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APPROPRIATE USE CRITERIA

ACCF/SCAI/AATS/AHA/ASE/ASNC/HFSA/HRS/SCCM/SCCT/SCMR/STS 2012 Appropriate Use Criteria for Diagnostic Catheterization

A Report of the American College of Cardiology Foundation Appropriate Use Criteria Task Force, Society for Cardiovascular Angiography and Interventions, American Association for Thoracic Surgery, American Heart Association, American Society of Echocardiography, American Society of Nuclear Cardiology, Heart Failure Society of America, Heart Rhythm Society, Society of Critical Care Medicine, Society of Cardiovascular Computed Tomography, Society for Cardiovascular Magnetic Resonance, and Society of Thoracic Surgeons

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TABLE OF CONTENTS

Abstract

The American College of Cardiology Foundation, in collaboration with the Society for Cardiovascular Angiography and Interventions and key specialty and subspecialty societies, conducted a review of common clinical scenarios where diagnostic catheterization is frequently considered.

The indications (clinical scenarios) were derived from common applications or anticipated uses, as well as from current clinical practice guidelines and results of studies examining the implementation of noninvasive imaging appropriate use criteria. The 166 indications in this document were developed by a diverse writing group and scored by a separate independent technical panel on a scale of 1 to 9, to designate appropriate use (median 7 to 9), uncertain use (median 4 to 6), and inappropriate use (median 1 to 3).

Diagnostic catheterization may include several different procedure components. The indications developed focused primarily on 2 aspects of diagnostic catheterization. Many indications focused on the performance of coronary angiography for the detection of coronary artery disease with other procedure components (e.g., hemodynamic measurements, ventriculography) at the discretion of the operator. The majority of the remaining indications focused on hemodynamic measurements to evaluate valvular heart disease, pulmonary hypertension, cardiomyopathy, and other conditions, with the use of coronary angiography at the discretion of the operator. Seventy-five indications were rated as appropriate, 49 were rated as uncertain, and 42 were rated as inappropriate.

The appropriate use criteria for diagnostic catheterization have the potential to impact physician decision making, healthcare delivery, and reimbursement policy. Furthermore, recognition of uncertain clinical scenarios facilitates identification of areas that would benefit from future research.

Preface

In an effort to respond to the need for the rational use of cardiovascular services, including imaging and invasive procedures in the delivery of high-quality care, the American College of Cardiology Foundation (ACCF) in collaboration with other professional organizations has undertaken a process to determine the appropriate use of cardiovascular procedures for selected patient indications.

Appropriate use criteria (AUC) publications reflect an ongoing effort to critically and systematically create, review, and categorize clinical situations where diagnostic tests and therapeutic procedures are utilized by physicians caring for patients with cardiovascular disease. The process is based on understanding the technical capabilities of the procedures examined. The diversity of clinical disease present makes it difficult to be comprehensive, but the indications presented hopefully identify common scenarios encompassing the majority of situations encountered in contemporary practice. Given the breadth of information conveyed, the indications do not directly correspond to the *Ninth Revision of the International Classification of Diseases* system as these codes do not include clinical information, such as symptom status.

The ACCF and the Society for Cardiovascular Angiography and Interventions (SCAI) believe that careful blending of a broad range of clinical experiences and available evidence-based information will help guide a more efficient and equitable allocation of healthcare resources in cardiovascular care and invasive catheterization. The ultimate objective of the AUC is to improve patient care and health outcomes in a cost-effective manner while recognizing that some ambiguity and nuance is intrinsic to clinical decision making. Therefore, the AUC should not be considered substitutes for sound clinical judgment and practice experience. However, when the clinical judgment and practice patterns routinely conflict with AUC ratings, further evaluation of the specific clinical circumstances should be considered.

The AUC development process itself is also evolving. Given the iterative nature of the process and incorporation of new information about the role for diagnostic and therapeutic interventions, readers are counseled that comparison of individual appropriate use ratings developed at different times over the past several years may not reflect the comparative utility of different modalities for a given indication, as the ratings may vary over time. Cardiac catheterization plays a central role in the care of patients with cardiovascular disease, and guidance around the rationale and evidence based use of the procedure is the goal of the current document.

We are grateful to the technical panel and its moderator, Pamela S. Douglas, MD, MACC, FAHA, FASE, a professional group with a wide range of skills and insights, for their thoughtful and thorough deliberation of the merits of diagnostic catheterization for various indications. We would also like to thank the 28 individuals who provided a careful review of the draft of indications, the parent AUC Task Force, and the ACCF staff, specifically Joseph M. Allen and Lea Binder for their exceptionally skilled support in the generation of this document.

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1. Introduction

The ACCF, in collaboration with SCAI and several other professional organizations, developed common clinical scenarios where diagnostic cardiac catheterization is frequently considered. The indications, as presented in these clinical scenarios, were derived from common presentations or anticipated uses, as well as from current clinical practice guidelines. The 166 indications in this document were developed by a writing group with diverse clinical expertise and scored by a separate independent technical panel on a scale of 1 to 9, to designate appropriate use (median scores 7 to 9), uncertain use (median scores 4 to 6), and inappropriate use (median scores 1 to 3).

The AUC for diagnostic catheterization has the potential to impact physician decision making, healthcare delivery, and reimbursement policy. Furthermore, it is hoped that recognition of uncertain clinical scenarios facilitates identification of areas that could benefit from future research.

This report addresses the appropriate use of diagnostic catheterization. Improvements in cardiovascular imaging technology and an expanding array of noninvasive diagnostic tools and therapeutic options for patients with cardiovascular disease have led to many more choices than in the past. As the field advances, the healthcare community needs to understand how to best incorporate this technology into daily clinical care. ACCF and SCAI are dedicated to this effort.

2. Methods

The indications included in this publication cover a variety of cardiovascular signs and symptoms as well as clinical judgments as to the likelihood of cardiovascular findings. Within each main disease category, a standardized approach was used to capture a significant number of clinical scenarios without making the list of indications excessive. The term "indication" is used interchangeably with "clinical scenario" in the document for brevity and does not imply that imaging should necessarily be done. Diagnostic catheterization may include several different procedure components. The indications developed focused primarily on 2 aspects of diagnostic catheterization. Many indications focused on the performance of coronary angiography for the detection of coronary artery disease (CAD), with other procedure components (e.g., hemodynamic measurements, ventriculography) performed at the discretion of the operator. The majority of the remaining indications focused on hemodynamic measurements to evaluate valvular heart disease, pulmonary hypertension, cardiomyopathy, and other conditions, with the addition of coronary angiography at the discretion of the operator.

The spectrum of cardiovascular disease was addressed as it would apply to the standard adult catheterization laboratory. The writing group did not consider invasive evaluations of complex adult congenital heart disease in this document, with the belief that such complex cases would be best performed by individuals with considerable specialized expertise and at institutions with sufficient patient volume. Recommendations in this area are addressed in separate subspecialty publications. Additionally, invasive procedures such as endomyocardial biopsy, pericardiocentesis, or right heart catheterization not performed in the catheterization laboratory are not covered in this document.

The indications were constructed by a varied group of experts in both invasive and noninvasive diagnostic cardiac imaging. Subsequent modifications in the indications were made based on discussions with the task force and feedback from independent reviewers. Wherever possible, indications were mapped to relevant clinical guidelines and key publications/references (see Online Appendix).

A detailed description of the methods used for rating the selected clinical indications is found in a previous publication, "ACCF Proposed Method for Evaluating the Appropriateness of Cardiovascular Imaging" (1). Briefly, this process combines evidence-based medicine and practice experience by engaging a technical panel in a modified Delphi exercise. The technical panel first rated the indications independently, after which the results were summarized and the panel convened for a face-to-face meeting to discuss each indication. At this meeting, panel members were provided with their scores and a blinded summary of their peers' scores. After the meeting, panel members once again independently rated each indication to determine the final scores.

Although panel members were not provided explicit cost information to help determine their ratings, they were asked to implicitly consider costs as an additional factor in their evaluation of appropriate use. In rating these criteria, the technical panel was asked to assess whether the use of the test for each indication is appropriate, uncertain, or inappropriate, and was provided with the following definition of appropriate use:

An appropriate diagnostic cardiac catheterization (left heart, right heart, ventriculography, and/or coronary angiography) is one in which the expected incremental information combined with clinical judgment exceeds the negative consequences by a sufficiently wide margin for a specific indication that the procedure is generally considered acceptable care and a reasonable approach for the indication.

Each member of the technical panel assigned a score to each indication, and the scores of the technical panel were tabulated for the final ratings and assigned an appropriateness rating as follows:

Median Score 7 to 9

Appropriate test for specific indication (test **is** generally acceptable and **is** a reasonable approach for the indication).

Median Score 4 to 6

Uncertain for specific indication (test **may** be generally acceptable and **may** be a reasonable approach for the indication). Uncertainty also implies that more research

and/or patient information is needed to classify the indication definitively.

Median Score 1 to 3

Inappropriate test for that indication (test **is not** generally acceptable and **is not** a reasonable approach for the indication).

The division of these scores into 3 levels of appropriateness should be viewed as a continuum. It is important to emphasize that the category of "uncertain" is a distinct category and *must not be considered either "appropriate" or "inappropriate" or lumped together with the other categories when characterizing appropriateness ratings*. A rating of uncertain will exist if: 1) there is considerable diversity in the ratings among individual members of the technical panel indicating a wide range of opinions; 2) there is insufficient clinical information provided in the clinical scenario for the raters to reach a firm conclusion about appropriateness; or 3) there is a lack of specific information in the medical literature to make a firm recommendation regarding appropriateness. The uncertain category designation should encourage investigators to perform definitive research whenever possible. A designation of "uncertain" does not imply that the test should not be used in a specific clinical scenario. Many other factors known by the clinician and difficult to characterize within the structure of the AUC could affect a decision to perform or not perform a procedure in a specific patient. It is anticipated that the AUC reports will continue to be revised as further data are generated and information from the implementation of the criteria is accumulated. The writing group recognizes that a large portion of routine medical care would be rated as uncertain when held to the standards of the AUC and therefore hope this rating is correctly interpreted and can be placed in proper context.

To prevent bias in the scoring process, the technical panel was deliberately comprised of a minority of specialists in cardiac catheterization. Specialists, although offering important clinical and technical insights, might have a natural tendency to rate the indications within their specialty as more appropriate than nonspecialists. In addition, care was taken in providing objective, nonbiased information, including guidelines and key references, to the technical panel.

The level of agreement among panelists as defined by RAND (2) was analyzed based on the BIOMED rule for a panel of 14 to 16 members. As such, agreement is defined as an indication where 4 or fewer panelists' ratings fell outside the 3-point region containing the median score.

Disagreement was defined as where at least 5 panelists' ratings fell in both the appropriate and the inappropriate categories. Any indication having disagreement was categorized as uncertain regardless of the final median score.

3. Assumptions

To limit inconsistencies in interpretation, specific assumptions were used by the writing group in drafting indications and by the technical panel when rating the clinical indications for the appropriate use of diagnostic catheterization.

1. The clinical scenarios were rated based on published literature and clinical practice guidelines regarding the risks and benefits of diagnostic catheterization, if available. In general, there are few randomized trials specifically examining diagnostic catheterization as a procedure. However, diagnostic catheterization was used within the study design of many randomized trials in which specific therapies were tested. Specific patient groups not well represented in the literature are not presented in the current clinical scenarios. However, the writing group recognizes that decisions about diagnostic catheterization in such patients are frequently required. Examples of such patients include those with end-stage renal disease, advanced age, or malignancy.
2. All patients are attempting to achieve optimal care, including guideline-based risk factor modification for primary or secondary prevention in cardiovascular patients unless specifically noted (3–7).
3. Despite the best efforts of the clinician, all patients may not achieve target goals for risk factor modification. However, a plan of care to address risk factors is assumed to be occurring in patients represented in the indications. For patients with chronic stable angina, the writing group recognizes that there is a wide variance in the medical therapy for angina.
4. Operators performing diagnostic catheterization have appropriate clinical training and experience and have satisfactory outcomes as assessed by quality assurance monitoring (8,9).
5. Diagnostic catheterization (left heart, right heart, and/or coronary angiography) is performed in a manner consistent with established standards of care (8,9).
6. All indications for diagnostic catheterization were considered with the following important assumptions:
   a. All indications were first evaluated on the basis of the available medical literature.
   b. In many cases, studies published in the medical literature provide minimal information about the role of the test in clinical decision making.
   c. Appropriate use criteria development requires a risk/benefit trade-off as determined by individual patient indications. Radiation exposure should be considered in risk estimates.
   d. No circumstances exist that would preclude cardiac catheterization (e.g., severe coagulopathy, patient refusal).
7. A complete clinical history and physical exam has been completed by a qualified clinician such that the clinical status of the patient can be assumed to be valid as stated in the indication (e.g., asymptomatic patient is truly asymptomatic for the condition in question and that sufficient questioning of the patient has been undertaken).

