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APPROPRIATE USE CRITERIA

ACC/AATS/AHA/ASE/ASNC/HRS/SCAI/SCCT/SCMR/STS 2017 Appropriate Use Criteria for Multimodality Imaging in Valvular Heart Disease

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

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ABSTRACT

This document is 1 of 2 companion appropriate use criteria (AUC) documents developed by the American College of Cardiology, American Association for Thoracic Surgery, American Heart Association, American Society of Echocardiography, American Society of Nuclear Cardiology, Heart Rhythm Society, Society for Cardiovascular Angiography and Interventions, Society of Cardiovascular Computed Tomography, Society for Cardiovascular Magnetic Resonance, and Society of Thoracic Surgeons. This document addresses the evaluation and use of multimodality imaging in the diagnosis and management of valvular heart disease, whereas the second, companion document addresses this topic with regard to structural heart disease. Although there is clinical overlap, the documents addressing valvular and structural heart disease are published separately, albeit with a common structure. The goal of the companion AUC documents is to provide a comprehensive resource for multimodality imaging in the context of valvular and structural heart disease, encompassing multiple imaging modalities.

Using standardized methodology, the clinical scenarios (indications) were developed by a diverse writing group to represent patient presentations encountered in everyday practice and included common applications and anticipated uses. Where appropriate, the scenarios were developed on the basis of the most current American College of Cardiology/American Heart Association guidelines.

A separate, independent rating panel scored the 92 clinical scenarios in this document on a scale of 1 to 9. Scores of 7 to 9 indicate that a modality is considered appropriate for the clinical scenario presented. Midrange scores of 4 to 6 indicate that a modality may be appropriate for the clinical scenario, and scores of 1 to 3 indicate that a modality is considered rarely appropriate for the clinical scenario.

The primary objective of the AUC is to provide a framework for the assessment of these scenarios by practices that will improve and standardize physician decision making. AUC publications reflect an ongoing effort by the American College of Cardiology to critically and systematically create, review, and categorize clinical situations where diagnostic tests and procedures are utilized by physicians caring for patients with cardiovascular diseases. The process is based on the current understanding of the technical capabilities of the imaging modalities examined.

PREFACE

Valvular and structural heart disease encompass a significant proportion of cardiovascular disease conditions. Initial diagnosis and subsequent follow-up frequently rely on imaging with more than 1 imaging modality. Rapidly evolving less-invasive and transcatheter treatment options have fueled the need for precise preprocedural and intraprocedural anatomic and functional imaging.

The publication of appropriate use criteria (AUC) reflects 1 of several ongoing efforts by the American College of Cardiology (ACC) and its partners to assist clinicians who are caring for patients with cardiovascular diseases and in support of high-quality cardiovascular care. The ACC/American Heart Association clinical practice guidelines provide a foundation for summarizing evidence-based cardiovascular care and, when evidence is lacking, expert consensus opinion that is approved in review by the ACC and American Heart Association. However, in many areas, variability remains in the use of cardiovascular imaging modalities, raising questions of overuse or underuse. The AUC provide a practical standard upon which to assess and better understand variability.

We are grateful to the writing committee for the development of the overall structure of the document and clinical scenarios, and to the rating panel, a professional group with a wide range of skills and insights, for their thoughtful deliberation of the merits of multimodality imaging for various clinical scenarios. A special thanks to Dr. Gregory Dehmer for serving as an expert moderator at our in-person rating panel meeting. We would also like to thank the AUC Task Force members who provided insight and guidance, and the ACC staff—Leah White and especially María Velásquez—for their skilled support in the generation of this document.

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1. INTRODUCTION

Improvements in cardiovascular imaging technology and their broader application to cardiovascular diagnosis and therapy have led to a sharp increase in cardiovascular imaging. Diagnostic imaging services reimbursed under Medicare's physician fee schedule grew more rapidly than any other type of physician service from 1999 to

2003, although more recently, the rate of imaging volume growth in Medicare has been slowing. Still, the armamentarium of noninvasive diagnostic tools has expanded greatly, offering a variety of new and more sophisticated imaging techniques. As imaging technologies and clinical applications continue to advance, the healthcare community must understand how best to incorporate these technologies into daily clinical care and how to choose between new and established imaging technologies.

Using standardized methodology, the clinical scenarios (indications) in this document were developed by a diverse writing group to represent patient presentations encountered in everyday practice and were evaluated and rated by a separate, independent rating panel.

Because there is significant clinical overlap between valvular and structural heart disease, separating the indications in the 2 AUC documents is somewhat arbitrary. The writing group therefore deliberately followed a common structure in creating the companion documents on valvular heart disease (VHD) and structural heart disease.

Specifically, this document is organized into 3 sections and 8 tables. Section 6.1. describes scenarios of initial evaluation with no prior imaging. **Table 1** lists scenarios for the asymptomatic patient, whereas **Table 2** lists scenarios for the symptomatic patient. Section 6.2. describes scenarios of sequential evaluation where prior imaging has been performed. **Table 3** rates scenarios in which additional testing is used to clarify the initial diagnosis. Where the initial imaging modality is assumed to be transthoracic echocardiography (TTE), TTE is grayed out and eliminated as a further option. **Tables 4 and 5** describe scenarios in which additional testing is used in the context of clinical follow-up after the initial diagnosis. **Table 4** describes scenarios in which additional testing is performed in asymptomatic patients or patients with stable symptoms to assess stability or change of valvular or myocardial function. **Table 5** describes scenarios in which follow-up testing is done in patients with worsening symptoms or to assess response to therapy. **Table 6** includes indications for patients undergoing follow-up imaging after surgical valve replacement or repair. Section 6.3. evaluates percutaneous aortic valve replacement (**Tables 7a to 7c**) and mitral valve repair (**Tables 8a to 8c**). **Tables 7 and 8** are further divided into preprocedural, intraprocedural, and postprocedural indications.

2. METHODS

Indication Development

This document addresses the appropriate use of multiple imaging modalities for clinical management of VHD. A standardized approach was used to create different categories of indications with the goal of capturing actual real-world clinical scenarios (1-3). Indications were created to cover established and emerging (specifically percutaneous structural interventions) treatment approaches for VHD.

To identify and categorize the scenarios, a multidisciplinary writing group of experts in the fields of cardiovascular imaging and VHD was convened. The group included representatives from a variety of related professional organizations and societies. Wherever possible during the writing process, the group members would map the scenarios to relevant clinical guidelines and key publications or references (see the Online Appendix). This included diagnosis-oriented guidelines (4-8) and imaging-modality-specific guidelines (9-12). After the scenarios were formed, they were reviewed and critiqued by the parent AUC Task Force and by numerous external reviewers, including interventional cardiologists, cardiac surgeons, imaging experts, and internists. After the writing group incorporated this initial feedback, the scenarios were sent to an independent rating panel to ensure an appropriate balance of specialized expertise and general practice in the rating panel (2). By design, the rating panel comprised a combination of experts in the cardiovascular realm but also members with more general expertise, including internists and an outcomes researcher. The inclusion of generalists is intended to prevent bias in the scoring process, as specialists might have a natural tendency to rate the indications within their specialty as more appropriate than might nonspecialists. The rating panel was provided with a standardized rating package that included relevant evidence, and formal roles were established for facilitating panel interaction at the subsequent face-to-face meeting. Care was taken in providing objective, nonbiased information, including guidelines and key references. Although panel members were not provided explicit cost information to help determine their appropriate use ratings, they were asked to implicitly consider cost as an additional factor in their evaluation of appropriate use. In rating these criteria, the AUC Rating Panel was asked to assess whether the use of the test for each scenario was Appropriate (A), May Be Appropriate (M), or Rarely Appropriate (R) (see definitions in the following text).

The members of the rating panel first evaluated the indications independently (first-round rating). Then, the panel was convened for a face-to-face meeting to discuss each indication. At this meeting, panel members were given their scores and a blinded summary of their peers' scores. Following the meeting, panel members were asked again to independently provide scores for each indication (second-round rating). The second-round

rating results were sent back to the writing group for additional vetting. At this point, the writing group had a final chance to clarify indications and, if necessary, return to the rating panel for rescoring. 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), as well as in the updated version of this publication, "Appropriate Use of Cardiovascular Technology: 2013 ACCF Appropriate Use Criteria Methodology Update" (2). Based on these multiple rounds of review and revision, each scenario was rated and classified as either Appropriate, May Be Appropriate, or Rarely Appropriate, using the following definition of appropriate use:

> *An appropriate imaging study is one in which the expected incremental information, combined with clinical judgment, exceeds the expected 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.*

Median Score 7 to 9: *Appropriate test* for specific indication (test *is* generally acceptable and *is* a reasonable approach for the indication).

