from unexplained sudden cardiac arrest¹¹ ~~(Al-Khatib, 2017)~~
 - Sustained VT or VF³ ~~(Patel, 2012)~~
 - Exercise-induced ~~non-sustained VT in a patient with signs or symptoms of ischemia~~³ ~~(Patel, 2012)~~

Prior to Non-Coronary Intervention and Cardiac Surgery

- Evaluation of coronary anatomy, with consideration of coronary revascularization, prior to cardiac surgery in patients with any of the following¹²⁻¹⁶ ~~(Doherty, 2017; Nishimura, 2014, 2017; Ramee, 2016; Svensson, 2013)~~:
 - Symptoms of angina
 - Stress imaging with evidence of ischemia
 - Decreased LV systolic function (EF < 50%)
 - History of CAD
 - Coronary risk factors, including men > 40 and postmenopausal women
 - Non-invasive data that is inconclusive
 - Chronic severe secondary mitral regurgitation
 - Requirement for detailed assessment of coronary artery anatomy prior to aortic valve homograft surgery, pulmonary autograft (Ross procedure), or aortic root procedure
 - Patients undergoing transcatheter aortic valve replacement (TAVR) or other transcatheter valve procedures
 - Can be done pre-organ transplant when required by transplant center protocol in place of, but not in addition to an imaging study

Hypertrophic Cardiomyopathy

- Patients with HCM, who are candidates for SRT, and for whom there is uncertainty of LVOT obstruction on noninvasive imaging studies, invasive hemodynamic assessment with cardiac catheterization is recommended¹⁷ ~~(Ommen, 2020)~~
- In patients with symptoms or evidence of myocardial ischemia (CCTA also allowed)
- ~~• Prior to surgical myectomy in HCM patients who are at risk for coronary atherosclerosis (CCTA also allowed)~~
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Post Cardiac Transplantation¹⁸

~~(Costanzo, 2010)~~

- Assessment for allograft vasculopathy annually for the first 5 years, followed by annual assessment in those with documented allograft vasculopathy, if stress imaging has not been performed
- Assessment of change in clinical status, including any of the following, if stress imaging has not been performed:
 - New left ventricular dysfunction
 - Symptoms of ischemia
 - Non-invasive findings of ischemia

Hemodynamic Assessment

- Indications for angiographic and/or hemodynamic assessment of valvular function or shunt physiology^{3, 12, 19} (~~Doherty, 2017; Patel, 2012; Stout, 2019~~)
 - Assessment of bioprosthetic valve when transthoracic echocardiography (TTE) and transesophageal ~~electrocardiography~~ echocardiography (TEE) were inadequate, and cardiac magnetic resonance (CMR) or cardiac computed tomography (CCT) are not available
 - Assessment of mechanical valve prostheses when TTE and TEE are inadequate and CCT is not available
 - Discordance between non-invasive data and clinical impression of severity of valvular disease
 - Evaluation of indeterminate shunt anatomy or shunt flows/ratio
- Indications for hemodynamic assessment only^{3, 19} (~~Patel, 2012; Stout, 2019~~)
 - Assessment of constrictive and restrictive physiology
 - Assessment of pulmonary hypertension when non-invasive data provides inadequate information for management, or to evaluate response to intravenous drug therapy
 - Assessment of hemodynamics in heart failure, cardiomyopathy, or adult congenital heart disease, when
 - Non-invasive data is discordant or conflicts with the clinical presentation
 - Non-invasive data is inadequate for clinical management

These guidelines only cover procedures that include left heart catheterization. NIA does not manage right heart catheterization as a stand-alone procedure.

BACKGROUND

Heart catheterization is an invasive angiographic procedure used to evaluate the presence and extent of coronary artery disease (CAD).

In addition to angiography, it can also include ventriculography, aortography, acquisition of hemodynamic data, measurement of cardiac output, detection and quantification of shunts and flows, intravascular ultrasound (IVUS), and fractional flow reserve (FFR)/instantaneous wave free ratio (iFR) for determination of a lesion's hemodynamic severity. CAD stenosis $\geq 70\%$ ($\geq 50\%$ in the left main coronary artery) is considered clinically significant or obstructive CAD.^{2, 5, 6, 20} (~~Fihn, 2012; Lotfi, 2018; Montalescot, 2013; Wolk, 2014~~).