8. Cost was be considered implicitly in the appropriate use determination.
9. For each indication, the rating reflected whether diagnostic catheterization is reasonable for the patient and not whether it is preferred over another modality.
10. The category of "uncertain" was used when insufficient clinical data are available for a definitive categorization or there is substantial disagreement regarding the appropriateness of that indication. Those scenarios designated as uncertain reflect variations in clinical practice patterns. **The designation of "uncertain" should not be used as grounds for denial of reimbursement.**
11. All procedures presented are to be considered for clinical indications and not part of a research protocol.
12. All prior noninvasive testing was adequately completed.

4. Definitions

Definitions of terms used throughout the indication set are listed here. These definitions were provided to and discussed with the technical panel prior to rating of indications.

Stress Testing and Risk of Findings on Noninvasive Testing: Stress testing is commonly used for both diagnosis (possible/presumed) and risk stratification of patients with established CAD. Using criteria defined for traditional exercise stress tests (10,11):

- **Low-risk stress test findings:** associated with a cardiac mortality of <1% per year
- **Intermediate-risk stress test findings:** associated with a 1% to 3% per year cardiac mortality
- **High-risk stress test findings:** associated with a >3% per year cardiac mortality

Symptomatic/Ischemic Equivalent: Chest Pain Syndrome, Anginal Equivalent, or Ischemic Electrocardiogram (ECG) Abnormalities: Any constellation of clinical findings that the physician believes is consistent with CAD manifestations. Examples of such findings include, but are not limited to, chest pain, chest tightness, chest burning, shoulder pain, left arm pain, jaw pain, new ECG abnormalities, or other symptoms/findings suggestive of CAD. Clinical presentations in the absence of chest pain (e.g., dyspnea with exertion or reduced/worsening effort tolerance) that are thought to be consistent with CAD may also be considered to be an ischemic equivalent.

Clinical Classification of Chest Pain:

- ***Typical* Angina (Definite):** defined as 1) substernal chest pain or discomfort that is 2) provoked by exertion or emotional stress and 3) relieved by rest and/or nitroglycerin (12).
- ***Atypical* Angina (Probable):** chest pain or discomfort that **lacks 1** of the characteristics of definite or typical angina.
- ***Nonanginal* Chest Pain:** chest pain or discomfort that **meets 1 or none** of the typical angina characteristics.

Grading of Angina Pectoris by the Canadian Cardiovascular Society Classification System (13):

Class I: ordinary physical activity does not cause angina, such as walking, climbing stairs. Angina occurs with strenuous, rapid, or prolonged exertion at work or recreation.

Class II: slight limitation of ordinary activity. Angina occurs on walking more than 2 blocks on the level and climbing more than 1 flight of ordinary stairs at a normal pace and in normal condition.

Class III: marked limitations of ordinary physical activity. Angina occurs on walking 1 or 2 blocks on the level and climbing 1 flight of stairs in normal conditions and at a normal pace.

Class IV: inability to carry on any physical activity without discomfort—anginal symptoms may be present at rest.

Pretest Probability of Coronary Artery Disease: Symptomatic (Ischemic Equivalent) Patients: Once the physician determines that symptoms are present that may represent CAD, the pretest probability of CAD should be assessed. There are a number of risk algorithms (14,15) available that can be used to calculate this probability. Clinicians should be familiar with those algorithms that pertain to the populations they encounter most often. In rating the appropriateness of cardiac catheterization for specific indications, the following probabilities, as calculated from any of the various available validated algorithms, should be applied (10):

- **Very low pretest probability:** <5% pretest probability of CAD
- **Low pretest probability:** between 5% and 10% pretest probability of CAD
- **Intermediate pretest probability:** between 10% and 90% pretest probability of CAD
- **High pretest probability:** >90% pretest probability of CAD

The method recommended by the ACCF/AHA guidelines for chronic stable angina (10) is provided as one example of a method used to calculate pretest probability and is a modification of a previously published literature review (16). Please refer to Table A and the clinical classification of chest pain definition angina characteristics. It is important to note that other historical factors or ECG findings (e.g., prior infarction) can affect pretest probability, although these factors are not accounted for in Table A. Similarly, while not incorporated into the algorithm, other CAD risk factors may also affect pretest likelihood of CAD. Detailed nomograms are available that incorporate the effects of a history of prior infarction, ECG Q waves and ST- and T-wave changes, diabetes, smoking, and hypercholesterolemia (17).

Table A. Pretest Probability of CAD by Age, Gender, and Symptoms*

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

High: >90% pretest probability. Intermediate: between 10% and 90% pretest probability. Low: between 5% and 10% pretest probability. Very low: <5% pretest probability. *Modified from the ACC/AHA Exercise Testing Guidelines to reflect all age ranges (18).
CAD = coronary artery disease.

Global CAD Risk: It is assumed that clinicians will use current standard methods of global risk assessment such as those presented in the National Heart, Lung, and Blood Institute report on Detection, Evaluation, and Treatment of High Blood Cholesterol in Adults (Adult Treatment Panel III [ATP III]) (19) or similar national guidelines.

Absolute risk is defined as the probability of developing CAD over a given time period. The ATP III report estimates the absolute risk for CAD over the next 10 years. CAD risk refers to 10-year risk for any hard cardiac event (e.g., myocardial infarction or CAD death). However, acknowledging that global absolute risk scores may have not been evaluated in certain populations (e.g., women, younger men, minority populations), clinical judgment must be applied in assigning categorical risk thresholds in such subpopulations.

- **Low global CAD risk**
  Defined by the age-specific risk level that is below average. In general, low risk will correlate with a 10-year absolute CAD risk <10%. However, in women and younger men, low risk may correlate with 10-year absolute CAD risk <6%.
- **Intermediate global CAD risk**
  Defined by the age-specific risk level that is average. In general, moderate risk will correlate with a 10-year absolute CAD risk range of 10% to 20%. Among women and younger men, an expanded intermediate risk range of 6% to 20% may be appropriate.
- **High global CAD risk**
  Defined by the age-specific risk level that is above average. In general, high risk will correlate with a 10-year absolute CAD risk of >20%. CAD equivalents (e.g., diabetes mellitus, peripheral arterial disease) can also define high risk.

Duke Treadmill Score (20): The equation for calculating the Duke treadmill score (DTS) is DTS = exercise time in minutes − (5 × ST-segment deviation) − (4 × exercise angina), with 0 = none, 1 = nonlimiting, and 2 = exercise-limiting.

The score typically ranges from −25 to +15. These values correspond to low-risk (with a score of ≥+5), moderate-risk (with scores ranging from −10 to +4), and high-risk (with a score of ≤−11) categories.

ECG—Uninterpretable: Refers to ECGs with resting ST-segment depression (≥0.10 mV), left bundle branch block (LBBB), pre-excitation (Wolff-Parkinson-White Syndrome), or paced rhythm.

Adjunct Invasive Diagnostic Testing:

- **Fractional flow reserve (FFR)**
  An invasive diagnostic tool used to provide physiological measurements as an adjunct to coronary angiography for the determination of lesion severity and to assist in decisions about revascularization. FFR is calculated using the ratio of the mean arterial pressure distal to a stenosis to the mean aortic pressure during maximal hyperemia. FFR measurements <0.75 are associated with ischemia on exercise testing and adjunct imaging (echo or nuclear) with high sensitivity (88%), specificity (100%), and overall accuracy (93%). FFR measurements >0.80 are associated with negative ischemic results with a predictive accuracy of 95%. Routine measurement of FFR in patients with multivessel coronary artery disease who are undergoing PCI with drug-eluting stents with deferral of lesions with FFR >0.80 has been shown to significantly reduce the rate of the composite endpoint of death, nonfatal myocardial infarction, and repeat revascularization at 1 year (21).
- **Intravascular ultrasound**
  An invasive diagnostic test performed as an adjunct to diagnostic catheterization to provide an ultrasound-based anatomic assessment that extends beyond conventional angiography. This technique is used to identify lesion and vessel characteristics and obtain basic measurements for diagnostic and interventional application (minimal and maximal

luminal diameters, cross-sectional area, and plaque area).

Evaluating Perioperative Risk for Noncardiac Surgery: See Figure A, "Stepwise Approach to Perioperative Cardiac Assessment," from the ACCF/AHA 2009 perioperative guidelines (22). According to the algorithm, once it is determined that the patient does not require urgent surgery, the clinician should determine the patient's active cardiac conditions (see Table B) and/or perioperative risk predictors (see Table C). If any active cardiac conditions and/or major risk predictors are present, Figure A suggests consideration of guideline-based care that may include coronary angiography and postponing or canceling noncardiac surgery. Once perioperative risk predictors are assessed, the surgical risk and the patient's functional status should be used to establish the need for noninvasive testing.

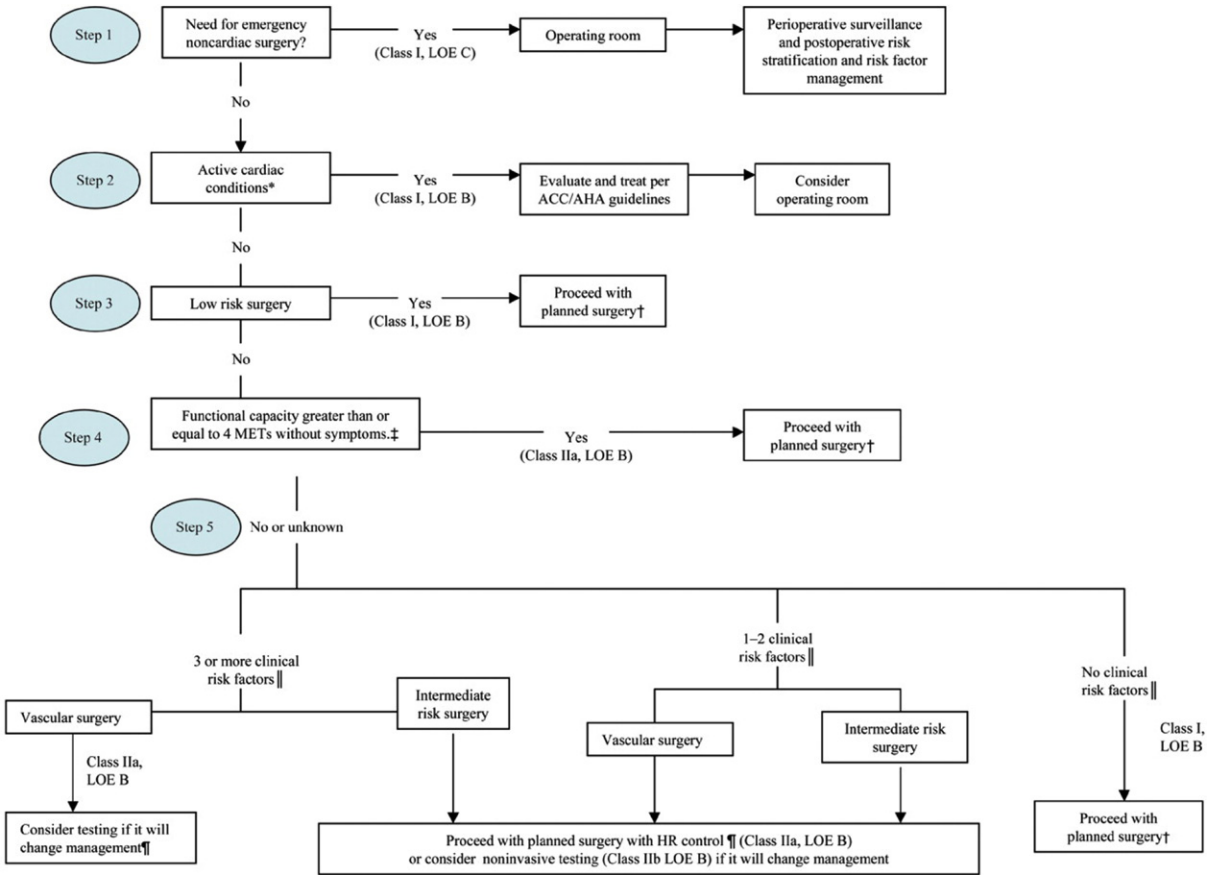

Figure A. Stepwise Approach to Perioperative Cardiac Assessment

Cardiac evaluation and care algorithm for noncardiac surgery based on active clinical conditions, known cardiovascular disease, or cardiac risk factors for patients ≥50 years of age. HR = heart rate; LOE = level of evidence; MET = metabolic equivalent. Modified from Fleisher et al. (22).