An appropriate option for management of patients in this population due to benefits generally outweighing risks; an effective option for individual care plans, although not always necessary depending on physician judgment and patient-specific preferences (i.e., procedure is generally acceptable and is generally reasonable for the indication).

Median Score 4 to 6: *May Be Appropriate test* for specific indication (test *may* be generally acceptable and *may* be a reasonable approach for the indication). May Be Appropriate also implies that more research and/or patient information is needed to classify the indication definitively.

At times an appropriate option for management of patients in this population due to variable evidence or agreement regarding the benefit-risk ratio, potential benefit based on practice experience in the absence of evidence, and/or variability in the population; effectiveness for individual care must be determined by a patient's physician in consultation with the patient based on additional clinical variables and judgment along with patient preferences (i.e., procedure may be acceptable and may be reasonable for the indication).

Median Score 1 to 3: *Rarely Appropriate test* for specific indication (test *is not* generally acceptable and *is not* a reasonable approach for the indication).

Rarely an appropriate option for management of patients in this population due to the lack of a clear benefit/risk advantage; rarely an effective option for individual care plans; exceptions should have documentation of the clinical reasons for proceeding with this care option (i.e., procedure is not generally acceptable and is not generally reasonable for the indication).

The division of the numerical scores into 3 levels of appropriateness is somewhat arbitrary, and the numeric designations should be viewed as a continuum. Further, clinical opinions may vary for particular clinical scenarios, such that scores in the intermediate level of appropriate use were labeled "May Be Appropriate," as critical patient or research data may be lacking or discordant. This designation should be a prompt to the field to carry out definitive research investigation whenever possible. It is anticipated that the AUC reports will continue to be revised as further data are generated and information from implementation of the criteria is accumulated.

The level of agreement among panelists as defined by RAND was analyzed on the basis of the BIOMED rule for a panel of 14 to 17 members (3). Thus, an agreement regarding an indication was considered to exist when 4 or fewer panelists' ratings fell outside of the 3-point region containing the median score.

Disagreement was defined as when at least 5 panelists' ratings fell in both the Appropriate and the Rarely Appropriate categories. Any indication having disagreement was categorized as May Be Appropriate regardless of the final median score.

3. GENERAL ASSUMPTIONS

1. This document will address the use of multimodality imaging for the evaluation and treatment of VHD.
2. Indication ratings contained herein supersede the ratings of similar indications contained in previous AUC documents.
3. Evaluation of all indications pertains only to nonurgent clinical circumstances.
4. For the purposes of this document, which evaluates cardiovascular imaging, cardiac catheterization/angiography did not include the assessment of hemodynamics when this modality was rated.
5. A qualified clinician has obtained a complete clinical history and performed a physical examination so that the clinical status of the patient can be assumed to be valid as stated in the indication. Example: an asymptomatic patient is truly asymptomatic, and sufficient questioning has been undertaken for the condition in question.
6. All patients are receiving optimal standard care, including guideline-based risk factor modification, primary and secondary prevention of ischemic heart

disease, or treatment of heart failure unless it is specifically noted otherwise.

7. The indications are, at times, intended to be broad to cover an array of cardiovascular signs and symptoms and to account for the ordering physician's best judgment as to the presence of cardiovascular abnormalities. Additionally, there are likely clinical scenarios that are not covered in this document.
8. If the reason for a test can be assigned to more than 1 indication, it is classified under the most clinically significant indication.
9. Testing modalities are rated for their level of appropriateness specific to clinical scenarios rather than a forced rank order comparison against other testing modalities. The goal of this document is to identify any and all tests that are considered reasonable for a given clinical indication. **Determination of the range of modalities that may or may not be reasonable for specific indications is the goal of this document rather than determining a single best test for each indication or a rank order.** As such, more than 1 test type may be considered Appropriate, May Be Appropriate, or Rarely Appropriate for any given clinical indication.
10. If more than 1 modality falls into the same appropriate use category, physician judgment and available local expertise should be used to determine the choice of test.
11. The appropriate use of testing is presumed to have the potential to affect clinical decision making and to direct therapeutic interventions.
12. Patients are suitable candidates for the procedure after consideration of procedural risk. Unless explicitly stated, it is presumed that patients presenting for a specific clinical indication are potential candidates for all tests to be rated and do not present with strong contraindications that preclude them from being tested (e.g., renal dysfunction, presence of an implanted device). It is further noted that appropriateness ratings may not be generalized to all populations. Patients in the elderly or very elderly populations, for example, may not have been adequately studied in clinical trials. This is especially true in such patients with VHD and multiple medical comorbidities.
13. Risk benefit: Overall patients' representation (age, comorbidities, and so on) was used in the risk/benefit calculation. Each modality considered in this document has inherent risks that may include but are not limited to radiation exposure, contrast sensitivity, other bodily injury, and interpretation errors. For any test, there may be certain patient populations that are more susceptible to its known risks that are not specifically captured in the indications but deserve consideration when rating. Such risks should be viewed "on balance" and not used as justification to systematically reduce the level of appropriateness of a particular test compared with other tests. (e.g., tests that expose the patient to ionizing radiation should not necessarily receive a lower score than those that do not). Thus, a given modality should be weighed specifically in the context of the clinical scenario with the potential harm considered relative to the potential benefit gained.
14. Radiation safety: No clinical evidence to date unequivocally supports the notion that low-dose ionizing radiation at the levels used in medical imaging is associated with an increased long-term risk of malignancy. In a conservative approach, many experts in the field have adopted the linear no-threshold hypothesis, which assumes a linear relationship between radiation dose and the risk of malignancy irrespective of the magnitude of the radiation dose. Accordingly, the following radiation safety principles should be applied to all testing involving ionizing radiation (13).
    - Clinical benefit should be as high as reasonably achievable (AHARA), embracing the guiding principle that testing should be performed on cohorts that are most likely to experience a net benefit.
    - Radiation exposure should be as low as reasonably achievable (ALARA). ALARA should be used to guide test choice and the imaging protocol. Implicit in the ALARA principle is that the use of tests involving ionizing radiation should be minimized in vulnerable populations such as younger patients, and that optimal test procedures are utilized to perform the test at the lowest possible radiation dose while preserving image quality and information output.
15. Selection of patients for and monitoring of patients during and after contrast administration are assumed to accord with published standards when available.
16. Cost: Clinical benefit should always be considered first, and cost should be considered in relationship to these benefits when determining net value. Example: a procedure with moderate clinical efficacy for a given AUC indication should not be scored as more appropriate than a procedure with a high clinical efficacy solely because of lower cost. Value may be informed by multiple measures of potential economic impact such as: a) induced downstream or layered testing rates; b) comparative cost savings or minimization for diagnostic or near-term follow-up; c) cost to reduce adverse outcomes (e.g., cost for hospitalization averted); and d) cost for life year gained.

17. All tests and procedures are presumed to be performed and interpreted by qualified individuals in a facility in compliance with national standards for performing such imaging studies or procedures. Therefore, the level of appropriateness does not consider issues of local availability or skill in the rating of any modality (14-18).
18. Time biases in available data: Newer technologies should not be considered necessarily more or less appropriate than older technologies. Apparent differences in diagnostic accuracy and risk stratification between older and newer techniques may not be accurate, especially when the techniques are not compared directly or when historical data are utilized. As treatment paradigms evolve, diagnosis may occur at earlier stages of disease, posing unique challenges for comparison of the performance of diagnostic modalities used at different stages of the disease process, owing to time lag bias.
19. Patients are suitable candidates for the procedure, including the patient's risk from the procedure.

4. DEFINITIONS

1. Family History

In this document, the term "family history" refers to first-degree relatives only.

2. Symptomatic

A patient is deemed to be symptomatic when he/she exhibits typical signs and/or symptoms (e.g., for congestive heart failure, symptoms such as dyspnea, rales, edema, and limited exercise capacity).

3. Asymptomatic

Patient is deemed asymptomatic when he/she exhibits none of the typical symptoms.

4. Low, Moderate, and High Pretest Probability

As defined by the "2013 ACC/AHA/AATS/PCNA/SCAI/STS Focused Update of the Guideline for the Diagnosis and Management of Patients with Stable Ischemic Heart Disease" (6a). Low pretest probability indicates <10% probability of disease prior to the test under consideration. Moderate pretest probability is a range of 10% to 90% pretest probability. High pretest probability is a >90% likelihood of the presence of the disease entity under question prior to any testing.

5. Clinically Significant

An abnormality, that if left untreated, can or will lead to functional impairment or death.