This guideline applies to patients with a stable clinical presentation, not to those with acute coronary syndromes or acute valvular abnormalities.

In stable patients, preliminary evaluation with non-invasive cardiac testing is usually indicated prior to a recommendation for cardiac catheterization.

Stable Patients without Known CAD fall into 2 categories^{2, 5, 6} (~~Fihn, 2012; Montalescot, 2013; Wolk, 2014~~):

- **Asymptomatic**, for whom global risk of CAD events can be determined from coronary risk factors, using calculators available online (see [Global Cardiovascular Risk Calculators](#) section).
- **Symptomatic**, for whom the pretest probability that chest-related symptoms are due to clinically significant CAD is estimated.

The Three Types of Chest Pain or Discomfort and Pretest Probability of CAD

- **Typical Angina (Definite)** is defined as including all **3** characteristics:
 - Substernal chest pain or discomfort with characteristic quality and duration
 - Provoked by exertion or emotional stress
 - Relieved by rest and/or nitroglycerine
- **Atypical Angina (Probable)** has only **2** of the above characteristics
- **Non-anginal Chest Pain/Discomfort** has only **0 - 1** of the above characteristics

Once the type of chest pain has been established from the medical record, the pretest probability of obstructive CAD is estimated from the **Diamond Forrester Table** below, recognizing that in some cases multiple additional coronary risk factors could increase pretest probability (~~Fihn, 2012; Wolk, 2014~~).^{2, 5}

Age (Years)	Gender	Typical/Definite Angina Pectoris	Atypical/Probable Angina Pectoris	Non-anginal Chest Pain
≤ 39	Men	Intermediate	Intermediate	Low
	Women	Intermediate	Very low	Very low
40 – 49	Men	High	Intermediate	Intermediate
	Women	Intermediate	Low	Very low
50 – 59	Men	High	Intermediate	Intermediate
	Women	Intermediate	Intermediate	Low
≥ 60	Men	High	Intermediate	Intermediate

	Women	High	Intermediate	Intermediate
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- **Low:** 5 - 10% pretest probability of CAD
- **Intermediate:** 10% - 90% pretest probability of CAD
- **High:** > 90% pretest probability of CAD

Coronary Risk Categories Derived from Non-invasive Testing^{2, 4}

(Fihn, 2012; Patel, 2017)

- **High risk (> 3% annual death or MI)**
 - Severe resting left ventricular (LV) dysfunction (LVEF < 35%) not readily explained by non-coronary causes
 - Resting perfusion abnormalities $\geq 10\%$ of the myocardium in patients without prior history or evidence of myocardial infarction (MI)
 - Stress ECG findings including ≥ 2 mm of ST-segment depression at low workload or persisting into recovery, exercise-induced ST-segment elevation, or exercise-induced ventricular tachycardia (VT)/ventricular fibrillation (VF)
 - Severe stress-induced left ventricular (LV) dysfunction (peak exercise EF < 45% or drop in EF with stress $\geq 10\%$)
 - Stress-induced perfusion abnormalities involving $\geq 10\%$ myocardium or stress segmental scores indicating multiple abnormal vascular territories
 - Stress-induced LV dilation. Transient ischemic dilation (TID) is the ratio of left ventricular area immediately post-exercise divided by the area of the 4-hour redistribution image, with an abnormal ratio defined as > 1.12 ²¹ (Weiss, 1987)
 - Inducible wall motion abnormality (involving ≥ 2 segments or ≥ 2 vascular territories)
 - Wall motion abnormality developing at low dose of dobutamine (≤ 10 mg/kg/min) or at a low heart rate (< 120 beats/min)
 - Multivessel obstructive CAD ($\geq 70\%$ stenosis) or left main stenosis ($\geq 50\%$ stenosis) on CCTA
- **Intermediate risk (1% to 3% annual death or MI)**
 - Mild or moderate resting LV dysfunction (EF 35% to 49%) not readily explained by non-coronary causes
 - Resting perfusion abnormalities in 5% to 9.9% of the myocardium in patients without a history or prior evidence of MI
 - ≥ 1 mm of ST-segment depression occurring with exertional symptoms
 - Stress-induced perfusion abnormalities involving 5% to 9.9% of the myocardium or stress segmental scores (in multiple segments) indicating 1 vascular territory with abnormalities but without LV dilation
 - Small Inducible wall motion abnormality involving 1 segment or 1 vascular territory
 - 1 to 2 segments and only 1 vascular territory