Table B. Active Cardiac Conditions for Which the Patient Should Undergo Evaluation and Treatment Before Noncardiac Surgery (Class I, Level of Evidence: B)

Condition	Examples
Unstable coronary syndromes	Unstable or severe angina* (CCS class III or IV)†
	Recent MI‡
Decompensated HF (NYHA functional class IV; worsening or new-onset HF)	
Significant arrhythmias	High-grade atrioventricular block
	Mobitz II atrioventricular block
	Third-degree atrioventricular heart block
	Symptomatic ventricular arrhythmias
	Supraventricular arrhythmias (including atrial fibrillation) with uncontrolled ventricular rate (HR >100 beats/min at rest)
	Symptomatic bradycardia
	Newly recognized ventricular tachycardia
Severe valvular disease	Severe aortic stenosis (mean pressure gradient >40 mm Hg, aortic valve area <1.0 cm^2, or symptomatic)
	Symptomatic mitral stenosis (progressive dyspnea on exertion, extertional presyncope, or HF)

*According to Campeau (13); †may include "stable" angina in patients who are unusually sedentary; ‡the American College of Cardiology National Database Library defines recent MI as >7 days but ≤1 month (within 30 days).
CCS = Canadian Cardiovascular Society; HF = heart failure; HR = heart rate; MI = myocardial infarction; NYHA = New York Heart Association.
Reprinted from Fleisher et al. (22).

Table C. Perioperative Clinical Risk Factors*

- History of ischemic heart disease
- History of compensated or prior heart failure
- History of cerebrovascular disease
- Diabetes mellitus (requiring insulin)
- Renal insufficiency (creatinine >2.0)

*As defined by the ACCF/AHA guidelines on perioperative cardiovascular evaluation and care for noncardiac surgery (22). Note that these are not standard coronary artery disease risk factors.
ACCF = American College of Cardiology Foundation; AHA = American Heart Association.

5. Abbreviations

ACS = acute coronary syndrome
AV = atrioventricular
CABG = coronary artery bypass grafting surgery
CAD = coronary artery disease
ECG = electrocardiogram
FFR = fractional flow reserve
LBBB = left bundle branch block
LV = left ventricular

6. Results of Ratings

The final ratings for diagnostic catheterization are listed by indication in Tables 1.1, 1.2, 1.3, 1.4, 1.5, 1.6, 1.7, 2.1, 2.2, 2.3, to 3.1. The final score reflects the median score of the 17 technical panel members and has been labeled according to the 3 appropriate use categories of appropriate (median 7 to 9), uncertain (median 4 to 6), and inappropriate (median 1 to 3). Tables 4, 5, and 6 present the same indications by the appropriate use categories.

7. Diagnostic Catheterization Appropriate Use Criteria (by Indication)

A. CAD Assessment

1. Coronary Angiography With or Without Left Heart Catheterization and Left Ventriculography

Coronary angiography is widely used to evaluate patients with known or suspected CAD. Depending on the clinical circumstances and prior testing, coronary angiography may be coupled with the measurement of left ventricular (LV) pressures (left heart catheterization) and/or the evaluation of LV systolic function and wall motion (left ventriculography).

The indications developed in Section A relate to appropriateness of coronary angiography. A decision about the performance of left heart catheterization and left ventriculography is left to the discretion of the operator and the patient's primary physician.

Table 1.1. Suspected or Known ACS

Indication		Appropriate Use Score (1–9)		
1.	• Cardiogenic shock due to suspected ACS	A (9)		
2.	• STEMI or suspected STEMI	A (9)		
	Risk Score (e.g., TIMI, GRACE)	**Low**	**Intermediate**	**High**
3.	• UA/NSTEMI	A (7)	A (8)	A (9)
4.	• Suspected ACS with newly diagnosed LV wall motion abnormality or newly diagnosed resting myocardial perfusion defect	A (7)	A (8)	A (9)

A = appropriate; ACS = acute coronary syndrome; GRACE = Global Registry of Acute Coronary Events; LV = left ventricular; STEMI = ST-elevation myocardial infarction; TIMI = Thrombolysis In Myocardial Infarction; UA/NSTEMI = unstable angina non–ST-elevation myocardial infarction.

Table 1.2. Suspected CAD: No Prior Noninvasive Stress Imaging (No Prior PCI, CABG, or Angiogram Showing ≥50% Angiographic Stenosis)

Indication		Appropriate Use Score (1–9)
	Asymptomatic	
5.	• Low global CAD risk	I (1)
6.	• Intermediate global CAD risk	I (3)
7.	• High global CAD risk	U (4)
	Symptomatic	
8.	• Low pretest probability	I (3)
9.	• Intermediate pretest probability	U (6)
10.	• High pretest probability	A (7)

A = appropriate; CABG = coronary bypass grafting surgery; CAD = coronary artery disease; I = inappropriate; PCI = percutaneous coronary intervention; U = uncertain.

Table 1.3. Suspected CAD: Prior Noninvasive Testing (No Prior PCI, CABG, or Angiogram Showing ≥50% Angiographic Stenosis)

Indication		Appropriate Use Score (1–9)	
		Pretest Symptom Status	
	ECG Stress Testing	**Asymptomatic**	**Symptomatic**
11.	• Low-risk findings (e.g., Duke treadmill score ≥5)	I (1)	U (4)
12.	• Intermediate-risk findings (e.g., Duke treadmill score 4 to −10)	U (4)	U (6)
13.	• High-risk findings (e.g., Duke treadmill score ≤−11)	A (7)	A (8)
14.	• Other high-risk findings (ST-segment elevation, hypotension with exercise, ventricular tachycardia, prolonged ST-segment depression)	A (7)	A (9)
		Pretest Symptom Status	
	Stress Test With Imaging (SPECT MPI, Stress Echocardiography, Stress PET, Stress CMR)	**Asymptomatic**	**Symptomatic**
15.	• Low-risk findings (e.g., <5% ischemic myocardium on stress SPECT MPI or stress PET, no stress-induced wall motion abnormalities on stress echo or stress CMR)	I (2)	U (4)
16.	• Intermediate-risk findings (e.g., 5% to 10% ischemic myocardium on stress SPECT MPI or stress PET, stress-induced wall motion abnormality in a single segment on stress echo or stress CMR)	U (4)	A (7)
17.	• High-risk findings (e.g., >10% ischemic myocardium on stress SPECT MPI or stress PET, stress-induced wall motion abnormality in 2 or more segments on stress echo or stress CMR)	A (7)	A (9)
18.	• Other high-risk findings (e.g., TID, significant stress-induced LV dysfunction)	A (7)	A (8)
19.	• Discordant findings (e.g., low-risk prior imaging with ongoing symptoms consistent with ischemic equivalent)	Not rated	A (7)
20.	• Discordant findings (e.g., low-risk stress imaging with high-risk stress ECG response or stress-induced typical angina)	U (5)	A (7)
21.	• Equivocal/uninterpretable findings (e.g., perfusion defect vs. attenuation artifact, uninterpretable stress imaging)	U (5)	A (7)
22.	• Fixed perfusion defect on SPECT MPI or a persistent wall motion abnormality on stress echo consistent with infarction without significant ischemia (<5% ischemic myocardium)	U (4)	U (6)
23.	• Baseline resting LV dysfunction (i.e., LVEF ≤40%) AND • Evidence (e.g., PET, CMR, delayed thallium uptake, dobutamine echo) of myocardial viability in dysfunctional segment	A (7)	A (8)

Table 1.3. Continued

	Indication	Appropriate Use Score (1–9)	
	Echocardiography (TTE)	**Pretest Symptom Status**	
		Asymptomatic	**Symptomatic**
24.	• Newly recognized LV systolic dysfunction (i.e., LVEF ≤40%) with an unknown etiology	U (6)	A (8)
25.	• Newly recognized LV systolic dysfunction (i.e., LVEF 41% to 49%) with an unknown etiology	U (5)	A (8)
26.	• New regional wall motion abnormality with an unknown etiology and normal LV systolic function	U (5)	A (7)
27.	• Suspected significant ischemic complication related to CAD (e.g., ischemic mitral regurgitation or VSD)	A (9)	
	Coronary Calcium Score	**Pretest Symptom Status**	
		Asymptomatic	**Symptomatic***
28.	• Agatston score <100	I (1)	Not rated
29.	• Agatston score 100–400	I (2)	Not rated
30.	• Agatston score 400–1,000	I (3)	Not rated
31.	• Agatston score >1,000	I (3)	Not rated
	Coronary CTA	**Pretest Symptom Status**	
		Asymptomatic	**Symptomatic**
32.	• Lesion <50% non-left main	I (1)	U (4)
33.	• Lesion ≥50% non-left main	U (4)	A (7)
34.	• Lesion ≥50% left main	Not rated	A (8)
35.	• Lesions ≥50% in more than 1 coronary territory	U (5)	A (7)
36.	• Lesion of unclear severity, possibly obstructive (non-left main)	U (4)	A (7)
37.	• Lesion of unclear severity, possibly obstructive (left main)	A (7)	A (8)
38.	• Lesion <50% with extensive partly calcified and non-calcified plaque	I (3)	U (5)
	CMR	**Pretest Symptom Status**	
		Asymptomatic	**Symptomatic**
39.	• Area of delayed gadolinium myocardial enhancement of unknown etiology	I (3)	Not rated

*Coronary calcium score only rated for asymptomatic patients as these patients are the population in which it is used.

A = appropriate; CABG = coronary bypass grafting surgery; CAD = coronary artery disease; CMR = cardiovascular magnetic resonance; CTA = computed tomography angiography; ECG = electrocardiogram; I = inappropriate; LV = left ventricular; LVEF = left ventricular ejection fraction; PET = positron emission tomography; SPECT MPI = single-photon emission computed tomography myocardial perfusion imaging; TID = transient ischemic dilation; TTE = transthoracic echocardiography; U = uncertain; VSD = ventricular septal defect.

Table 1.4. Adjunctive Invasive Diagnostic Testing in Patients Undergoing Appropriate Diagnostic Coronary Angiography

	Indication	Appropriate Use Score (1–9)		
		Unexpected Angiographic Finding or No Prior Noninvasive Testing	**Prior Testing = No Ischemic Findings**	**Prior Testing = Concordant* Ischemic Findings**
	FFR for Lesion Severity			
40.	• Angiographically indeterminate severity left main stenosis (defined as 2 or more orthogonal views contradictory whether stenosis >50%)	A (7)	A (7)	A (7)
41.	• Nonobstructive disease by angiography (non-left main) <50%	I (3)	I (2)	U (5)
42.	• Angiographically intermediate disease (non-left main) 50% to 69%	A (7)	U (6)	A (7)
43.	• Angiographically obstructive significant disease (non-left main) ≥70% stenosis	A (7)	A (7)	I (3)
	IVUS for Lesion Severity			
44.	• Angiographically indeterminate left main stenosis (defined as 2 or more orthogonal views contradictory whether stenosis >50%)	A (7)	A (7)	A (7)
45.	• Nonobstructive disease by angiography (non-left main) <50%	I (3)	I (3)	U (6)
46.	• Angiographically intermediate disease (non-left main) 50% to 69%	U (5)	U (5)	U (6)
47.	• Angiographically obstructive significant disease (non-left main) ≥70% stenosis	U (4)	U (5)	I (3)
	IVUS—Examination of Lesion or Artery Morphology			
48.	• Coronary lesions or structures difficult to characterize angiographically (e.g., aneurysm, extent of calcification, stent fracture, stent apposition, stent expansion, dissections) or for sizing of vessel before stent placement			A (8)

*Concordance refers to noninvasive imaging studies that demonstrate evidence of abnormal myocardial perfusion that is in the same distribution as a coronary artery stenosis, or degree of valvular disease that is similar to clinical impression.

A = appropriate; FFR = fractional flow reserve; I = inappropriate; IVUS = intravascular ultrasound; U = uncertain.

Table 1.5. Patients With Known Obstructive CAD (e.g., Prior MI, Prior PCI, Prior CABG, or Obstructive Disease on Invasive Angiography)

Indication		Appropriate Use Score (1–9)	
	Medically Managed Patients	Asymptomatic/Controlled Symptoms OR Unchanged Findings	Worsening or Limiting Symptoms AND Worsening Findings
49.	• Low-risk noninvasive findings	I (2)	U (6)
50.	• Intermediate-risk noninvasive findings	U (4)	A (7)
51.	• High-risk noninvasive findings	A (7)	A (9)
	Post Revascularization (PCI or CABG)		
52.	• Asymptomatic or stable symptoms		I (1)
53.	• Low-risk noninvasive findings • Worsening or limiting symptoms		U (6)
54.	• Intermediate-risk noninvasive findings • Worsening or limiting symptoms		A (7)
55.	• High-risk noninvasive findings • Worsening or limiting symptoms		A (8)
	Post Revascularization (PCI)		
56.	• Asymptomatic • Prior unprotected left main PCI		U (5)

A = appropriate; CABG = coronary bypass grafting surgery; CAD = coronary artery disease; I = inappropriate; MI = myocardial infarction; PCI = percutaneous coronary intervention; U = uncertain.