TABLE A Stages of Valvular Heart Disease

Stage	Definition	Description
A	At risk	Patients with risk factors for development of VHD
B	Progressive	Patients with progressive VHD (mild-to-moderate severity and asymptomatic)
C	Asymptomatic severe	Asymptomatic patients who meet criteria for severe VHD: C1: Asymptomatic patients with severe VHD in whom the left or right ventricle remains compensated C2: Asymptomatic patients with severe VHD with decompensation of the left or right ventricle
D	Symptomatic severe	Patients who have developed symptoms as a result of severe VHD

Reproduced from Nishimura et al. (4a).
VHD = valvular heart disease.

6. Mild, Moderate, and Severe Valvular Disease

As defined by the "2017 AHA/ACC Focused Update of the 2014 AHA/ACC Guideline for the Management of Patients with Valvular Heart Disease" (4).

7. Stages of VHD

VHD as defined by the "2017 AHA/ACC Focused Update of the 2014 AHA/ACC Guideline for the Management of Patients with Valvular Heart Disease" (4,4a) (Table A).

8. Uninterpretable or Technically Limited Images

Images that are not of diagnostic quality despite performance of the study by a skilled sonographer, technician, or other provider using appropriate equipment. This may be due to patient-related factors such as body habitus or motion artifact.

9. Nonsustained Ventricular Tachycardia

Ventricular arrhythmia of 3 or more consecutive complexes but lasting <30 seconds in duration at a rate >100 bpm.

10. Sustained Ventricular Tachycardia

Ventricular tachycardia lasting more than 30 seconds or requiring therapy because of hemodynamic compromise in <30 seconds.

11. Syncope

Transient loss of consciousness due to global cerebral hypoperfusion characterized by rapid onset, short duration, and spontaneous complete recovery, not lightheadedness or dizziness alone.

12. Presyncope

Near loss of consciousness.

TABLE B Stages of Heart Failure

Stage	Definition
Stage A	Patients with risk factors for heart failure but without structural disease or symptoms (e.g., patient with hypertension but without left ventricular hypertrophy).
Stage B	Patient with structural disease but no symptoms (e.g., asymptomatic left ventricular hypertrophy)
Stage C	Current or prior symptoms of heart failure
Stage D	Drug-refractory heart failure

13. Heart Failure

Signs and symptoms explainable on the basis of systolic or diastolic dysfunction.

14. Heart Failure Stages A, B, C, and D

Heart failure as defined by the "2009 Focused Update Incorporated into the ACC/AHA 2005 Guidelines for the Diagnosis and Management of Heart Failure in Adults" (5) (Table B).

15. Indication

Synonymous with scenario. A set of patient-specific conditions defines "indication." The term clinical indication does not necessarily imply that testing is warranted. In other words, for some clinical indications, all modalities may be rated as Rarely Appropriate.

16. Low-Flow, Low-Gradient Valvular Aortic Stenosis

Severe aortic stenosis (AS) by valve area in the presence of a low transaortic volume flow rate due to either left ventricular (LV) systolic dysfunction with a low LV ejection fraction (stage D2) or to a small hypertrophied LV with a low stroke volume (stage D3, also known as paradoxical low-flow AS).

17. Primary Mitral Regurgitation

Mitral regurgitation (MR) related to pathology of at least 1 of the components of the valve (leaflets, chordae tendineae, papillary muscles, or annulus) resulting in valve incompetence.

18. Secondary MR

MR in the presence of a relatively normal mitral valve, related to LV dysfunction caused by coronary artery disease, myocardial infarction (ischemic chronic secondary MR), or idiopathic myocardial disease (nonischemic chronic secondary MR). The abnormal and dilated LV causes papillary muscle displacement, which in turn results in leaflet tethering and/or associated annular dilation that prevents coaptation.

5. ABBREVIATIONS

AS = aortic stenosis

AUC = appropriate use criteria

CCT = cardiac computed tomography

LV = left ventricle/left ventricular

MR = mitral regurgitation

TAVR = transcatheter aortic valve replacement

TEE = transesophageal echocardiography

TTE = transthoracic echocardiography

VHD = valvular heart disease

6. MULTIMODALITY IMAGING IN VHD: APPROPRIATE USE CRITERIA (BY INDICATION)

6.1. Initial Evaluation for VHD

TABLE 1 Initial Evaluation of an Asymptomatic Patient

Indication		TTE	TEE (With Possible 3D)	3D TTE	CMR	CCT
1.	■ Unexplained murmur or abnormal heart sounds	A (9)	R (2)	R (3)	R (2)	R (1)
2.	■ Reasonable suspicion of VHD	A (9)	R (2)	M (4)	R (1)	R (1)
3.	■ History of rheumatic heart disease	A (9)	R (3)	M (4)	R (1)	R (1)
4.	■ Known systemic or acquired disease associated with VHD	A (9)	R (2)	R (3)	R (3)	R (2)
5.	■ First-degree family history of a bicuspid aortic valve	A (8)	R (1)	R (1)	R (1)	R (1)
6.	■ Exposure to medications that could result in development of VHD	A (7)	R (1)	R (1)	R (1)	R (1)

3D = 3-dimensional; A = appropriate; CCT = cardiac computed tomography; CMR = cardiovascular magnetic resonance imaging; M = may be appropriate; R = rarely appropriate; TEE = transesophageal echocardiography; TTE = transthoracic echocardiography; VHD = valvular heart disease.

TABLE 2 Initial Evaluation of a Patient with Clinical Signs and/or Symptoms

	Indication	TTE	TEE (With Possible 3D)	3D TTE	Ex.-SE	DSE	RVG	FDG-PET	MPI (SPECT/PET)	CMR	CCT
Arrhythmias											
7.	■ Palpitations AND ■ No other symptoms or signs of cardiovascular disease	M (4)	R (1)	R (1)	R (1)	R (1)	R (1)		R (1)	R (1)	R (1)
Presyncope/Syncope											
8.	■ Presyncope AND ■ No other symptoms or signs of cardiovascular disease	M (6)	R (1)	R (1)	R (1)	R (1)	R (1)		R (1)	R (1)	R (1)
9.	■ Syncope AND ■ No other symptoms or signs of cardiovascular disease	A (8)	R (1)	R (1)	M (4)	R (1)	R (1)		R (2)	R (3)	R (1)
Hypotension or Hemodynamic Instability											
10.	■ Hypotension or hemodynamic instability AND ■ Uncertain or suspected cardiac etiology	A (9)	R (3)	R (1)	R (1)	R (1)	R (1)		R (1)	R (1)	R (1)
11.	■ Assessment of volume status in a critically ill patient	M (6)	R (2)	R (1)	R (1)	R (1)	R (1)		R (1)	R (1)	R (1)
12.	■ Suspected acute mitral or aortic regurgitation	A (9)	M (6)	R (3)	R (1)	R (1)	R (1)		R (1)	R (1)	R (2)
Respiratory Failure											
13.	■ Respiratory failure or hypoxemia of uncertain etiology	A (8)	M (4)	R (2)	R (1)	R (1)	R (1)		R (1)	R (1)	M (5)
14.	■ Respiratory failure or hypoxemia AND ■ Noncardiac etiology of respiratory failure has been established	M (4)	R (1)	R (1)	R (1)	R (1)	R (1)		R (1)	R (1)	R (1)
Heart Failure											
15.	■ Initial evaluation in patients presented with HF to exclude the presence of primary or secondary valve disease	A (9)	R (3)	R (3)	R (1)	R (1)	R (1)		R (1)	R (3)	R (1)
Bacteremia/Endocarditis											
16.	■ Suspected IE (native valve, prosthetic valve, endocardial lead) AND ■ Positive blood cultures or a new murmur	A (9)	A (8)	M (4)	R (1)	R (1)	R (1)	R (3)	R (1)	R (2)	R (3)
17.	■ Transient fever AND ■ No evidence of bacteremia or a new murmur	R (2)	R (1)	R (1)	R (1)	R (1)	R (1)	R (1)	R (1)	R (1)	R (1)
18.	■ Transient bacteremia AND ■ Pathogen not typically associated with IE and/or a documented nonendovascular source or infection	R (3)	R (1)	R (1)	R (1)	R (1)	R (1)	R (1)	R (1)	R (1)	R (1)
Cardiac Mass/Cardiac Source of Emboli											
19.	■ Suspected cardiac mass, suspected tumor or thrombus, or potential cardiac source of emboli	A (9)	A (7)	M (5)	R (1)	R (1)	R (1)	R (1)	R (1)	M (6)	M (6)

3D = 3-dimenstional; A = appropriate; CCT = cardiac computed tomography; CMR = cardiovascular magnetic resonance imaging; DSE = dobutamine stress echocardiography; Ex.-SE = exercise stress echocardiography; FDG-PET = fluorodeoxyglucose-positron emission tomography; HF = heart failure; IE = infective endocarditis; M = may be appropriate; MPI = myocardial perfusion imaging; PET = positron emission tomography; R = rarely appropriate; RVG = radionuclide ventriculography; SPECT = single-photon emission computed tomography; TEE = transesophageal echocardiography; TTE = transthoracic echocardiography.