- CAC score 100 to 399 Agatston units (only for use in primary prevention, not for heart catheterization decision making)^{2, 3, 6, 22} ~~(Fihn, 2012; Goff, 2014; Montalescot, 2013; Patel, 2012)~~
- One vessel CAD with $\geq 70\%$ stenosis or moderate CAD stenosis (50% to 69% stenosis) in ≥ 2 arteries on CCTA
- **Low risk (< 1% annual death or MI)**
 - Low-risk treadmill score (score ≥ 5) or no new ST segment changes or exercise-induced chest pain symptoms, when achieving maximal levels of exercise
 - Normal or small myocardial perfusion defect at rest or with stress involving < 5% of the myocardium
 - Normal stress or no change of baseline wall motion abnormalities during stress
 - CAC score < 100 Agatston units (only for use in primary prevention, not for heart catheterization decision making)^{2, 3, 6, 22} ~~(Fihn, 2012; Goff, 2014; Montalescot, 2013; Patel, 2012)~~
 - No coronary stenosis > 50% on CCTA

Global Risk of Cardiovascular Disease

Global risk of CAD is defined as the probability of manifesting cardiovascular disease over the next 10 years and refers to **asymptomatic** patients without known cardiovascular disease. It should be determined using one of the risk calculators below. A high risk is considered greater than a 20% risk of a cardiovascular event over the ensuing 10 years. **High global risk by itself generally lacks scientific support as an indication for stress imaging** ~~(Douglas, 2016)~~.²³ There are rare exemptions, such as patients requiring I-C antiarrhythmic drugs, who might require coronary risk stratification prior to initiation of the drug, when global risk is moderate or high.

- **CAD Risk—Low**
—10-year absolute coronary or cardiovascular risk less than 10%
- **CAD Risk—Moderate**
10-year absolute coronary or cardiovascular risk between 10% and 20%
- **CAD Risk—High**
10-year absolute coronary or cardiovascular risk of greater than 20%

Websites for Global Cardiovascular Risk Calculators

Patients who have already manifested cardiovascular disease are already at high global risk and are not applicable to the calculators.^{22, 24-27}

~~(Arnett, 2019; D'Agostino, 2008; Goff, 2014; McClelland, 2015; Ridker, 2007)~~

Risk Calculator	Websites for Online Calculator
Framingham Cardiovascular Risk	https://reference.medscape.com/calculator/framingham-cardiovascular-disease-risk
Reynolds Risk Score	http://www.reynoldsriskscore.org/

Can use if no diabetes Unique for use of family history	
Pooled Cohort Equation	http://clincalc.com/Cardiology/ASCVD/PooledCohort.aspx?example
ACC/AHA Risk Calculator	http://tools.acc.org/ASCVD-Risk-Estimator/
MESA Risk Calculator With addition of Coronary Artery Calcium Score, for CAD-only risk	https://www.mesa-nhlbi.org/MESACHDRisk/MesaRiskScore/RiskScore.aspx

Definitions of Coronary Artery Disease^{2, 4, 6, 28}

(Fihn, 2012; Mintz, 2016; Montalescot, 2013; Patel, 2017)

- Percentage stenosis refers to the reduction in diameter stenosis when angiography is the method and can be estimated or measured using angiography or more accurately measured with intravascular ultrasound (IVUS).
- Coronary artery calcification is a marker of risk, as measured by Agatston score on coronary artery calcium imaging. It is not a diagnostic tool so much as it is a **risk stratification** tool. Its incorporation into global risk can be achieved by using the MESA risk calculator.
- Ischemia-producing disease (also called hemodynamically or functionally significant disease, for which revascularization might be appropriate) generally implies at least one of the following:
 - Suggested by percentage diameter stenosis $\geq 70\%$ by angiography; intermediate lesions are 50 – 69%²⁹ (Fihn, 2012)
 - For a left main artery, suggested by a percentage stenosis $\geq 50\%$ or minimum luminal cross-sectional area on IVUS ≤ 6 square mm^{2, 20, 28} (Fihn, 2012; Lotfi, 2018; Mintz, 2016)
 - FFR (fractional flow reserve) ≤ 0.80 for a major vessel^{20, 28} (Lotfi, 2018; Mintz, 2016)
 - iFR (instantaneous wave-free ratio) ≤ 0.89 for a major vessel^{20, 30-32} (Davies, 2017; Gotberg, 2017; Lotfi, 2018)
- A major vessel would be a coronary vessel that would be amenable to revascularization, if indicated. This assessment is made based on the diameter of the vessel and/or the extent of myocardial territory served by the vessel.
- FFR is the distal to proximal pressure ratio across a coronary lesion during maximal hyperemia induced by either intravenous or intracoronary adenosine. Less than or equal to 0.80 is considered a significant reduction in coronary flow.