Table 1.6. Arrhythmias

Indication		Appropriate Use Score (1–9)		
	Etiology Unclear After Initial Evaluation			
57.	• Resuscitated cardiac arrest with return of spontaneous circulation	A (8)		
58.	• VF or sustained VT with or without symptoms	A (8)		
59.	• Nonsustained VT (<6 beats VT) • Normal LV systolic function	U (5)		
	No Prior Noninvasive Assessment of Ischemia With Normal Systolic Function			
	CHD Risk	**Low**	**Intermediate**	**High**
60.	• Syncope	I (2)	U (4)	U (6)
61.	• New-onset atrial fibrillation or flutter	I (2)	I (3)	U (5)
62.	• Heart block (e.g., second-degree type II or third-degree AV block) OR • Symptomatic bradyarrhythmias	I (2)	I (3)	U (5)
63.	• Newly diagnosed LBBB	U (4)	U (5)	U (6)

A = appropriate; AV = atrioventricular; CHD = coronary heart disease; I = inappropriate; LBBB = left bundle branch block; LV = left ventricular; U = uncertain; VF = ventricular fibrillation; VT = ventricular tachycardia.

Table 1.7. Preoperative Coronary Evaluation for Noncardiac Surgery in Stable Patients

Indication		Appropriate Use Score (1–9)	
64.	• Low-risk surgery	I (2)	
65.	• ≥4 METS functional capacity without symptoms	I (2)	
66	• Prior to solid organ transplantation	U (5)	
	<4 METS Functional Capacity, No Noninvasive Testing Performed, With or Without Clinical Risk Factors Present (Preoperative Clinical Risk Factors: Ischemic Heart Disease, Heart Failure, Cerebrovascular Disease, Insulin-Requiring Diabetes Mellitus, Renal Insufficiency Cr >2.0)		
	Procedure Planned	**Intermediate-Risk Surgery**	**Vascular Surgery**
67.	• No risk factors	I (2)	I (3)
68.	• 1 to 2 risk factors	I (3)	U (4)
69.	• ≥3 risk factors	U (4)	U (6)

Cr = creatinine; I = inappropriate; METS = metabolic equivalents; U = uncertain.

B. **Assessment for Conditions Other Than Coronary Artery Disease**

2. **Right and Left Heart Catheterization or Right Heart Catheterization Alone With or Without Left Ventriculography and Coronary Angiography**

Right and left heart catheterization (including the measurement of cardiac output and intracardiac oxygen saturations) is used to evaluate a variety of conditions. The syndrome of heart failure may or may not be present in these clinical scenarios. Depending on the clinical circumstances and prior testing, coronary angiography, left or right ventriculography, and additional angiography such as supravalvular aortography may be coupled with hemodynamic measurements. A decision about the need for coronary angiography in addition to the hemodynamic study should be at the discretion of the operator and the patient's primary physician.

2.1. **Valvular Disease**

Patients with valvular heart disease can be challenging to evaluate, and these challenges are even greater in the setting of multivalve involvement. Failure to intervene with appropriate therapies at the correct time can result in the permanent impairment of heart function and a poor prognosis. The evaluation of valvular disease should start with a careful history and physical examination and is then augmented by noninvasive imaging, most frequently echocardiography. One of the challenges faced by clinicians occurs when the clinical impression of valve lesion severity based on the history and physical exam differs from that derived from an imaging test. The presence of concordant or conflicting impressions may affect the decision to perform an invasive evaluation and this is tested in the table below. For patients in whom valve surgery is planned, the indication for cardiac catheterization is covered in Indication 70.

Table 2.1 only considers isolated lesions of left-sided valves and does not consider mixed disease of a valve (e.g., aortic stenosis and regurgitation) or multivalve disease. Invasive evaluation may be necessary in these settings but often requires the assessment of several other variables such as LV function and should be at the discretion of the clinician. Scenarios were not developed for isolated or mixed disease of the tricuspid or pulmonic valve because they are relatively uncommon in adults and, when present, are often associated with left-sided valve lesions.

2.2. **Cardiomyopathies**

A variety of conditions present with signs and/or symptoms of heart failure. Right heart catheterization alone or combined right and left heart catheterization (including the measurement of cardiac and pulmonary pressures, cardiac output, vascular resistance, and intracardiac oxygen saturations) is used to evaluate many of these conditions. Depending on the clinical circumstances and prior testing, coronary angiography, left or right ventriculography, and additional angiography may be coupled with these hemodynamic measurements. The indications developed below relate to appropriateness of the right and left heart catheterization. A decision about the performance of coronary angiography should be at the discretion of the operator and the patient's primary physician.

Table 2.1. Valvular Disease

Indication		Appropriate Use Score (1–9)
70.	• Preoperative assessment before valvular surgery	A (7)
71.	• Pulmonary hypertension out of proportion to the severity of valvular disease	A (8)
72.	• Left ventricular dysfunction out of proportion to the severity of valvular disease	A (8)
	Chronic Native or Prosthetic Valvular Disease Asymptomatic Related to Valvular Disease	
73.	• Mild or moderate mitral stenosis	I (2)
74.	• Severe mitral stenosis	U (6)
75.	• Mild or moderate mitral regurgitation	I (2)
76.	• Severe mitral regurgitation	U (5)
77.	• Mild or moderate aortic stenosis	I (2)
78.	• Severe aortic stenosis	U (4)
79.	• Mild or moderate aortic regurgitation	I (2)
80.	• Severe aortic regurgitation	U (5)

Table 2.1. Continued

Indication		Appropriate Use Score (1–9)	
Chronic Native or Prosthetic Valvular Disease Symptomatic Related to Valvular Disease			
Noninvasive Imaging for Valvular Disease		Concordant With Clinical Impression of Severity	Conflicting With Clinical Impression of Severity
81.	• Mild or moderate mitral stenosis	I (2)	A (7)
82.	• Severe mitral stenosis	I (3)	A (7)
83.	• Mild or moderate mitral regurgitation	I (2)	A (7)
84.	• Severe mitral regurgitation	I (3)	A (7)
85.	• Mild or moderate aortic stenosis	I (3)	A (7)
86.	• Severe aortic stenosis	I (3)	A (8)
87.	• Equivocal aortic stenosis/low gradient aortic stenosis • May include pharmacological challenge (e.g., dobutamine)	Not rated	A (8)
88.	• Mild or moderate aortic regurgitation	I (2)	A (7)
89.	• Severe aortic regurgitation	I (3)	A (8)
90.	• Acute moderate or severe mitral or aortic regurgitation	U (4)	A (8)

A = appropriate; I = inappropriate; U = uncertain.

Table 2.2. Pericardial Diseases

Indication		Appropriate Use Score (1–9)
91.	• Suspected pericardial tamponade	A (8)
92.	• Suspected or clinical uncertainty between constrictive vs. restrictive physiology	A (8)

A = appropriate.

Table 2.3. Cardiomyopathies

Indication		Appropriate Use Score (1–9)
93.	• Known or suspected cardiomyopathy with or without heart failure	A (7)
94.	• Re-evaluation of known cardiomyopathy • Change in clinical status or cardiac exam or to guide therapy	A (7)
95.	• Suspected arrhythmogenic right ventricular dysplasia • Assessment of right ventricular morphology	U (5)

A = appropriate; U = uncertain.

3. Right Heart Catheterization

In several clinical situations, the performance of right heart catheterization (hemodynamics and cardiac output) alone is used. This can be performed in the cardiac catheterization laboratory.

Table 3.1. Pulmonary Hypertension or Intracardiac Shunt Evaluation

Indication		Appropriate Use Score (1–9)
96.	• Known or suspected intracardiac shunt with indeterminate shunt anatomy or shunt fraction	A (8)
Evaluation of Pulmonary Hypertension		
97.	• Suspected pulmonary artery hypertension • Equivocal or borderline elevated estimated right ventricular systolic pressure on resting echo study	A (7)
98.	• Suspected pulmonary hypertension • Elevated estimated right ventricular systolic pressure on resting echo study	A (7)
99.	• Resting pulmonary hypertension • Determine response to pulmonary vasodilators given in cath lab	A (8)
100.	• Resting pulmonary hypertension • Determine response after initiation of drug therapy	A (7)
101.	• Post heart transplant patient • With or without the performance of endomyocardial biopsy	A (7)
102.	• Indeterminate intravascular volume status • Etiology unclear after initial evaluation	A (7)

A = appropriate.

8. Diagnostic Catheterization Appropriate Use Criteria (by Appropriate Use Rating)

Table 4. Appropriate Indications (Median Score 7–9)

	Indication	Appropriate Use Score (1–9)
	Suspected Acute Coronary Syndrome	
1.	• Cardiogenic shock due to suspected ACS	A (9)
2.	• STEMI or suspected STEMI	A (9)
3.	• UA/NSTEMI • Low-risk score (e.g., TIMI, GRACE)	A (7)
3.	• UA/NSTEMI • Intermediate-risk score (e.g., TIMI, GRACE)	A (8)
3.	• UA/NSTEMI • High-risk score (e.g., TIMI, GRACE)	A (9)
4.	• Suspected ACS with newly diagnosed LV wall motion abnormality or newly diagnosed resting myocardial perfusion defect • Low-risk score (e.g., TIMI, GRACE)	A (7)
4.	• Suspected ACS with newly diagnosed LV wall motion abnormality or newly diagnosed resting myocardial perfusion defect • Intermediate risk score (e.g., TIMI, GRACE)	A (8)
4.	• Suspected ACS with newly diagnosed LV wall motion abnormality or newly diagnosed resting myocardial perfusion defect • High-risk score (e.g., TIMI, GRACE)	A (9)
	Suspected CAD: No Prior Noninvasive Stress Imaging (No Prior PCI, CABG, or Angiogram Showing ≥50% Angiographic Stenosis)	
10.	• High pretest probability • Symptomatic	A (7)
	Suspected CAD: Prior Noninvasive Testing (No Prior PCI, CABG, or Angiogram Showing ≥50% Angiographic Stenosis)	
	ECG Stress Testing	
13.	• High-risk findings (e.g., Duke treadmill score ≤−11) • Asymptomatic	A (7)
13.	• High-risk findings (e.g., Duke treadmill score ≤−11) • Symptomatic	A (8)
14.	• Other high-risk finding (ST-segment elevation, hypotension with exercise, ventricular tachycardia, prolonged ST-segment depression) • Asymptomatic	A (7)
14.	• Other high-risk finding (ST-segment elevation, hypotension with exercise, ventricular tachycardia, prolonged ST-segment depression) • Symptomatic	A (9)
	Stress Test With Imaging (SPECT MPI, Stress Echocardiography, Stress PET, Stress CMR)	
16.	• Intermediate-risk findings (e.g., 5% to 10% ischemic myocardium on stress SPECT MPI or stress PET, stress-induced wall motion abnormality in a single segment on stress echo or stress CMR) • Symptomatic	A (7)
17.	• High-risk findings (e.g., >10% ischemic myocardium on stress SPECT MPI or stress PET, stress-induced wall motion abnormality in 2 or more segments on stress echo or stress CMR) • Asymptomatic	A (7)
17.	• High-risk findings (e.g., >10% ischemic myocardium on stress SPECT MPI or stress PET, stress-induced wall motion abnormality in 2 or more segments on stress echo or stress CMR) • Symptomatic	A (9)
18.	• Other high-risk finding (e.g., TID, significant stress-induced LV dysfunction) • Asymptomatic	A (7)
18.	• Other high-risk finding (e.g., TID, significant stress-induced LV dysfunction) • Symptomatic	A (8)
19.	• Discordant findings (e.g., low-risk prior imaging with ongoing symptoms consistent with ischemic equivalent) • Symptomatic	A (7)
20.	• Discordant findings (e.g., low-risk stress imaging with high-risk stress ECG response or stress-induced typical angina) • Symptomatic	A (7)
21.	• Equivocal/uninterpretable findings (e.g., perfusion defect vs. attenuation artifact, uninterpretable stress imaging) • Symptomatic	A (7)