6.2. Prior Testing

TABLE 3 Additional Testing to Clarify Diagnosis

Indication	TTE	TTE With Contrast	TEE (With Possible 3D)	3D TTE	Ex.-SE	DSE	Low-Dose DSE	RVG	FDG-PET	MPI (SPECT/PET)	CMR	CCT	ANG	Fluoro
Inadequate TTE Images														
20. ■ Inadequate TTE images for the evaluation of possible valvular heart disease due to patient characteristics		M (5)	A (8)	R (2)	R (1)	R (1)	R (1)	R (1)		R (1)	M (6)	M (5)	R (1)	R (1)
21. ■ Characterization of native or prosthetic valves with clinical signs or symptoms suggesting valve dysfunction		M (4)	A (8)	R (2)	R (1)	R (1)	R (1)	R (1)		R (1)	M (5)	M (6)	R (2)	M (6)
Suspected Endocarditis With Negative TTE														
22. ■ Suspected IE with moderate to high pretest probability (i.e., staph bacteremia, fungemia, prosthetic heart valve, or intracardiac device)		R (2)	A (9)	R (2)	R (1)	R (1)	R (1)	R (1)	M (5)	R (1)	R (3)	M (5)	R (1)	R (1)
Aortic Stenosis														
23. ■ Symptomatic, severe AS by calculated valve area (stage D2) AND ■ Low flow/low gradient AND ■ Low LVEF		R (3)	M (5)	R (1)	R (1)	R (1)	A (8)	R (1)		R (1)	M (4)	M (4)	R (1)	R (1)
24. ■ Severe AS, by calculated valve area AND ■ Low flow/low gradient AND ■ Preserved LVEF and for assessment of morphology, including calcification		R (2)	M (6)	R (3)	R (1)	R (1)	M (4)	R (1)		R (1)	M (5)	M (6)	R (1)	R (1)
25. ■ Moderate or asymptomatic severe AS (stages B and C), for measurement of changes in valve hemodynamics with exercise or pharmacological stress		R (1)	R (1)	R (1)	A (8)	R (1)	M (4)	R (1)		R (1)	R (1)	R (1)	R (1)	R (1)
26. ■ Symptomatic severe AS (stage D), for measurement of changes in valve hemodynamics with exercise or pharmacological stress		R (1)	R (1)	R (1)	R (1)	R (1)	R (1)	R (1)		R (1)	R (1)	R (1)	R (1)	R (1)
Mitral Stenosis														
27. ■ Discrepancy between resting Doppler echocardiographic findings and clinical symptoms or signs to evaluate mean mitral gradient and pulmonary artery pressure		R (3)	M (6)	M (4)	A (8)	R (1)	R (2)	R (1)		R (1)	M (4)	M (4)	R (1)	R (1)
Mitral Regurgitation														
28. ■ Severe MR suspected clinically AND ■ Potentially underestimated on TTE despite optimal images ■ Better imaging of MR jet needed		R (2)	A (9)	M (5)	M (4)	R (1)	R (1)	R (1)		R (1)	A (7)	R (2)	M (4)	R (1)

Continued on the next page

TABLE 3 Continued

Indication	TTE	TTE With Contrast	TEE (With Possible 3D)	3D TTE	Ex.-SE	DSE	Low-Dose DSE	RVG	FDG-PET	MPI (SPECT/PET)	CMR	CCT	ANG	Fluoro
Mitral Regurgitation														
29. ■ Chronic symptomatic primary MR with discrepancy between exertional symptoms and the severity of MR at rest ■ Symptoms are disproportionate to the severity of MR determined at rest		R (1)	A (7)	M (4)	A (8)	R (1)	R (1)	R (1)		R (1)	M (5)	R (1)	R (2)	R (1)
30. ■ Chronic asymptomatic patient, to distinguish between moderate or severe primary MR		R (1)	A (7)	M (4)	A (7)	R (1)	R (1)	R (1)		R (1)	A (7)	R (2)	R (3)	R (1)
31. ■ Chronic secondary MR (stages B to D), to establish etiology, including a possible ischemic etiology		M (4)	A (8)	M (5)	A (7)	M (6)	R (1)	R (1)		A (7)	A (7)	M (6)	A (7)	R (1)
32. ■ Chronic secondary MR (stages B to D), to assess myocardial viability		R (1)	R (1)	R (1)	M (4)	A (7)	M (5)	R (1)	A (8)	A (7)	A (8)	R (3)	R (1)	R (1)
Aortic Regurgitation														
33. ■ Dilated aortic sinuses or ascending aorta or a bicuspid aortic valve (stages A and B), to evaluate the presence and severity of AR assuming optimal TTE images		R (1)	M (5)	R (3)	R (1)	R (1)	R (1)	R (1)		R (1)	M (5)	M (4)	R (2)	R (1)
34. ■ Discordance between clinical assessment and TTE about the severity of AR		R (1)	A (8)	R (3)	M (5)	R (1)	R (1)	R (1)		R (1)	A (7)	M (4)	M (4)	R (1)
35. ■ Assessment of symptoms and functional capacity in patients with moderate or severe AR		R (1)	R (1)	R (1)	A (7)	R (1)	R (1)	R (1)		R (1)	R (1)	R (1)	R (1)	R (1)
Other Valvular Regurgitation														
36. ■ Severe tricuspid regurgitation (stages C and D) and suboptimal TTE images, for assessment of RV systolic function and systolic and diastolic volumes		R (3)	R (3)	R (3)	R (1)	R (1)	R (1)	R (1)		R (1)	A (8)	M (6)	R (1)	R (1)
37. ■ Assessment of pulmonary pressures during stress in patient with severe asymptomatic valve regurgitation prior to pregnancy		R (1)	R (1)	R (1)	M (4)	R (1)	R (1)	R (1)		R (1)	R (1)	R (1)	R (1)	R (1)
Valvular Mass														
38. ■ Further evaluation of valvular mass (including incidental findings noted on noncardiac imaging studies)	A (9)	M (4)	A (7)	M (5)	R (1)	R (1)	R (1)	R (1)	R (1)	R (1)	M (6)	M (5)	R (1)	R (1)

3D = 3-dimensional; A = appropriate; ANG = invasive coronary angiography/ventriculography/aortography; AR = aortic regurgitation; AS = aortic stenosis; CCT = cardiac computed tomography; CMR = cardiovascular magnetic resonance imaging; DSE = dobutamine stress echocardiography; Ex.-SE = exercise stress echocardiography; FDG-PET = fluorodeoxyglucose-positron emission tomography; Fluoro = fluoroscopy; IE = infective endocarditis; LVEF = left ventricular ejection fraction; M = may be appropriate; MPI = myocardial perfusion imaging; MR = mitral regurgitation; PET = positron emission tomography; R = rarely appropriate; RVG = radionuclide ventriculography; SPECT = single photon emission computed tomography; TEE = transesophageal echocardiography; TTE = transthoracic echocardiography.