- Instantaneous wave-free ratio (iFR) measures the ratio of distal coronary to aortic pressure during the wave free period of diastole, with a value ≤ 0.89 considered hemodynamically significant.³⁰⁻³² ~~(Gotberg, 2017; Davies, 2017).~~

Anginal Equivalent^{2, 33, 34}

~~(Fihn, 2012; Moya, 2009; Shen, 2017)~~

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

Abbreviations

CABG	<u>Coronary artery bypass grafting surgery</u>
CAC	Coronary artery calcium
CAD	Coronary artery disease
CCT	Cardiac computed tomography
CCTA	Coronary computed tomographic angiography
CMR	Cardiac magnetic resonance
CT(A)	<u>Computed tomography (angiography)</u>
ECG	<u>Electrocardiogram</u>
EF	<u>Ejection fraction</u>
FFR	<u>Fractional flow reserve</u>
FFR-CT	<u>Fractional flow reserve – computed tomography</u>
HCM	<u>Hypertrophic cardiomyopathy</u>
iFR	<u>Instantaneous wave-free ratio</u>
IVUS	<u>Intravascular ultrasound</u>
LV	Left ventricular
LVEF	Left ventricular ejection fraction
LVOT	<u>Left ventricular outflow tract</u>
MESA	<u>Multi-Ethnic Study of Atherosclerosis</u>
MI	Myocardial infarction
MR	Mitral regurgitation
OMT	<u>Optimal medical therapy</u>
PCI	<u>Percutaneous coronary intervention</u>
PFT	<u>Pulmonary function test</u>
SRT	<u>Septal reduction therapy</u>
TAVR	Transcatheter aortic valve replacement
TID	<u>Transient ischemic dilation</u>

TTE	Transthoracic echocardiography
TEE	Transesophageal echocardiography
VT	Ventricular tachycardia
VF	Ventricular fibrillation

POLICY HISTORY

Date	Summary
February 2022	<ul style="list-style-type: none"> Added indications to CCTA section regarding left main disease, single vessel disease >50% stenosis Modified indication for exercise-induced VT removing statement “requiring signs and symptoms of ischemia” Clarified definition of intermediate findings, non-invasive testing FFR-CT statement updated Modified indication for newly diagnosed HF removing statement “requiring signs and symptoms of ischemia”
March 2021	<ul style="list-style-type: none"> Added general section discussing indications without requiring prior noninvasive study Removed statement on newly recognized EF <40% in patients for viability Added pretransplant indication Added indications and reference for hypertrophic obstructive cardiomyopathy
March 2020	<ul style="list-style-type: none"> Added general information section as Introduction which outlines requirements for documentation of pertinent office notes by a licensed clinician, and inclusion of laboratory testing and relevant imaging results for case review Added indication for coronary angiography prior to transcatheter valve procedures in addition to transcatheter aortic valve replacement (TAVR) Added edits to the Coronary Artery Disease definition section Updated and added new references
August 2019	<ul style="list-style-type: none"> Added indications for new heart failure/ cardiomyopathy/wall motion abnormality, in patients who are candidates and would be eligible for coronary revascularization including one of the following: <ul style="list-style-type: none"> Newly recognized reduction in ejection fraction to \leq 50%, with intermediate risk findings on noninvasive testing and symptoms or signs of ischemia Newly recognized reduction in ejection fraction to \leq 40% with evidence of viability on stress imaging

	<ul style="list-style-type: none"> • Removed indication for diastolic heart failure, when symptoms, signs or stress imaging provides evidence of contributory ischemia • Clarified indication for evaluation of coronary anatomy prior to TAVR • Clarified indication for assessment of allograft vasculopathy if stress imaging has not been performed • Clarified indications for assessment of hemodynamics in heart failure, cardiomyopathy or adult congenital heart disease.
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ADDITIONAL RESOURCES

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Reviewed / Approved by NIA Clinical Guideline Committee

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