Table 4. Continued

Indication		Appropriate Use Score (1–9)
23.	• Baseline resting LV dysfunction (i.e., LVEF ≤40%) AND • Evidence (e.g., PET, CMR, delayed thallium uptake, dobutamine echo) of myocardial viability in dysfunctional segment • Asymptomatic	A (7)
23.	• Baseline resting LV dysfunction (i.e., LVEF ≤40%) AND • Evidence (e.g., PET, CMR, delayed thallium uptake, dobutamine echo) of myocardial viability in dysfunctional segment • Symptomatic	A (8)
Echocardiography (TTE)		
24.	• Newly recognized LV systolic dysfunction (i.e., LVEF ≤40%) with an unknown etiology • Symptomatic	A (8)
25.	• Newly recognized LV systolic dysfunction (i.e., LVEF 41% to 49%) with an unknown etiology • Symptomatic	A (8)
26.	• New regional wall motion abnormality with an unknown etiology and normal LV systolic function • Symptomatic	A (7)
27.	• Suspected significant ischemic complication related to CAD (e.g., ischemic mitral regurgitation or VSD)	A (9)
Coronary CTA		
33.	• Lesion ≥50% non-left main • Symptomatic	A (7)
34.	• Lesion ≥50% left main • Symptomatic	A (8)
35.	• Lesions ≥50% in more than 1 coronary territory • Symptomatic	A (7)
36.	• Lesion of unclear severity, possibly obstructive (non-left main) • Symptomatic	A (7)
37.	• Lesion of unclear severity, possibly obstructive (left main) • Asymptomatic	A (7)
37.	• Lesion of unclear severity, possibly obstructive (left main) • Symptomatic	A (8)
Adjunctive Invasive Diagnostic Testing in Patients Undergoing Appropriate Diagnostic Coronary Angiography		
FFR for Lesion Severity		
40.	• Angiographically indeterminate severity left main stenosis (defined as 2 or more orthogonal views contradictory whether stenosis >50%) • Unexpected angiographic finding or no prior noninvasive testing	A (7)
40.	• Angiographically indeterminate severity left main stenosis (defined as 2 or more orthogonal views contradictory whether stenosis >50%) • Prior testing = no ischemic findings	A (7)
40.	• Angiographically indeterminate severity left main stenosis (defined as 2 or more orthogonal views contradictory whether stenosis >50%) • Prior testing = concordant ischemic findings	A (7)
42.	• Angiographically intermediate disease (non-left main) 50% to 69% • Unexpected angiographic finding or no prior noninvasive testing	A (7)
42.	• Angiographically intermediate disease (non-left main) 50% to 69% • Prior testing = concordant ischemic findings	A (7)
43.	• Angiographically obstructive significant disease (non-left main) ≥70% stenosis • Unexpected angiographic finding or no prior noninvasive testing	A (7)
43.	• Angiographically obstructive significant disease (non-left main) ≥70% stenosis • Prior testing = no ischemic findings	A (7)
IVUS for Lesion Severity		
44.	• Angiographically indeterminate severity left main stenosis (defined as 2 or more orthogonal views contradictory whether stenosis >50%) • Unexpected angiographic finding or no prior noninvasive testing	A (7)
44.	• Angiographically indeterminate severity left main stenosis (defined as 2 or more orthogonal views contradictory whether stenosis >50%) • Prior testing = no ischemic findings	A (7)
44.	• Angiographically indeterminate severity left main stenosis (defined as 2 or more orthogonal views contradictory whether stenosis >50%) • Prior testing = concordant ischemic findings	A (7)

Table 4. Continued

Indication		Appropriate Use Score (1–9)
IVUS—Examination of Lesion or Artery Morphology		
48.	• Coronary lesions or structures difficult to characterize angiographically (e.g., aneurysm, extent of calcification, stent fracture, stent apposition, stent expansion, dissections) or for sizing of vessel before stent placement	A (8)
Patients With Known Obstructive CAD (e.g., Prior MI, Prior PCI, Prior CABG, or Obstructive Disease on Invasive Angiography)		
Medically Managed Patients		
50.	• Intermediate-risk noninvasive findings • Worsening or limiting symptoms and worsening findings	A (7)
51.	• High-risk noninvasive findings • Asymptomatic/controlled symptoms or unchanged findings	A (7)
51.	• High-risk noninvasive findings • Worsening or limiting symptoms and worsening findings	A (9)
Post Revascularization (PCI or CABG)		
54.	• Intermediate-risk noninvasive findings • Worsening or limiting symptoms	A (7)
55.	• High-risk noninvasive findings • Worsening or limiting symptoms	A (8)
Arrhythmias		
Etiology Unclear After Initial Evaluation		
57.	• Resuscitated cardiac arrest with return of spontaneous circulation	A (8)
58.	• VF or sustained VT with or without symptoms	A (8)
Valvular Disease		
70.	• Preoperative assessment before valvular surgery	A (7)
71.	• Pulmonary hypertension out of proportion to the severity of valvular disease	A (8)
72.	• Left ventricular dysfunction out of proportion to the severity of valvular disease	A (8)
Chronic Native or Prosthetic Valvular Disease Symptomatic Related to Valvular Disease		
81.	• Mild or moderate mitral stenosis • Noninvasive imaging for valvular disease conflicting with clinical impression of severity	A (7)
82.	• Severe mitral stenosis • Noninvasive imaging for valvular disease conflicting with clinical impression of severity	A (7)
83.	• Mild or moderate mitral regurgitation • Noninvasive imaging for valvular disease conflicting with clinical impression of severity	A (7)
84.	• Severe mitral regurgitation • Noninvasive imaging for valvular disease conflicting with clinical impression of severity	A (7)
85.	• Mild or moderate aortic stenosis • Noninvasive imaging for valvular disease conflicting with clinical impression of severity	A (7)
86.	• Severe aortic stenosis • Noninvasive imaging for valvular disease conflicting with clinical impression of severity	A (8)
87.	• Equivocal aortic stenosis/low gradient aortic stenosis • May include pharmacological challenge (e.g., dobutamine) • Noninvasive imaging for valvular disease conflicting with clinical impression of severity	A (8)
88.	• Mild or moderate aortic regurgitation • Noninvasive imaging for valvular disease conflicting with clinical impression of severity	A (7)
89.	• Severe aortic regurgitation • Noninvasive imaging for valvular disease conflicting with clinical impression of severity	A (8)
90.	• Acute moderate or severe mitral or aortic regurgitation • Noninvasive imaging for valvular disease conflicting with clinical impression of severity	A (8)
Pericardial Diseases		
91.	• Suspected pericardial tamponade	A (8)
92.	• Suspected or clinical uncertainty between constrictive vs. restrictive physiology	A (8)
Cardiomyopathies		
93.	• Known or suspected cardiomyopathy with or without heart failure	A (7)
94.	• Re-evaluation of known cardiomyopathy • Change in clinical status or cardiac exam or to guide therapy	A (7)
Pulmonary Hypertension or Intracardiac Shunt Evaluation		
96.	• Known or suspected intracardiac shunt with indeterminate shunt anatomy or shunt fraction	A (8)

Table 4. Continued

	Indication	Appropriate Use Score (1–9)
	Evaluation of Pulmonary Hypertension	
97.	• Suspected pulmonary artery hypertension • Equivocal or borderline elevated estimated right ventricular systolic pressure on resting echo study	A (7)
98.	• Suspected pulmonary hypertension • Elevated estimated right ventricular systolic pressure on resting echo study	A (7)
99.	• Resting pulmonary hypertension • Determine response to pulmonary vasodilators given in cath lab	A (8)
100.	• Resting pulmonary hypertension • Determine response after initiation of drug therapy	A (7)
101.	• Post heart transplant patient • With or without the performance of endomyocardial biopsy	A (7)
102.	• Indeterminate intravascular volume status • Etiology unclear after initial evaluation	A (7)

A = appropriate; ACS = acute coronary syndrome; CABG = coronary bypass grafting surgery; CAD = coronary artery disease; CMR = cardiovascular magnetic resonance; CTA = computed tomography angiography; ECG = electrocardiogram; FFR = fractional flow reserve; GRACE = Global Registry of Acute Coronary Events; IVUS = intravascular ultrasound; LV = left ventricular; LVEF = left ventricular ejection fraction; MI = myocardial infarction; PET = positron emission tomography; PCI = percutaneous coronary intervention; SPECT MPI = single-photon emission computed tomography myocardial perfusion imaging; STEMI = ST-elevation myocardial infarction; TID = transient ischemic dilation; TIMI = Thrombolysis In Myocardial Infarction; TTE = transthoracic echocardiography; UA/NSTEMI = unstable angina/non–ST-elevation myocardial infarction; VF = ventricular fibrillation; VSD = ventricular septal defect; VT = ventricular tachycardia.

Table 5. Uncertain Indications (Median Score 4–6)

	Indication	Appropriate Use Score (1–9)
	Suspected CAD: No Prior Noninvasive Stress Imaging (No Prior PCI, CABG, or Angiogram Showing ≥50% Angiographic Stenosis)	
7.	• High global CAD risk • Asymptomatic	U (4)
9.	• Intermediate pretest probability • Symptomatic	U (6)
	Suspected CAD: Prior Noninvasive Testing (No Prior PCI, CABG, or Angiogram Showing ≥50% Angiographic Stenosis)	
	ECG Stress Testing	
11.	• Low-risk findings (e.g., Duke treadmill score ≥5) • Symptomatic	U (4)
12.	• Intermediate-risk findings (e.g., Duke treadmill score 4 to −10) • Asymptomatic	U (4)
12.	• Intermediate-risk findings (e.g., Duke treadmill score 4 to −10) • Symptomatic	U (6)
	Stress Test With Imaging (SPECT MPI, Stress Echocardiography, Stress PET, Stress CMR)	
15.	• Low-risk findings (e.g., <5% ischemic myocardium on stress SPECT MPI or stress PET, no stress-induced wall motion abnormalities on stress echo or stress CMR) • Symptomatic	U (4)
16.	• Intermediate-risk findings (e.g., 5% to 10% ischemic myocardium on stress SPECT MPI or stress PET, stress-induced wall motion abnormality in a single segment on stress echo or stress CMR) • Asymptomatic	U (4)
20.	• Discordant findings (e.g., low-risk stress imaging with high-risk stress ECG response or stress-induced typical angina) • Asymptomatic	U (5)
21.	• Equivocal/uninterpretable findings (e.g., perfusion defect vs. attenuation artifact, uninterpretable stress imaging) • Asymptomatic	U (5)
22.	• Fixed perfusion defect on SPECT MPI or a persistent wall motion abnormality on stress echo consistent with infarction without significant ischemia (<5% ischemic myocardium) • Asymptomatic	U (4)
22.	• Fixed perfusion defect on SPECT MPI or a persistent wall motion abnormality on stress echo consistent with infarction without significant ischemia (<5% ischemic myocardium) • Symptomatic	U (6)
	Echocardiography (TTE)	
24.	• Newly recognized LV systolic dysfunction (i.e., LVEF ≤40%) with an unknown etiology • Asymptomatic	U (6)
25.	• Newly recognized LV systolic dysfunction (i.e., LVEF 41% to 49%) with an unknown etiology • Asymptomatic	U (5)
26.	• New regional wall motion abnormality with an unknown etiology and normal LV systolic function • Asymptomatic	U (5)

Table 5. Continued

Indication		Appropriate Use Score (1–9)
Coronary CTA		
32.	• Lesion <50% non-left main • Symptomatic	U (4)
33.	• Lesion ≥50% non-left main • Asymptomatic	U (4)
35.	• Lesions ≥50% in more than 1 coronary territory • Asymptomatic	U (5)
36.	• Lesion of unclear severity, possibly obstructive (non-left main) • Asymptomatic	U (4)
38.	• Lesion <50% with extensive partly calcified and noncalcified plaque • Symptomatic	U (5)
Adjunctive Invasive Diagnostic Testing in Patients Undergoing Appropriate Diagnostic Coronary Angiography		
FFR for Lesion Severity		
41.	• Nonobstructive disease by angiography (non-left main) <50% • Prior testing = concordant ischemic findings	U (5)
42.	• Angiographically intermediate disease (non-left main) 50% to 69% • Prior testing = no ischemic findings	U (6)
IVUS for Lesion Severity		
45.	• Non-obstructive disease by angiography (non-left main) <50% • Prior testing = concordant ischemic findings	U (6)
46.	• Angiographically intermediate disease (non-left main) 50% to 69% • Unexpected angiographic finding or no prior noninvasive testing	U (5)
46.	• Angiographically intermediate disease (non-left main) 50% to 69% • Prior testing = no ischemic findings	U (5)
46.	• Angiographically intermediate disease (non-left main) 50% to 69% • Prior testing = concordant ischemic findings	U (6)
47.	• Angiographically obstructive significant disease (non-left main) ≥70% stenosis • Unexpected angiographic finding or no prior noninvasive testing	U (4)
47.	• Angiographically obstructive significant disease (non-left main) ≥70% stenosis • Prior testing = no ischemic findings	U (5)
Patients With Known Obstructive CAD (e.g., Prior MI, Prior PCI, Prior CABG, or Obstructive Disease on Invasive Angiography)		
Medically Managed Patients		
49.	• Low-risk noninvasive findings • Worsening or limiting symptoms and worsening findings	U (6)
50.	• Intermediate-risk noninvasive findings • Asymptomatic/controlled symptoms or unchanged findings	U (4)
Post Revascularization (PCI or CABG)		
53.	• Low-risk noninvasive findings • Worsening or limiting symptoms	U (6)
Post Revascularization (PCI)		
56.	• Asymptomatic • Prior unprotected left main PCI	U (5)
Arrhythmias		
Etiology Unclear After Initial Evaluation		
59.	• Nonsustained VT (<6 beats VT) • Normal LV systolic function	U (5)
No Prior Noninvasive Assessment of Ischemia With Normal Systolic Function		
60.	• Syncope • Intermediate CHD risk	U (4)
60.	• Syncope • High CHD risk	U (6)
61.	• New-onset atrial fibrillation or flutter • High CHD risk	U (5)
62.	• Heart block (e.g., second-degree type II or third-degree AV block) OR • Symptomatic bradyarrhythmias • High CHD risk	U (5)
63.	• Newly diagnosed LBBB • Low CHD risk	U (4)