TABLE 4 Sequential or Follow-Up Testing: Asymptomatic or Stable Symptoms

Indication	TTE	TEE (With Possible 3D)	3D TTE	Ex.-SE	DSE	Low-Dose DSE	RVG	MPI (SPECT/PET)	CMR	CCT	ANG	Fluoro
Stage A VHD												
39. ■ Routine surveillance (every 3-5 y) for patients with stage A (bicuspid AV or aortic sclerosis) for exclusion of progression to stage B.	A (9)	R (2)	R (1)	R (1)	R (1)	R (1)	R (1)	R (1)	R (3)	R (2)	R (1)	R (1)
Mild or Moderate VHD												
40. ■ Re-evaluation (3-5 y) of mild (stage B) valvular regurgitation	A (8)	R (1)	R (1)	R (1)	R (1)	R (1)	R (1)	R (1)	R (1)	R (1)	R (1)	R (1)
41. ■ Re-evaluation (1-2 y) of mild (stage B) VHD without a change in clinical status or cardiac examination	M (4)	R (1)	R (1)	R (1)	R (1)	R (1)	R (1)	R (1)	R (1)	R (1)	R (1)	R (1)
42. ■ Re-evaluation (1-2 y) of moderate (stage B) VHD without a change in clinical status of cardiac examination	A (7)	R (1)	R (1)	R (1)	R (1)	R (1)	R (1)	R (1)	R (1)	R (1)	R (1)	R (1)
43. ■ Re-evaluation (<1 y) in patients with moderate AS who will be subjected to increased hemodynamic demands (e.g., noncardiac surgery, pregnancy)	M (6)	R (1)	R (1)	R (1)	R (1)	R (1)	R (1)	R (1)	R (1)	R (1)	R (1)	R (1)
Severe VHD												
44. ■ Re-evaluation (6-12 m) of asymptomatic severe (stage C1) AS without a change in clinical status or cardiac examination	M (6)	R (1)	R (1)	R (3)	R (1)	R (1)	R (1)	R (1)	R (1)	R (1)	R (1)	R (1)
45. ■ Re-evaluation (every 1 y) for asymptomatic (stage C1) patients with AS	A (8)	R (1)	R (1)	M (4)	R (1)	R (1)	R (1)	R (1)	R (1)	R (1)	R (1)	R (1)
46. ■ Re-evaluation (6-12 m) of stage C1 patients with asymptomatic severe AR with preserved ejection fraction and normal LV size	M (6)	R (1)	R (1)	R (1)	R (1)	R (1)	R (1)	R (1)	R (1)	R (1)	R (1)	R (1)
47. ■ Re-evaluation (every 6-12 m) of stage C1 patients with asymptomatic severe MR	A (7)	R (1)	R (1)	R (3)	R (1)	R (1)	R (1)	R (1)	R (1)	R (1)	R (1)	R (1)
48. ■ Re-evaluation (<1 y) in patients with severe AS who will be subjected to increased hemodynamic demands (e.g., noncardiac surgery, pregnancy)	M (6)	R (1)	R (1)	R (1)	R (1)	R (1)	R (1)	R (1)	R (1)	R (1)	R (1)	R (1)
49. ■ Re-evaluation after control of hypertension in patients with low-flow/low-gradient severe AS with preserved LVEF	A (7)	R (1)	R (1)	R (1)	R (1)	R (1)	R (1)	R (1)	R (1)	R (1)	R (1)	R (1)
Bicuspid AV With Dilated Aorta												
50. ■ Re-evaluation (<1 y) of the size and morphology of the aortic sinuses and ascending aorta in patients with a bicuspid AV and an ascending aortic diameter >4 cm with 1 of the following: ■ aortic diameter >4.5 cm ■ rapid rate of change in aortic diameter ■ family history (first-degree relative) of aortic dissection	A (7)	R (3)	R (1)	R (1)	R (1)	R (1)	R (1)	R (1)	A (8)	A (8)	R (1)	R (1)

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TABLE 4 Continued

Indication	TTE	TEE (With Possible 3D)	3D TTE	Ex.-SE	DSE	Low-Dose DSE	RVG	MPI (SPECT/PET)	CMR	CCT	ANG	Fluoro
Bicuspid AV With Dilated Aorta												
51. ■ Re-evaluation (<1 y) of the size and morphology of the aortic sinuses and ascending aorta in patients with a bicuspid AV and an aortic diameter of 4.0–4.5 cm without any of the risk factors listed in Indication 50.	R (2)	R (1)	R (1)	R (1)	R (1)	R (1)	R (1)	R (1)	R (1)	R (1)	R (1)	R (1)

Indication	TTE	TEE (With Possible 3D)	3D TTE	Ex.-SE	DSE	Low-Dose DSE	RVG	FDG-PET	MPI (SPECT/PET)	CMR	CCT	ANG	Fluoro
Endocarditis													
52. ■ Re-evaluation of prior TTE/TEE finding for interval change (e.g., resolution of vegetation after antibiotic therapy) when no change in therapy is anticipated	M (4)	R (1)	R (1)	R (1)	R (1)	R (1)	R (1)	R (1)	R (1)	R (1)	R (1)	R (1)	R (1)
53. ■ Re-evaluation of prior TTE/TEE finding for interval change (e.g., resolution of vegetation after antibiotic therapy) when a change in therapy is anticipated	A (8)	M (6)	R (3)	R (1)	R (1)	R (1)	R (1)	R (1)	R (1)	R (1)	R (1)	R (1)	R (1)
54. ■ Re-evaluation of patient with IE at high risk of progression or complications (e.g., extensive infective tissue/large vegetation on initial echocardiogram, or staphylococcal, enterococcal, or fungal infections) in the absence of clinical change	A (7)	M (6)	R (1)	R (1)	R (1)	R (1)	R (1)	R (3)	R (1)	R (3)	R (2)	R (1)	R (1)

3D = 3-dimensional; A = appropriate; ANG = invasive coronary angiography/ventriculography/aortography; AS = aortic stenosis; AV = aortic valve; CCT = cardiac computed tomography; CMR = cardiovascular magnetic resonance imaging; DSE = dobutamine stress echocardiography; Ex.-SE = exercise stress echocardiography; FDG-PET = fluorodeoxyglucose-positron emission tomography; Fluoro = fluoroscopy; IE = infective endocarditis; LVEF = left ventricular ejection fraction; M = may be appropriate; MPI = myocardial perfusion imaging; PET = positron emission tomography; R = rarely appropriate; RVG = radionuclide ventriculography; SPECT = single photon emission computed tomography; TEE = transesophageal echocardiography; TTE = transthoracic echocardiography.

TABLE 5 Sequential or Follow-Up Testing of New or Worsening Symptoms or to Guide Therapy

Indication	TTE	TEE (With Possible 3D)	3D TTE	Ex.-SE	DSE	Low-Dose DSE	RVG	FDG-PET	MPI (SPECT/PET)	CMR	CCT	ANG	Fluoro
General													
55. ■ Re-evaluation of known VHD with a change in clinical status or cardiac examination or to guide therapy	A (9)	M (5)	R (1)	R (3)	R (1)	R (1)	R (1)		R (1)	R (3)	R (1)	R (1)	R (1)
Endocarditis													
56. ■ Re-evaluation of IE in a patient with a change in clinical status or cardiac examination (e.g., new murmur, embolism, persistent fever, HF, abscess, or atrioventricular heart block)	A (9)	A (8)	R (3)	R (1)	R (1)	R (1)	R (1)	R (3)	R (1)	M (4)	M (5)	R (1)	R (1)

3D = 3-dimensional; A = appropriate; ANG = invasive coronary angiography/ventriculography/aortography; CCT = cardiac computed tomography; CMR = cardiovascular magnetic resonance imaging; DSE = dobutamine stress echocardiography; Ex.-SE = exercise stress echocardiography; FDG-PET = fluorodeoxyglucose-positron emission tomography; Fluoro = fluoroscopy; HF = heart failure; IE = infective endocarditis; M = may be appropriate; MPI = myocardial perfusion imaging; PET = positron emission tomography; R = rarely appropriate; RVG = radionuclide ventriculography; SPECT = single-photon emission computed tomography; TEE = transesophageal echocardiography; TTE = transthoracic echocardiography; VHD = valvular heart disease.