Table 5. Continued

Indication		Appropriate Use Score (1–9)
63.	• Newly diagnosed LBBB • Intermediate CHD risk	U (5)
63.	• Newly diagnosed LBBB • High CHD risk	U (6)
Preoperative Coronary Evaluation for Noncardiac Surgery in Stable Patients		
66.	• Prior to solid organ transplantation	U (5)
<4 METS Functional Capacity, No Noninvasive Testing Performed, With or Without Clinical Risk Factors Present (Preoperative Clinical Risk Factors: Ischemic Heart Disease, Heart Failure, Cerebrovascular Disease, Insulin-Requiring Diabetes Mellitus, Renal Insufficiency Cr >2.0)		
68.	• 1 to 2 risk factors • Vascular surgery	U (4)
69.	• ≥3 risk factors • Intermediate-risk surgery	U (4)
69.	• ≥3 risk factors • Vascular surgery	U (6)
Valvular Disease		
Chronic Native or Prosthetic Valvular Disease Asymptomatic Related to Valvular Disease		
74.	• Severe mitral stenosis	U (6)
76.	• Severe mitral regurgitation	U (5)
78.	• Severe aortic stenosis	U (4)
80.	• Severe aortic regurgitation	U (5)
Chronic Native or Prosthetic Valvular Disease Symptomatic Related to Valvular Disease		
90.	• Acute moderate or severe mitral or aortic regurgitation • Noninvasive imaging for valvular disease concordant with clinical impression of severity	U (4)
Cardiomyopathies		
95.	• Suspected arrhythmogenic right ventricular dysplasia • Assessment of right ventricular morphology	U (5)

AV = atrioventricular; CABG = coronary bypass grafting surgery; CAD = coronary artery disease; CHD = coronary heart disease; CMR = cardiovascular magnetic resonance; Cr = creatinine; CTA = computed tomography angiography; ECG = electrocardiogram; FFR = fractional flow reserve; IVUS = intravascular ultrasound; LBBB = left bundle branch block; LV = left ventricular; LVEF = left ventricular ejection fraction; METS = metabolic equivalents; MI = myocardial infarction; PCI = percutaneous coronary intervention; PET = positron emission tomography; SPECT MPI = single-photon emission computed tomography myocardial perfusion imaging; TTE = transthoracic echocardiography; U = uncertain; VT = ventricular tachycardia.

Table 6. Inappropriate Indications (Median Score 1–3)

Indication		Appropriate Use Score (1–9)
Suspected CAD: No Prior Noninvasive Stress Imaging (No Prior PCI, CABG, or Angiogram Showing ≥50% Angiographic Stenosis)		
5.	• Low global CAD risk • Asymptomatic	I (1)
6.	• Intermediate global CAD risk • Asymptomatic	I (3)
8.	• Low pretest probability • Symptomatic	I (3)
Suspected CAD: Prior Noninvasive Testing (No Prior PCI, CABG, or Angiogram Showing ≥50% Angiographic Stenosis)		
ECG Stress Testing		
11.	• Low-risk findings (e.g., Duke treadmill score ≥5) • Asymptomatic	I (1)
Stress Test With Imaging (SPECT MPI, Stress Echocardiography, Stress PET, Stress CMR)		
15.	• Low-risk findings (e.g., <5% ischemic myocardium on stress SPECT MPI or stress PET, no stress-induced wall motion abnormalities on stress echo or stress CMR) • Asymptomatic	I (2)
Coronary Calcium Score		
28.	• Agatston score <100 • Asymptomatic	I (1)
29.	• Agatston score 100 to 400 • Asymptomatic	I (2)
30.	• Agatston score 400–1,000 • Asymptomatic	I (3)

Table 6. Continued

Indication		Appropriate Use Score (1–9)
31.	• Agatston score >1,000 • Asymptomatic	I (3)
Coronary CTA		
32.	• Lesion <50% non-left main • Asymptomatic	I (1)
38.	• Lesion <50% with extensive partly calcified and noncalcified plaque • Asymptomatic	I (3)
CMR		
39.	• Area of delayed gadolinium myocardial enhancement of unknown etiology • Asymptomatic	I (3)
Adjunctive Invasive Diagnostic Testing in Patients Undergoing Appropriate Diagnostic Coronary Angiography		
FFR for Lesion Severity		
41.	• Nonobstructive disease by angiography (non-left main) <50% • Unexpected angiographic finding or no prior noninvasive testing	I (3)
41.	• Nonobstructive disease by angiography (non-left main) <50% • Prior testing = no ischemic findings	I (2)
43.	• Angiographically obstructive significant disease (non-left main) ≥70% stenosis • Prior testing = concordant ischemic findings	I (3)
IVUS for Lesion Severity		
45.	• Nonobstructive disease by angiography (non-left main) <50% • Unexpected angiographic finding or no prior noninvasive testing	I (3)
45.	• Nonobstructive disease by angiography (non-left main) <50% • Prior testing = no ischemic findings	I (3)
47.	• Angiographically obstructive significant disease (non-left main) ≥70% stenosis • Prior testing = concordant ischemic findings	I (3)
Patients With Known Obstructive CAD (e.g., Prior MI, Prior PCI, Prior CABG, or Obstructive Disease on Invasive Angiography)		
Medically Managed Patients		
49.	• Low-risk noninvasive findings • Asymptomatic/controlled symptoms or unchanged findings	I (2)
Post Revascularization (PCI or CABG)		
52.	• Asymptomatic or stable symptoms	I (1)
Arrhythmias		
No Prior Noninvasive Assessment of Ischemia With Normal Systolic Function		
60.	• Syncope • Low CHD risk	I (2)
61.	• New-onset atrial fibrillation or flutter • Low CHD risk	I (2)
61.	• New-onset atrial fibrillation or flutter • Intermediate CHD risk	I (3)
62.	• Heart block (e.g., second-degree type II or third-degree AV block) OR • Symptomatic bradyarrhythmias • Low CHD risk	I (2)
62.	• Heart block (e.g., second-degree type II or third-degree AV block) OR • Symptomatic bradyarrhythmias • Intermediate CHD risk	I (3)
Preoperative Coronary Evaluation for Noncardiac Surgery in Stable Patients		
64.	• Low-risk surgery	I (2)
65.	• ≥4 METS functional capacity without symptoms	I (2)
<4 METS Functional Capacity, No Noninvasive Testing Performed, With or Without Clinical Risk Factors Present (Preoperative Clinical Risk Factors: Ischemic Heart Disease, Heart Failure, Cerebrovascular Disease, Insulin-Requiring Diabetes Mellitus, Renal Insufficiency Cr >2.0)		
67.	• No risk factors • Intermediate-risk surgery	I (2)
67.	• No risk factors • Vascular surgery	I (3)
68.	• 1 to 2 risk factors • Intermediate-risk surgery	I (3)

Table 6. Continued

	Indication	Appropriate Use Score (1–9)
	Valvular Disease	
	Chronic Native or Prosthetic Valvular Disease Asymptomatic Related to Valvular Disease	
73.	• Mild or moderate mitral stenosis	I (2)
75.	• Mild or moderate mitral regurgitation	I (2)
77.	• Mild or moderate aortic stenosis	I (2)
79.	• Mild or moderate aortic regurgitation	I (2)
	Chronic Native or Prosthetic Valvular Disease Symptomatic Related to Valvular Disease	
81.	• Mild or moderate mitral stenosis • Noninvasive imaging for valvular disease concordant with clinical impression of severity	I (2)
82.	• Severe mitral stenosis • Noninvasive imaging for valvular disease concordant with clinical impression of severity	I (3)
83.	• Mild or moderate mitral regurgitation • Noninvasive imaging for valvular disease concordant with clinical impression of severity	I (2)
84.	• Severe mitral regurgitation • Noninvasive imaging for valvular disease concordant with clinical impression of severity	I (3)
85.	• Mild or moderate aortic stenosis • Noninvasive imaging for valvular disease concordant with clinical impression of severity	I (3)
86.	• Severe aortic stenosis • Noninvasive imaging for valvular disease concordant with clinical impression of severity	I (3)
88.	• Mild or moderate aortic regurgitation • Noninvasive imaging for valvular disease concordant with clinical impression of severity	I (2)
89.	• Severe aortic regurgitation • Noninvasive imaging for valvular disease concordant with clinical impression of severity	I (3)

AV = atrioventricular; CABG = coronary bypass grafting surgery; CAD = coronary artery disease; CHD = coronary heart disease; CMR = cardiovascular magnetic resonance; Cr = creatinine; CTA = computed tomography angiography; ECG = electrocardiogram; FFR = fractional flow reserve; I = inappropriate; IVUS = intravascular ultrasound; METS = metabolic equivalents; MI = myocardial infarction; PCI = percutaneous coronary intervention; PET = positron emission tomography; SPECT MPI = single-photon emission computed tomography myocardial perfusion imaging.

9. Figures

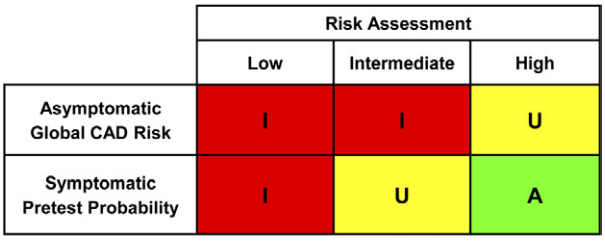

Figure 1. Suspected CAD: No Prior Noninvasive Stress Imaging

A = appropriate; CAD = coronary artery disease; I = inappropriate; U = uncertain.

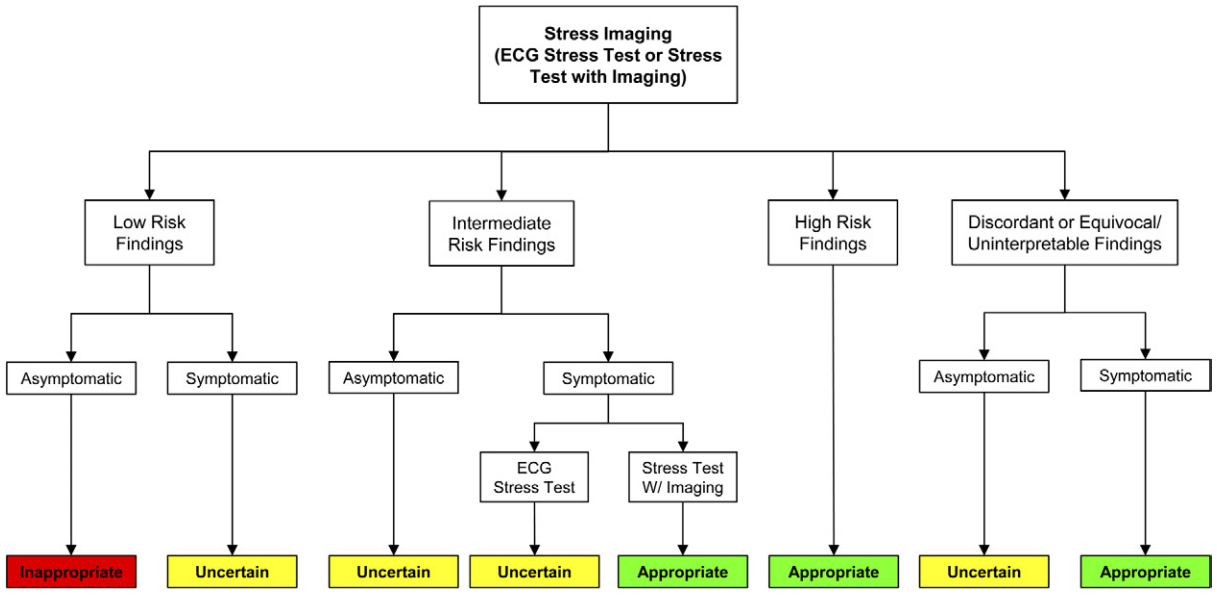

Figure 2. Suspected CAD: Prior Noninvasive Stress Testing

Indications 22 to 27 not covered in figure. CAD = coronary artery disease; ECG = electrocardiography.