TABLE 6 Postoperative Imaging After Surgical Valve Replacement or Repair

Indication	TTE	TEE (With Possible 3D)	3D TTE	Ex.-SE	DSE	Low-Dose DSE	RVG	FDG-PET	MPI (SPECT/PET)	CMR	CCT	ANG	Fluoro
Surgical Valve Replacement (No or Stable Symptoms)													
57. ■ Initial postoperative evaluation of bioprosthetic or mechanical valve for establishment of baseline (6 w to 3 m postoperative)	A (9)	R (1)	R (1)	R (1)	R (1)	R (1)	R (1)		R (1)	R (1)	R (1)	R (1)	R (1)
58. ■ Re-evaluation (<3 y after valve implantation) of bioprosthetic or mechanical valve if no known or suspected valve dysfunction	M (5)	R (1)	R (1)	R (1)	R (1)	R (1)	R (1)		R (1)	R (1)	R (1)	R (1)	R (1)
59. ■ Re-evaluation (≥3 y after valve implantation) of bioprosthetic or mechanical valve if no known or suspected valve dysfunction	A (7)	R (1)	R (1)	R (1)	R (1)	R (1)	R (1)		R (1)	R (1)	R (1)	R (1)	R (1)
60. ■ Re-evaluation in patients with a bioprosthetic valve after the first 10 years, even in the absence of a change in clinical status	A (9)	R (1)	R (2)	R (1)	R (1)	R (1)	R (1)		R (1)	R (1)	R (1)	R (1)	R (1)
61. ■ Evaluation prior to pregnancy in patients with a prosthetic valve and no echocardiography within the past year	A (9)	R (1)	R (3)	R (1)	R (1)	R (1)	R (1)		R (1)	R (1)	R (1)	R (1)	R (1)
Surgical Valve Replacement (Suspicion of Valve Dysfunction)													
62. ■ Characterization of mechanical prosthetic valve if clinical signs or symptoms suggesting valve dysfunction	A (9)	A (8)	M (6)	R (1)	R (1)	R (1)	R (1)		R (1)	R (3)	M (6)	R (1)	A (7)
63. ■ Characterization of bioprosthetic valve if clinical signs or symptoms suggesting valve dysfunction	A (9)	A (7)	M (6)	R (2)	R (1)	R (1)	R (1)		R (1)	M (4)	M (4)	R (1)	R (1)
64. ■ Characterization of bioprosthetic valve if suspected clinically significant valvular dysfunction and inadequate images from TTE or TEE			R (2)	M (4)	R (1)	R (1)	R (1)		R (1)	A (7)	A (7)	M (5)	R (1)
65. ■ Characterization of mechanical prosthetic valve if suspected clinically significant valvular dysfunction and inadequate images from TTE or TEE			R (1)	R (2)	R (1)	R (1)	R (1)		R (1)	M (5)	A (7)	M (5)	A (7)
66. ■ Re-evaluation of known prosthetic valve dysfunction when it would change management or guide therapy	A (9)	A (7)	M (5)	R (2)	R (1)	R (1)	R (1)		R (1)	M (4)	M (5)	R (1)	M (4)
67. ■ Evaluation of documented prosthetic valve IE when medical management is considered, in a patient who is at high risk for progression or complication or with a change in clinical status or cardiac examination	A (9)	A (7)	M (5)	R (1)	R (1)	R (1)	R (1)	R (3)	R (1)	R (3)	M (6)	R (1)	R (1)
Mitral Valve Repair													
68. ■ Initial postoperative assessment of valve repair (6 w to 3 m postoperatively)	A (9)	R (1)	M (4)	R (1)	R (1)	R (1)	R (1)		R (1)	R (1)	R (1)	R (1)	R (1)

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TABLE 6 Continued

Indication	TTE	TEE (With Possible 3D)	3D TTE	Ex.-SE	DSE	Low-Dose DSE	RVG	FDG-PET	MPI (SPECT/PET)	CMR	CCT	ANG	Fluoro
Mitral Valve Repair													
69. ■ Re-evaluation (<3 y) in patients without suspected repaired valve dysfunction	R (1)	R (1)	R (1)	R (1)	R (1)	R (1)	R (1)		R (1)	R (1)	R (1)	R (1)	R (1)
70. ■ Re-evaluation (≥3 y) in patients without suspected repaired valve dysfunction	A (8)	R (1)	M (4)	R (1)	R (1)	R (1)	R (1)		R (1)	R (1)	R (1)	R (1)	R (1)
71. ■ Re-evaluation (<3 y) for suspected repaired valve dysfunction	A (9)	M (6)	M (6)	M (4)	R (1)	R (1)	R (1)		R (1)	M (4)	R (3)	R (1)	R (1)

3D = 3-dimensional; A = appropriate; ANG = invasive coronary angiography/ventriculography/aortography; CCT = cardiac computed tomography; CMR = cardiovascular magnetic resonance imaging; DSE = dobutamine stress echocardiography; Ex.-SE = exercise stress echocardiography; FDG-PET = fluorodeoxyglucose-positron emission tomography; Fluoro = fluoroscopy; IE = infective endocarditis; M = may be appropriate; MPI = myocardial perfusion imaging; PET = positron emission tomography; R = rarely appropriate; RVG = radionuclide ventriculography; SPECT = single photon emission computed tomography; TEE = transesophageal echocardiography; TTE = transthoracic echocardiography.

6.3. Transcatheter Intervention for VHD

TABLE 7A Pre-TAVR Evaluation

Indication	TTE	TEE (With Possible 3D)	3D TTE	Ex.-SE	DSE	Low-Dose DSE	RVG	MPI (SPECT/PET)	CMR	CCT	ANG	Fluoro
72. ■ Assessment for concomitant coronary artery disease	R (1)	R (1)	R (1)	R (1)	R (1)	R (1)	R (1)	M (4)	R (1)	M (5)	A (9)	R (1)
73. ■ Accurate assessment of annular size and shape*	R (3)	A (7)	M (4)	R (1)	R (1)	R (1)	R (1)	R (1)	A (7)	A (9)	R (1)	R (1)
74. ■ Assessment of number of cusps and degree of calcification	A (7)	A (7)	M (6)	R (1)	R (1)	R (1)	R (1)	R (1)	M (4)	A (9)	R (1)	R (1)
75. ■ Measurement of the distance between annulus and the coronary ostia	R (1)	M (6)	R (1)	R (1)	R (1)	R (1)	R (1)	R (1)	M (5)	A (9)	M (4)	R (1)
76. ■ Precise coaxial alignment of the implant within the centerline of the aortic valve	R (1)	R (3)	R (1)	R (1)	R (1)	R (1)	R (1)	R (1)	R (2)	A (8)	R (1)	R (1)
77. ■ Assessment of aortic dimensions	R (1)	M (4)	R (1)	R (1)	R (1)	R (1)	R (1)	R (1)	A (7)	A (9)	R (2)	R (1)
78. ■ Assessment of aortic atherosclerotic burden	R (1)	M (5)	R (1)	R (1)	R (1)	R (1)	R (1)	R (1)	M (4)	A (9)	M (4)	R (1)
79. ■ Assessment of iliofemoral vessels	R (1)	R (1)	R (1)	R (1)	R (1)	R (1)	R (1)	R (1)	M (5)	A (9)	M (5)	R (1)

*Multimodality imaging might improve the accuracy of the measurements (1).

3D = 3-dimensional; A = appropriate; ANG = invasive coronary angiography/ventriculography/aortography; CCT = cardiac computed tomography; CMR = cardiovascular magnetic resonance imaging; DSE = dobutamine stress echocardiography; Ex.-SE = exercise stress echocardiography; Fluoro = fluoroscopy; M = may be appropriate; MPI = myocardial perfusion imaging; PET = positron emission tomography; R = rarely appropriate; RVG = radionuclide ventriculography; SPECT = single photon emission computed tomography; TAVR = transcatheter aortic valve replacement; TEE = transesophageal echocardiography; and TTE = transthoracic echocardiography.

TABLE 7B Intraprocedural Evaluation During TAVR

Indication		TTE	TEE (With Possible 3D)	3D TTE	ANG	Fluoro
80.	■ Guidewire placement into the LV	A (7)	A (7)	M (5)	R (1)	A (9)
81.	■ Valve placement	A (7)	A (8)	M (6)	A (7)	A (9)
82.	■ Postdeployment assessment (position, function, regurgitation)	A (7)	A (8)	A (7)	A (8)	A (7)
83.	■ Evaluate immediate complications ■ Hypotension ■ Coronary occlusion ■ LV depression from rapid pacing ■ LV outflow tract obstruction ■ Severe MR ■ Prosthesis dislodgment ■ Tamponade ■ Right ventricular perforation ■ Air embolism ■ Aortic dissection (paravalvular leak needs to be excluded)	A (8)	A (9)	A (7)	A (8)	A (8)

3D = 3-dimensional; A = appropriate; ANG = invasive coronary angiography/ventriculography/aortography; Fluoro = fluoroscopy; LV = left ventricle; M = may be appropriate; R = rarely appropriate; TAVR = transcatheter aortic valve replacement; TEE = transesophageal echocardiography; TTE = transthoracic echocardiography.

TABLE 7C Postprocedural Assessment After TAVR (Out of Procedure and <30 days)

Indication		TTE	TEE (With Possible 3D)	3D TTE	Ex.-SE	DSE	Low-Dose DSE	RVG	MPI (SPECT/PET)	CMR	CCT	Brain CT/MRI
84.	■ Assessment of degree of aortic regurgitation (including valvular and paravalvular) with suspicion of valve dysfunction	A (8)	A (7)	M (5)	R (1)	R (1)	R (1)	R (1)	R (1)	M (4)	M (4)	R (1)
85.	■ Assessment of stroke with suspicion of valve dysfunction	A (7)	M (6)	R (3)	R (1)	R (1)	R (1)	R (1)	R (1)	R (1)	M (6)	A (9)

3D = 3-dimensional; A = appropriate; ANG = invasive coronary angiography/ventriculography/aortography; CCT = cardiac computed tomography; CMR = cardiovascular magnetic resonance imaging; CT = computed tomography; DSE = dobutamine stress echocardiography; Ex.-SE = exercise stress echocardiography; M = may be appropriate; MPI = myocardial perfusion imaging; MRI = magnetic resonance imaging; R = rarely appropriate; RVG = radionuclide ventriculography; TAVR = transcatheter aortic valve replacement; TEE = transesophageal echocardiography; TTE = transthoracic echocardiography.

TABLE 8A Evaluation Prior to Percutaneous Mitral Valve Repair

Indication		TTE	TEE (With Possible 3D)	3D TTE	Exercise Testing	CMR	ANG
86.	■ Determine patient eligibility*	A (8)	A (9)	A (7)	A (7)	R (2)	A (7)
87.	■ Exclude the presence of intracardiac mass, thrombus, or vegetation prior to (within 3 d of the procedure)	M (4)	A (9)	M (5)	R (1)	R (3)	R (1)

*Determine patient eligibility. Currently, MitraClip is the only FDA-approved device available.

3D = 3-dimensional; A = appropriate; ANG = invasive coronary angiography/ventriculography/aortography; CMR = cardiovascular magnetic resonance imaging; FDA = U.S. Food and Drug Administration; M = may be appropriate; R = rarely appropriate; TEE = transesophageal echocardiography; TTE = transthoracic echocardiography.

TABLE 8B Intraprocedural Evaluation During Percutaneous Mitral Valve Repair

Indication		TTE	TEE (With Possible 3D)	3D TTE	Angiography/ Fluoro
88.	■ Alignment of the device over the origin of the regurgitant jet and advance to the LV	R (1)	A (9)	M (4)	A (8)
89.	■ Guidance for grasping the mitral valve leaflets and device closure	R (1)	A (9)	R (2)	A (9)
90.	■ Assess for adequacy in the reduction of the MR	M (4)	A (9)	M (6)	A (7)
91.	■ Assess for presence of mitral stenosis	M (5)	A (9)	M (6)	R (1)

3D = 3-dimensional; A = appropriate; Fluoro = fluoroscopy; M = may be appropriate; MR = mitral regurgitation; R = rarely appropriate; TEE = transesophageal echocardiography; TTE = transthoracic echocardiography.

TABLE 8C Postprocedural Assessment After Percutaneous Mitral Valve Repair (Out of Procedure)

Indication	TTE	TEE (With Possible 3D)	3D TTE	Exercise Testing	CMR
92. ■ Reassessment for degree of MR and left ventricular function (predischarge at 1, 6, and 12 m, and then annually to 5 y)	A (9)	R (3)	M (5)	R (1)	R (3)

3D = 3-dimensional; A = appropriate; CMR = cardiovascular magnetic resonance imaging; M = may be appropriate; MR = mitral regurgitation; R = rarely appropriate; TEE = transesophageal echocardiography; TTE = transthoracic echocardiography.

7. DISCUSSION

AUC are intended to inform clinicians, patients, and health policy makers about the reasonable use of technologies to help improve patient symptoms and health outcomes. Since 2005, the ACC, along with its professional partners, has worked to provide criteria for both invasive and noninvasive testing and selected treatments, with the intention of further expanding the AUC portfolio (1,2,6,9-12).

The "2017 Appropriate Use Criteria for Multimodality Imaging in Valvular Heart Disease" is the culmination of the analysis of various modalities used in the evaluation and treatment of patients with VHD. This document signals a shift from documents evaluating a single modality in various disease states to documents evaluating multiple imaging modalities and focusing on evidence and clinical experience within a given category of disease. We believe that this approach better reflects clinical decision making in real-world scenarios and offers the diagnostic choices available to the clinician.

Because a given modality may address diverse disease states, indications previously compiled in a single document may be spread over several AUC documents. The previous VHD-related indications that the current paper supplants are contained in the echocardiography (12), radionuclide imaging (11), and computed tomography/magnetic resonance imaging (9,10) AUC documents. Other indications in these documents remain in force until these scenarios are evaluated in subsequent documents.

The tables in this paper are organized to reflect the spectrum of patients with VHD—from patients with no symptoms suspected of having VHD to patients with signs and symptoms ranging from mild to severe. The first 2 tables are for initial evaluation when no prior imaging has been done. As is noted, the diagnostic choices vary between the tables and reflect the options that would be considered in the initial evaluation by most clinicians. If a diagnostic test would seldom or never be considered, it was not included as an option for the rating panel.

In the asymptomatic patient either who is at risk of developing VHD or in whom VHD was clinically suspected, TTE was rated Appropriate for these indications. Three-dimensional (3D) TTE was rated May Be Appropriate for indications 2 and 3. All other modalities (computed tomography, magnetic resonance imaging, and TEE) were rated Rarely Appropriate. These are new indications, so there are no prior ratings in older documents for comparison.

Table 2 evaluates the symptomatic patient. This table adds exercise stress echocardiography, dobutamine stress echocardiography, radionuclide ventriculography, fluorodeoxyglucose-positron emission tomography, and myocardial perfusion imaging/single-photon emission computed tomography/positron emission tomography. In general, echocardiography was the preferred option for initial testing in such patients. The ratings correlate well with those in the prior echocardiography AUC (12), with the exception of the evaluation of presyncope, which was rated May Be Appropriate here and Inappropriate ("I" in the old nomenclature) in the prior document. This difference is minor and is attributable to the fact that the symptom of lightheadedness was included with presyncope in the older document, which may have prompted the rating panel to apply a lower rating to echocardiography. All other ratings in this table are either in line with prior rankings or are new scenarios not included in prior documents.

Table 3 evaluates the use of subsequent imaging in scenarios in which prior imaging—presumably using TTE—did not yield a clear diagnosis. The diagnostic options are the same as in Table 2, with the exclusion of TTE. The table is further subdivided into inadequate TTE images, suspected endocarditis, various types of VHD, and valvular mass.

In Table 3, TEE is rated Appropriate and TTE with contrast as May Be Appropriate in evaluating native and prosthetic valves with inadequate images (19,20). TEE is also rated Appropriate and fluorodeoxyglucose-positron emission tomography as May Be Appropriate in the diagnosis of endocarditis in patients with a negative TTE. Scenarios 23 to 25 identify the role of low-dose dobutamine stress echocardiography in patients with low-flow, low-gradient severe aortic stenosis (with low ejection fraction as Appropriate and preserved ejection fraction as May Be Appropriate) (21-23). Exercise stress echocardiography and dobutamine stress echocardiography were rated Rarely Appropriate in patients with severe, symptomatic AS. The common conundrum of evaluating the severity of MR—examined in scenarios 28 to

32—particularly distinguishing moderate from severe MR, elucidating the discrepancy between symptoms and severity, and evaluating an ischemic etiology of MR, demonstrates the role of various modalities in these very specific but very common scenarios (24). These indications are new and are not included in prior documents.

Table 4 evaluates sequential or follow-up imaging in various stages of VHD and incorporates the newer VHD classification (4) where TTE ratings are in line with the prior echocardiography AUC (12) and reflect the primacy of TTE at appropriate intervals in following patients with VHD. Time intervals shorten with the severity of VHD, and the role of exercise stress echocardiography—rated May Be Appropriate—in evaluating patients with severe and asymptomatic AS to aid in clinical decision making is highlighted. TTE in patients with moderate or severe AS imaged with a less than 1-year time interval when subjected to increased hemodynamic demands is rated May Be Appropriate and can be considered on a case-by-case basis. The utility of cardiac computed tomography (CCT) or cardiovascular magnetic resonance imaging in evaluating the ascending aorta in patients with a bicuspid aortic valve is defined in indications 49 to 51.

Table 5 evaluates new or worsening symptoms. In the general scenarios, TTE is rated Appropriate and TEE is rated May Be Appropriate. In the specific endocarditis scenario, both TTE and TEE are rated Appropriate.

Table 6 evaluates postoperative imaging in patients undergoing surgical valve replacement and/or mitral repair. In patients with no symptoms (indications 57 to 61), the interval of follow-up (which is limited to TTE) aligns well with the prior document, with the exception of the evaluation of a mechanical or bioprosthetic valve with TTE in <3 years—indication 58 (12). In the current document, it is rated May Be Appropriate. In the prior AUC, it was rated Inappropriate (old nomenclature). Reasons for this difference are not apparent, but may be related to rating panel composition, which can account for small differences. The authors suggest that there are cases in which follow-up imaging may be done in a shorter time frame, such as small prosthesis size and an elevated transvalvular gradient by Doppler.

Whereas TTE is the modality of choice in the asymptomatic patient, TEE is considered Appropriate, and 3D TTE May Be Appropriate and useful in the evaluation of patients with suspected prosthetic valve dysfunction.