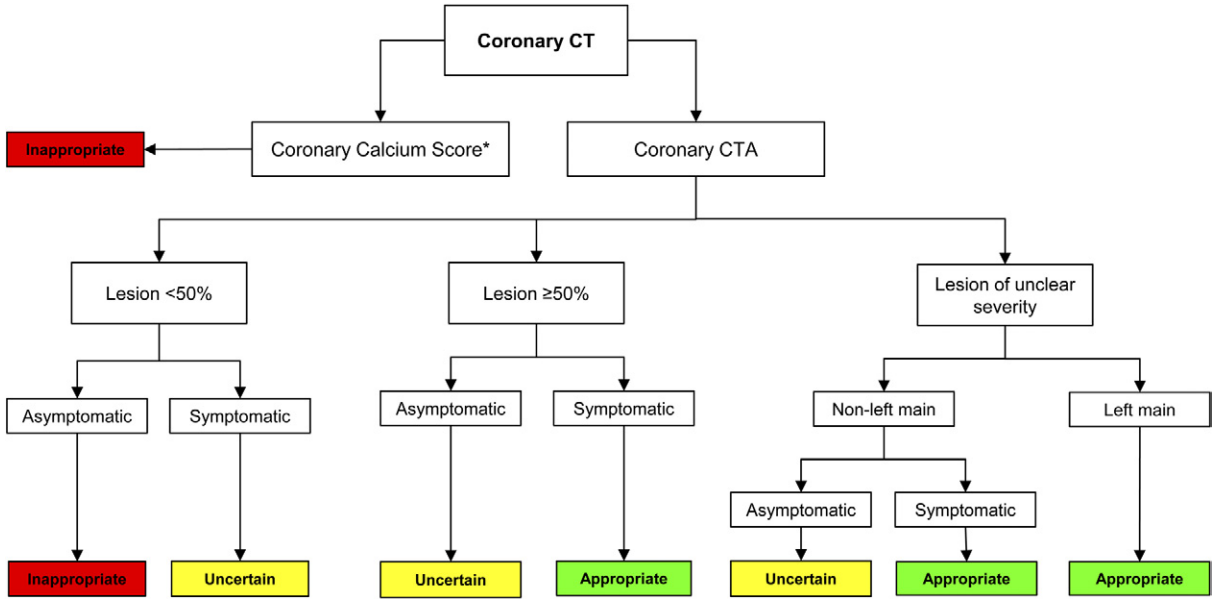

Figure 3. Suspected CAD: Prior Noninvasive Cardiac CT (Calcium Score and CTA)

*Coronary calcium score only rated for asymptomatic patients as these patients are the population in which it is used. CT = computed tomography; CTA = computed tomography angiography.

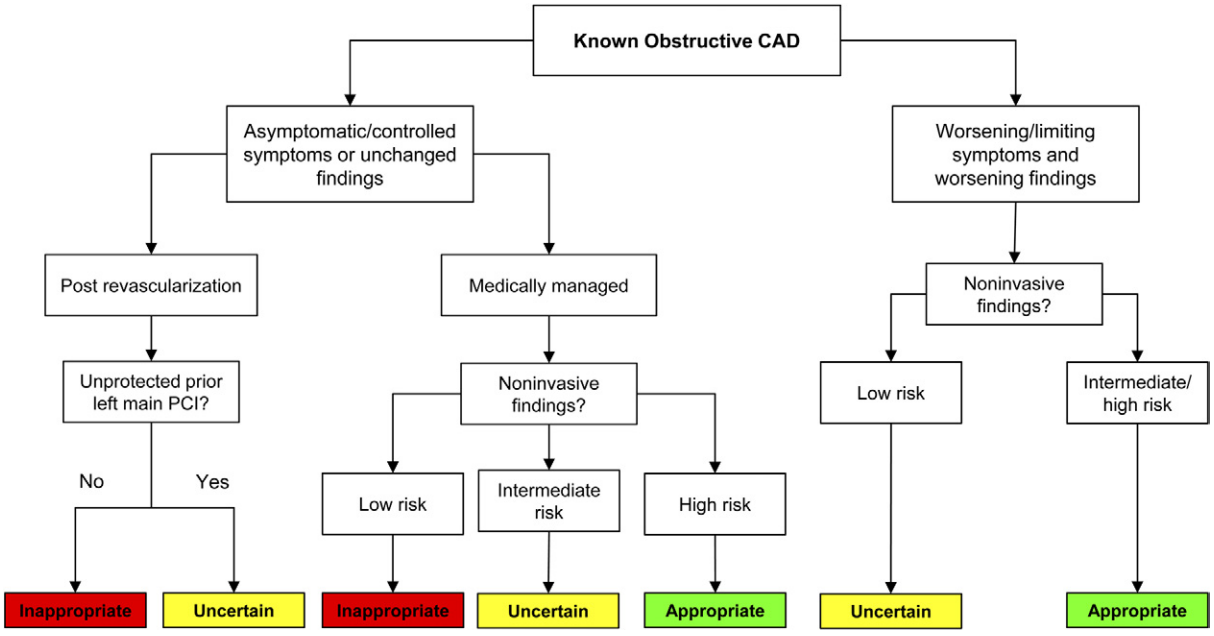

Figure 4. Patients With Known Obstructive CAD

CAD = coronary artery disease; PCI = percutaneous coronary intervention.

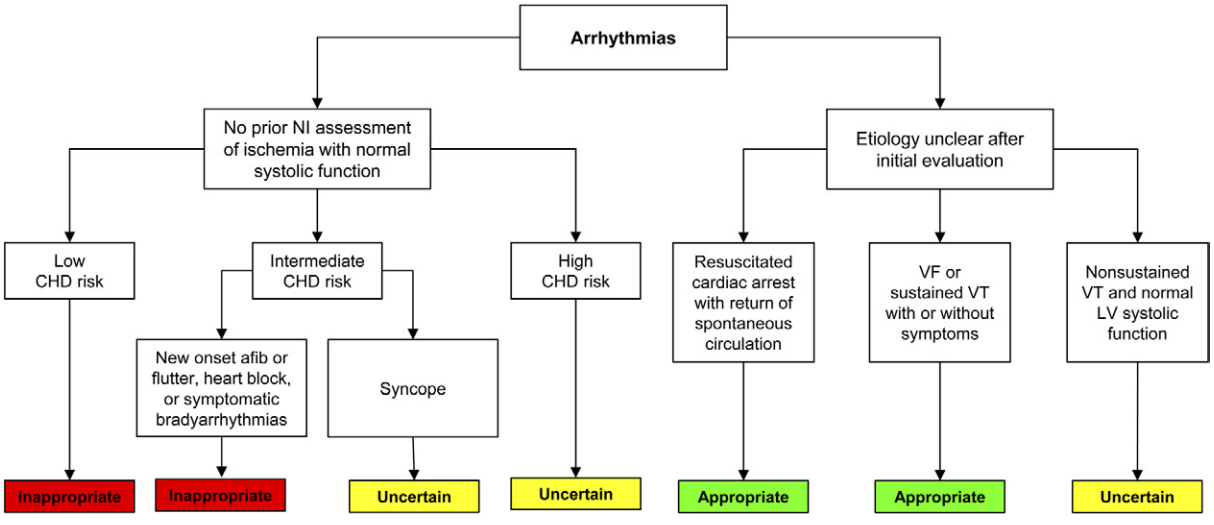

Figure 5. Evaluation of Arrhythmias

Indication 63 for newly diagnosed LBBB is not represented in this figure and was rated as "uncertain." CHD = coronary heart disease; LBBB = left bundle branch block; LV = left ventricular; NI = noninvasive; VF = ventricular fibrillation; VT = ventricular tachycardia.

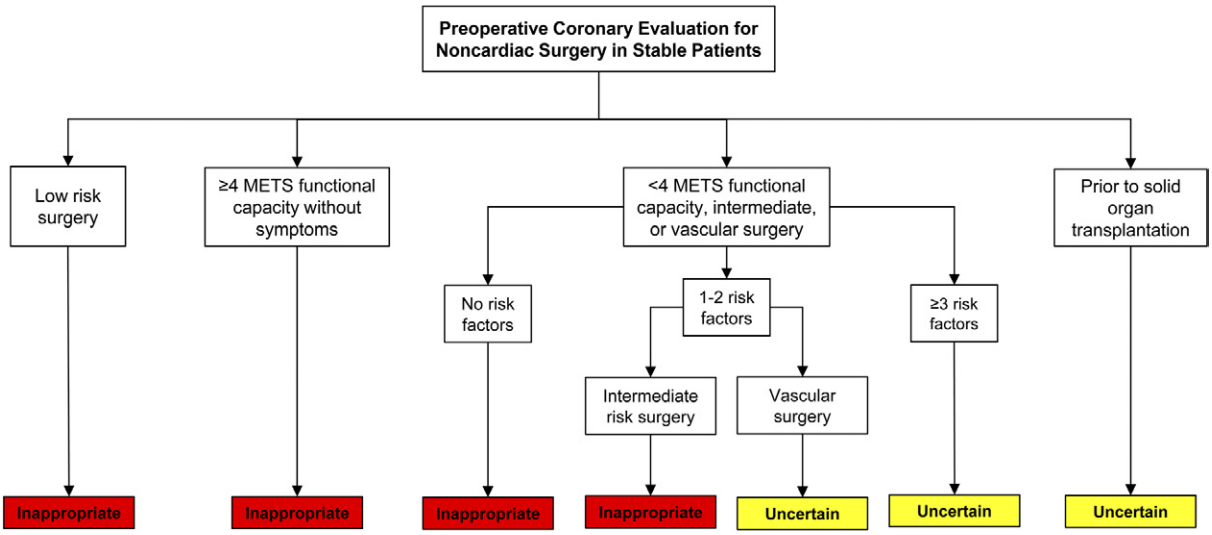

Figure 6. Preoperative Coronary Evaluation: Patients With No Prior Noninvasive Stress Testing

METS = metabolic equivalents.

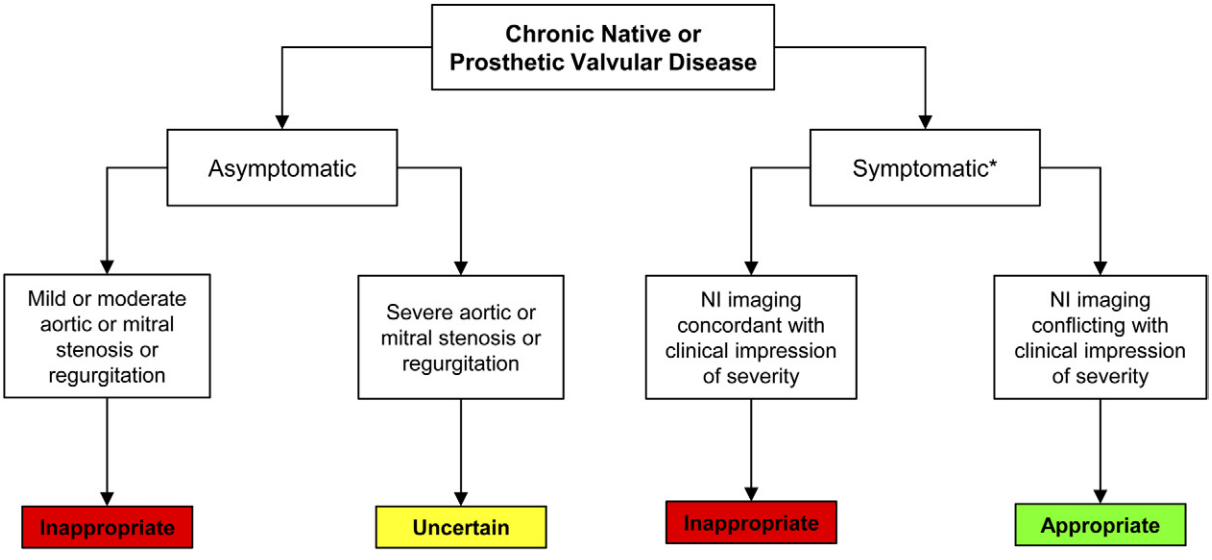

Figure 7. Evaluation of Valvular Disease

Preoperative assessment before valvular surgery is not represented in this figure and is rated "appropriate." *Indication 90 for acute moderate or severe mitral or aortic regurgitation is not represented in this figure. Rating for concordant imaging is "uncertain" and conflicting imaging is "appropriate." NI = noninvasive.

10. Discussion

Diagnostic cardiac catheterization incorporates both imaging and hemodynamic procedures aimed at providing information to document specific cardiovascular disease states as well as help care for and improve the health of patients with known or suspected heart disease. The AUC are meant to provide guidance concerning the rational and timely use of diagnostic cardiac catheterization and coronary angiography. The current document provides an evaluation of many of the indications commonly considered in clinical practice. The writing group felt that review of the recommendations by general procedures and indications would be of the highest utility to clinical practice.