Section 6.3. (**Tables 7** and **8**) evaluates the dynamic field of structural valve interventions. **Tables 7a to 7c** cover preprocedural, intraprocedural, and postprocedural imaging for transcatheter aortic valve replacement (TAVR) for AS (25,26). **Table 7a** catalogues all of the necessary measurements in the pre-TAVR evaluation. It is worth noting that this table covers the imaging support needed and not whether the procedure should be done. The latter is being evaluated in an AUC document for severe AS, which is currently under development. It is in the AS AUC that CCT and cardiovascular magnetic resonance imaging, as advanced imaging techniques, establish themselves as essential technologies for planning these procedures. Likewise, assessment for concomitant coronary artery disease is accomplished through CCT, myocardial perfusion imaging/single-photon emission computed tomography/positron emission tomography, and angiography.

Intraprocedural evaluation (**Table 7b**) is accomplished with TTE, TEE, angiography, and fluoroscopy. Because TAVR procedures are increasingly being performed with conscious sedation, TTE (27) is being increasingly used in lieu of TEE. Both modalities are rated Appropriate.

Postprocedural assessment (**Table 7c**) for valve dysfunction can be accomplished with TTE or TEE rated as Appropriate tests, with the additional use of 3D TTE rated as May Be Appropriate. CCT or cardiovascular magnetic resonance imaging are both rated May Be Appropriate. For assessment of stroke, TTE is rated Appropriate, whereas TEE and CCT are rated May Be Appropriate. Brain imaging with computed tomography or magnetic resonance imaging is rated Appropriate.

For percutaneous mitral valve repair (**Table 8**), there is only 1 U.S. Food and Drug Administration–approved device and imaging support, especially in follow-up, hence, the U.S. Food and Drug Administration–directed protocol (28). Patient eligibility (including assessment for concomitant coronary artery disease) is assessed with TTE, TEE, 3D TTE, exercise testing of various types, and coronary angiography, all of which are rated Appropriate. If there is concern regarding an intracardiac mass, thrombus, or vegetation, this is assessed with TEE, as Appropriate, whereas TTE is rated as May Be Appropriate, as is 3D TTE.

Intraprocedural assessment is accomplished with TEE as Appropriate and angiography/fluoroscopy as Appropriate for all measures except for the presence of mitral stenosis, which is assessed with TEE as Appropriate. TTE and 3D TTE are also useful for some determinations during the procedure as May Be Appropriate, but TEE offers a more comprehensive examination and is rated Appropriate.

The postprocedure assessment is currently determined by U.S. Food and Drug Administration regulations and involves echocardiography predischarge at 1, 6, and 12 months and annually up to 5 years. TTE is rated Appropriate and 3D TTE is rated May Be Appropriate.

8. CONCLUSIONS

This document assesses a wide array of imaging modalities available to the clinician in the evaluation of patients

with VHD. Presented here is a broad spectrum of clinical scenarios in such patients. Some of these scenarios replicate those of prior documents, but many are new, specifically, structural valve interventions, which were not in the armamentarium of clinicians when prior, single-modality documents were published. Where comparisons can be made, the ratings are remarkably consistent with prior documents.

We believe the multimodality approach more closely replicates clinical decision making and will be useful. Future documents will not provide single-source guidance for appropriateness in all disease states. Echocardiography indications, for example, will be spread across complimentary documents such as multimodality stable ischemic heart disease AUC, multimodality structural heart disease AUC, the current document, and multimodality preoperative evaluation AUC, which is under development.

A few clinical scenarios, describing evaluation of symptoms that could be secondary to valvular or structural heart disease, can be found in both documents (e.g., the evaluation of pre-syncope/syncope in **Table 2**). Although these scenarios were developed against a background of both valvular and structural heart disease, they were rated separately in the context of other clinical scenarios focused on either valvular or structural heart disease. The writing group and its representatives have placed particular emphasis on this issue during all stages of the development of the AUC document to avoid discordant recommendations for these scenarios.

As with all prior documents, the evaluation is a product of current guidelines, where available, and expert consensus. The modalities are not to be considered in a rank order and may be used relative to individual patient circumstances and risk versus benefit. Accordingly, a study rated May Be Appropriate should not be denied reimbursement in lieu of one rated Appropriate. There will be individual circumstances when a study ranked Rarely Appropriate may be clinically useful if properly documented.

ACC PRESIDENT AND STAFF

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KEY WORDS ACC Appropriate Use Criteria, imaging, multimodality, valvular heart disease

APPENDIX A. APPROPRIATE USE CRITERIA FOR MULTIMODALITY IMAGING IN VALVULAR HEART DISEASE: MEMBERS OF THE WRITING GROUP, RATING PANEL, INDICATION REVIEWERS, AND AUC TASK FORCE—RELATIONSHIPS WITH INDUSTRY AND OTHER ENTITIES (RELEVANT)

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APPENDIX A. CONTINUED

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APPENDIX A. CONTINUED

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Rajan Patel, MD, FACC, FAHA, FSCAI	Ochsner Medical Center—Interventional Cardiology Specialist	SCAI	None	None	None	None	■ Aastrom ■ Abbott ■ NHLBI ■ ACC (Imaging Committee) ■ SCAI Carotid Stent Committee ■ SCAI Publications Committee	None
Jeffrey A. Brinker, MD, FACC	Johns Hopkins Hospital—Professor of Medicine	SCAI	None	None	None	None	None	None
Michael V. McConnell, MD, FACC	Stanford University Medical Center—Professor of Medicine	SCMR	None	None	None	■ AHA—Vascular Medicine* ■ GE Healthcare—Noninvasive Imaging* ■ Morpheus Medical Inc.—Noninvasive Imaging ■ NIH—Vascular Medicine Invasive CV Angiography & Interventions Noninvasive Imaging* ■ Tiara Pharmaceuticals—Prevention, Vascular Medicine*	None	None
Raymond Y. Kwong, MD	Brigham & Women's Hospital Medicine, Cardiovascular Division—Instructor of Medicine	SCMR	None	None	None	■ Alynlam Pharmaceutical*	■ SCMR (officer)	None
Andrew J. Powell, MD, FACC	Children's Hospital, Boston, Department of Cardiology—Associate in Cardiology, Associate Professor of Pediatrics	SCMR	None	None	None	None	None	None
Joseph Wu, MD, PhD, FACC	Stanford University School of Medicine—Director, Stanford Cardiovascular Institute; Professor, Department of Medicine/Cardiology	AHA	None	None	■ Stem Cell Theranostics†	None	None	None
Harold Litt, MD, PhD, FACC	University of Pennsylvania—Associate Professor of Radiology; Chief, Cardiovascular Imaging Section, Department of Radiology; Director, Center for Advanced Computed Tomography Imaging Sciences; Fellowship Director, Cardiovascular Imaging Fellowship	AHA	None	None	None	■ American College of Radiology Imaging Network—Noninvasive Imaging* ■ Heartflow—Noninvasive Imaging* ■ Siemens Medical Solutions—Noninvasive Imaging*	■	■ Defendant, chest mass imaging, 2016

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APPENDIX A. CONTINUED

Participant	Employment	Representing	Consultant	Speakers Bureau	Ownership/ Partnership/ Principal	Personal Research	Institutional, Organizational, or Other Financial Benefit	Expert Witness
Thomas C. Gerber, MD, PhD, FACC	Mayo Clinic—Professor of Medicine and Radiology	AHA	None	None	None	None	■ American Journal of Radiology (officer) ■ Mayo Clinic Proceedings (officer)	None
Amish Raval, MD, FACC	University of Wisconsin School of Medicine—Associate Professor	AHA	None	None	None	None	None	None
Marcelo F. DiCarli	Brigham and Women's Hospital—Chief of Nuclear Medicine; Harvard Medical School—Assistant Professor of Radiology and Medicine	SNMMI	None	None	None	■ NHLBI T32HL094301—Noninvasive Imaging* ■ Spectrum Dynamics—Noninvasive Imaging*	■ AHA Circulation: Cardiovascular Imaging (Editor) ■ NIH* ■ Spectrum Dynamics*	None

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*Significant relationship.

†No financial benefit.

AATS = American Association for Thoracic Surgery; ACC = American College of Cardiology; AHA = American Heart Association; ASE = American Society of Echocardiography; ASNC = American Society of Nuclear Cardiology; CV = cardiovascular; DSMB = Data and Safety Monitoring Board; EP = electrophysiology; HRS = Heart Rhythm Society; NHLBI = National Heart, Lung, and Blood Institute; NIH = National Institutes of Health; PCORI = Patient-Centered Outcomes Research Institute; PI = principal investigator; SCAI = Society for Cardiovascular Angiography and Interventions; SCCT = Society of Cardiovascular Computed Tomography; SCMR = Society for Cardiovascular Magnetic Resonance; STS = Society of Thoracic Surgeons.