10.1. Assessment for CAD

Several sets of indications were rated regarding the use of invasive coronary angiography for the evaluation of CAD. The writing group felt that the decision to include left heart catheterization, left ventriculography, and perhaps other invasive procedures with coronary angiography should be at the discretion of the operator, depending on the clinical situation, the presence or absence of noninvasive assessments of LV function and pulmonary pressures, and the perceived accuracy of these noninvasive results.

In general, these indications were grouped by the clinical suspicion for acute coronary syndromes, suspected or known obstructive CAD, use of adjunctive invasive diagnostic technologies, evaluation of arrhythmias, and preoperative evaluation. Although these scenarios represented many common clinical indications for the evaluation of CAD, the writing group acknowledges that this is not comprehensive and thus there are likely clinical scenarios encountered in practice that are not rated in this document. Nevertheless, review of these scenarios should provide clinicians guidance on the use of coronary angiography.

Overall, patients with definite or suspected acute coronary syndromes were rated as appropriate for coronary angiography. These ratings reflect the current management and risk stratification of patients with acute coronary syndrome (ACS), which usually involves defining the presence, location, and degree of coronary stenosis and is based on abundant clinical studies on the management of ACS patients that used coronary angiography. Alternatively, in patients without known CAD, referral directly for coronary angiography for the suspicion of obstructive disease was felt to be appropriate only in symptomatic patients with a high pretest probability. The remaining patients (asymptomatic patients and symptomatic patients with low or intermediate pretest probability) were felt to be uncertain or inappropriate for a management strategy that used coronary angiography as the initial diagnostic test.

In patients with prior noninvasive testing, coronary angiography was rated inappropriate for asymptomatic patients with low-risk findings. Symptomatic patients with intermediate- or high-risk findings or equivocal/discordant noninvasive findings were rated appropriate for coronary angiography. Coronary calcium scores, regardless of severity, were rated as inappropriate indications for invasive coronary angiography in asymptomatic patients. The technical panel was not asked to rate calcium scores in symptomatic patients as this test is usually only performed in asymptomatic patients to assess risk. For patients with known CAD, asymptomatic patients following revascularization and medically managed patients with stable symptoms and low-risk noninvasive test findings were rated inappropriate in general for coronary angiography, whereas patients with high-risk noninvasive findings or those with limiting or worsening symptoms were rated as appropriate.

Several clinical scenarios related to the use of coronary angiography in the evaluation of certain cardiac arrhythmias were developed. Coronary angiography was rated as appropriate for patients resuscitated after cardiac arrest (assuming return of reasonable neurologic function) and for those with sustained VT regardless of symptoms. The other scenarios developed related to syncope, new onset atrial fibrillation/flutter, high-degree atrioventricular block, or new LBBB and were generally inappropriate for patients with a low coronary heart disease (CHD) risk and uncertain with a high CHD risk.

Scenarios for patients scheduled for noncardiac surgical procedures were also rated. In the preoperative setting for noncardiac surgery, direct catheterization and angiography was not generally considered appropriate unless the patient had significant risk factors or was undergoing transplantation of a solid organ or vascular surgery.

10.2. Assessment for Conditions Other Than CAD

Assessment of intracardiac and pulmonary pressures and other testing such as measurement of cardiac output were evaluated primarily in the setting of valvular heart disease, cardiomyopathies, and pulmonary hypertension. In the section on CAD assessment, the scenarios developed considered the use of coronary angiography and considered other procedures during the invasive evaluation (e.g., left heart catheterization, left ventriculography) as secondary to the primary purpose of the evaluation and at the discretion of the operator. In a similar format, the scenarios developed in this section rated the use of the hemodynamic evaluations and considered coronary angiography as secondary to the primary purpose of the evaluation and at the discretion of the operator.

It should be noted that, in general, for patients with planned valvular surgery, preoperative catheterization for coronary anatomy was rated as appropriate. Additionally, in patients with symptomatic and severe valvular heart disease with discordant clinical and noninvasive imaging findings, hemodynamic assessment was rated as appropriate. Specific groups such as those with low transvalvular gradient, depressed LV function or decreased cardiac output were rated as appropriate for further evaluation using hemodynamic studies.

Patients without symptoms, with mild to moderate stenosis or concordant clinical and noninvasive findings were generally rated as inappropriate for diagnostic catheterization procedures with hemodynamic assessment. Those

without symptoms but with severe disease were rated as uncertain. Asymptomatic patients with valvular heart disease were rated based on the noninvasive findings alone since discordance between a clinical impression and noninvasive findings in these patients would not be easily determined. Patients with pulmonary hypertension, either clinically suspected or documented and requiring evaluation for pharmacological therapy, were identified as appropriate for invasive hemodynamic assessment at rest as well as with provocative maneuvers (exercise or pharmacological challenge).

Specific groups such as those suspected of pericardial disease, intracardiac shunts, tamponade, suspected cardiomyopathy or patients who have received cardiac transplant were rated as appropriate for hemodynamic studies and endomyocardial biopsy.

10.3. Application of the Criteria

In their work developing and rating these clinical scenarios, the writing group and technical panel focused on the multiple goals of diagnostic cardiac catheterization and coronary angiography and common clinical scenarios seen in clinical practice. Clinical scenarios and ultimately the ratings of the technical panel were focused on obtaining information from the procedure that should help in the management of patients with suspected or known heart disease including providing needed reassurance about the clinical status of the patient. Additionally, the diagnostic catheterization AUC was written with recognition that these indications would be linked with the coronary revascularization AUC. In fact, the hope of the writing group was to develop a system that would inform patients and clinicians to increase the right patients undergoing appropriate invasive catheterization procedures before discussions and considerations around revascularization.

With these goals in mind, there are many potential applications for the AUC in this document. Decision support and educational tools should be developed. Ideally, these would translate these ratings into clinical tools used at the point of care to aid clinicians and patients in the decision to perform or undergo an invasive procedure. Figures 1 to 7 are meant to provide some initial algorithms for the overall ratings.

Facilities and payers may choose to use these criteria, either prospectively in the design of protocols or review procedures, or retrospectively for quality reports. It is hoped that payers would use these criteria to ensure that their members receive necessary, beneficial, and cost-effective cardiovascular care, rather than for other purposes. It is expected that services performed for appropriate and/or uncertain indications will receive reimbursement. In contrast, services performed for inappropriate indications may require additional documentation to justify payment because of the unique circumstances or the clinical profile that may exist in such a patient. This additional documentation should not be required for uncertain indications. It is critical to emphasize that the writing group, technical panel, AUC Task Force, and clinical community do not believe an uncertain rating justifies denial of reimbursement for these invasive procedures. Rather, uncertain ratings are those in which the available data vary and many other factors exist that may affect the decision to perform or not perform cardiac catheterization and coronary angiography. The opinions of the technical panel often varied for these indications, reflecting that additional research is needed. Indications with high clinical volume that are rated as uncertain identify important areas for further research. The writing group and technical panel favor the collaborative interaction between patients, referring clinicians, and cardiologists in determining the need for these invasive procedures.

When evaluating physician or facility performance, AUC should be used in conjunction with efforts that lead to quality improvement. Prospective preauthorization procedures, if put in place, are most effective once a retrospective review has identified a pattern of potential inappropriate use. Because these criteria are based on current scientific evidence and the deliberations of the technical panel, they should be used prospectively to generate future discussions about reimbursement, but should not be applied retrospectively to cases completed before issuance of this report or documentation of centers/providers performing an unexpectedly high proportion of inappropriate cases as compared with their peers.

The writing group recognizes that these criteria will be evaluated during routine clinical care. To that end, specific data fields such as symptom status, presence or absence of acute coronary syndrome, history of CAD or revascularization, and type of noninvasive testing and findings will be required to determine individual appropriate use ratings. It is recognized that the characterization of symptoms is inherently subjective, and there is variability in the interpretation of many noninvasive tests. Fundamental to the application of the AUC is the understanding that the characterization of symptoms or interpretation of noninvasive tests is performed in a manner such that independent qualified reviewers would reach the same conclusions or support the conclusions of the individual physician about symptoms or noninvasive test results.

The primary objective of this report is to provide guidance regarding the use of diagnostic catheterization including coronary angiography, left heart catheterization and left ventriculography, and right heart catheterization for a diverse set of clinical scenarios. As with previous AUC documents, consensus among the raters was desirable, but an attempt to achieve complete agreement within this diverse panel would have been artificial and was not the goal of the process. Two rounds of ratings with substantial discussion among the technical panel members between the ratings did lead to some consensus among panelists. However, further attempts to drive consensus would have diluted true differences in opinion among panelists and, therefore, was not undertaken.

Future research analyzing patient outcomes for indications rated as appropriate and inappropriate will help ensure the equitable and efficient allocation of resources for cardiac catheterization. Further exploration of the indications rated as "uncertain" will help generate the information required to further define the appropriate use of cardiac catheterization procedures. Addition-

ally, the criteria will need to be updated with the publication of ongoing trials in imaging and revascularization occurs.

In conclusion, this document represents the current understanding of the clinical utility of diagnostic cardiac catheterization. It is intended to provide a practical guide to clinicians and patients when these procedures.

Appendix A: Additional Diagnostic Catheterization Definitions

TIMI Risk Score—For Patients With Suspected ACS (23):
Variables (1 point each)

- Age ≥65 years
- ≥3 risk factors (hypertension, diabetes mellitus, family history, lipids, smoking)
- Known CAD (stenosis ≥50%)
- Aspirin use in past 7 days
- Severe angina (≥2 episodes within 24 hours)
- ST-segment deviation ≥0.5 mm
- Elevated cardiac markers

Risk of death or ischemic event through 14 days

- Low: 0 to 2 (<8.3% event rate)
- Intermediate: 3 to 4 (<19.3% event rate)
- High: 5 to 7 (41% event rate)

GRACE ACS Risk Model (24):
At admission (in-hospital/to 6 months)

- Age
- Heart rate
- Systolic blood pressure mm Hg
- Creatinine
- Congestive heart failure Killip class
- Cardiac arrest at admission
- ST-segment deviation
- Elevated cardiac enzymes/markers

At discharge (to 6 months)

- Age
- Heart rate
- Systolic blood pressure mm Hg
- Creatinine
- Congestive heart failure
- In-hospital PCI
- In-hospital CABG
- Past history of myocardial infarction
- ST-segment depression
- Elevated cardiac enzymes/markers

Appendix B: Additional Methods

Relationships With Industry and Other Entities

The American College of Cardiology Foundation and the Society for Cardiovascular Angiography and Interventions and its partnering organizations rigorously avoid any actual, perceived, or potential conflicts of interest that might arise as a result of an outside relationship or personal interest of a member of the technical panel. Specifically, all panelists were asked to provide disclosure statements of all relationships that might be perceived as real or potential conflicts of interest. These statements were reviewed by the Appropriate Use Criteria Task Force, discussed with all members of the technical panel at the face-to-face meeting, and updated and reviewed as necessary. A table of disclosures by all participants, listed in Appendix C, in the Appropriate Use Criteria for Diagnostic Catheterization can be found in Appendix D. In addition, to ensure complete transparency, complete disclosure information—including relationships not pertinent to this document—is available online as a document supplement.

Literature Review

The technical panel members were asked to refer to the relevant guidelines for a summary of the relevant literature, guideline recommendation tables, and reference lists provided for each indication table when completing their ratings (Online Appendix).

Appendix C: ACCF/SCAI/AATS/AHA/ASE/ASNC/HFSA/HRS/SCCM/SCCT/SCMR/STS 2012 Appropriate Use Criteria For Diagnostic Catheterization Participants

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APPENDIX D: ACCF/SCAI/AATS/AHA/ASE/ASNC/HFSA/HRS/SCCM/SCCT/SCMR/STS 2012 APPROPRIATE USE CRITERIA FOR DIAGNOSTIC CATHETERIZATION WRITING GROUP, TECHNICAL PANEL, INDICATION REVIEWERS, AND TASK FORCE—RELATIONSHIPS WITH INDUSTRY AND OTHER ENTITIES (IN ALPHABETICAL ORDER)

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This table represents the relevant relationships with industry and other entities that were disclosed by participants at the time of participation. It does not necessarily reflect relationships with industry at the time of publication. A person is deemed to have a significant interest in a business if the interest represents ownership of ≥5% of the voting stock or share of the business entity, or ownership of ≥$10,000 of the fair market value of the business entity; or if funds received by the person from the business entity exceed 5% of the person's gross income for the previous year. A relationship is considered to be modest if it is less than significant under the preceding definition. Relationships in this table are modest unless otherwise noted. Names are listed in alphabetical order within each category of review. Participation does not imply endorsement of this document.

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