

**American College of Radiology  
ACR Appropriateness Criteria®  
Suspected and Known Heart Failure**

**Variant 1:                      Adult. Suspected heart failure. No history of heart failure. Initial imaging.**

Procedure	Appropriateness Category	Relative Radiation Level
US echocardiography transthoracic resting	Usually Appropriate	○
Radiography chest	Usually Appropriate	☼
US echocardiography transthoracic stress	May Be Appropriate	○
MRI heart function and morphology without and with IV contrast	May Be Appropriate	○
MRI heart function and morphology without IV contrast	May Be Appropriate	○
Nuclear medicine ventriculography	May Be Appropriate	☼☼☼
CT heart function and morphology with IV contrast	May Be Appropriate	☼☼☼☼
US echocardiography transesophageal	Usually Not Appropriate	○
MRA coronary arteries without and with IV contrast	Usually Not Appropriate	○
MRI heart function with stress without and with IV contrast	Usually Not Appropriate	○
Arteriography coronary	Usually Not Appropriate	☼☼☼
CT chest with IV contrast	Usually Not Appropriate	☼☼☼
CT chest without and with IV contrast	Usually Not Appropriate	☼☼☼
CT chest without IV contrast	Usually Not Appropriate	☼☼☼
CT coronary calcium	Usually Not Appropriate	☼☼☼
CTA coronary arteries with IV contrast	Usually Not Appropriate	☼☼☼
FDG-PET/CT heart	Usually Not Appropriate	☼☼☼☼
Rb-82 PET/CT heart	Usually Not Appropriate	☼☼☼☼
SPECT or SPECT/CT MPI rest and stress	Usually Not Appropriate	☼☼☼☼

**Variant 2:****Adult. Known heart failure. Unknown etiology. Initial imaging.**

Procedure	Appropriateness Category	Relative Radiation Level
US echocardiography transthoracic resting	Usually Appropriate	○
US echocardiography transthoracic stress	Usually Appropriate	○
MRI heart function and morphology without and with IV contrast	Usually Appropriate	○
MRI heart function and morphology without IV contrast	Usually Appropriate	○
MRI heart function with stress without and with IV contrast	Usually Appropriate	○
CTA coronary arteries with IV contrast	Usually Appropriate	☼☼☼
SPECT or SPECT/CT MPI rest and stress	Usually Appropriate	☼☼☼☼
US echocardiography transesophageal	May Be Appropriate	○
Arteriography coronary	May Be Appropriate	☼☼☼
CT heart function and morphology with IV contrast	May Be Appropriate	☼☼☼☼
FDG-PET/CT heart	May Be Appropriate	☼☼☼☼
Rb-82 PET/CT heart	May Be Appropriate	☼☼☼☼
Radiography chest	Usually Not Appropriate	☼
MRA coronary arteries without and with IV contrast	Usually Not Appropriate	○
CT chest with IV contrast	Usually Not Appropriate	☼☼☼
CT chest without and with IV contrast	Usually Not Appropriate	☼☼☼
CT chest without IV contrast	Usually Not Appropriate	☼☼☼
CT coronary calcium	Usually Not Appropriate	☼☼☼
Nuclear medicine ventriculography	Usually Not Appropriate	☼☼☼

**Variant 3:****Adult. Known heart failure. Follow-up imaging.**

Procedure	Appropriateness Category	Relative Radiation Level
US echocardiography transthoracic resting	Usually Appropriate	○
US echocardiography transthoracic stress	Usually Appropriate	○
MRI heart function and morphology without and with IV contrast	Usually Appropriate	○
MRI heart function and morphology without IV contrast	Usually Appropriate	○
MRI heart function with stress without and with IV contrast	Usually Appropriate	○
Radiography chest	May Be Appropriate	⊕
Nuclear medicine ventriculography	May Be Appropriate	⊕⊕⊕
CT heart function and morphology with IV contrast	May Be Appropriate	⊕⊕⊕⊕
FDG-PET/CT heart	May Be Appropriate	⊕⊕⊕⊕
Rb-82 PET/CT heart	May Be Appropriate	⊕⊕⊕⊕
SPECT or SPECT/CT MPI rest and stress	May Be Appropriate	⊕⊕⊕⊕
US echocardiography transesophageal	Usually Not Appropriate	○
Arteriography coronary	Usually Not Appropriate	⊕⊕⊕
MRA coronary arteries without and with IV contrast	Usually Not Appropriate	○
CT chest with IV contrast	Usually Not Appropriate	⊕⊕⊕
CT chest without and with IV contrast	Usually Not Appropriate	⊕⊕⊕
CT chest without IV contrast	Usually Not Appropriate	⊕⊕⊕
CT coronary calcium	Usually Not Appropriate	⊕⊕⊕
CTA coronary arteries with IV contrast	Usually Not Appropriate	⊕⊕⊕

## SUSPECTED AND KNOWN HEART FAILURE

Expert Panel on Cardiac Imaging: James Roberts, MD, MSc<sup>a</sup>; Kate Hanneman, MD, MPH<sup>b</sup>; Prabhakar Shantha Rajiah, MD<sup>c</sup>; Shawn Ahmad, MD, MBA<sup>d</sup>; Ryan Avery, MD<sup>e</sup>; William M. Brown, MD<sup>f</sup>; Ahmed H. El-Sherief, MD<sup>g</sup>; Joe Y. Hsu, MD<sup>h</sup>; Veronica Lenge de Rosen, MD<sup>i</sup>; Fay Lin, MD<sup>j</sup>; Gurusher Panjra, MD<sup>k</sup>; Rahul D. Renapurkar, MD, MBBS<sup>l</sup>; James A. White, MD<sup>m</sup>; Michael A. Bolen, MD.<sup>n</sup>

### Summary of Literature Review

#### **Introduction/Background**

Heart failure (HF) is a widely prevalent and complex clinical syndrome, with evolving classification systems and treatment options [1]. In the United States, HF affects an estimated 6.7 million adults [2], and approximately 1 million individuals develop HF annually [3]. The risk of HF increases with age, and as the population ages, HF prevalence is increasing. The lifetime risk of developing HF varies, with estimates between 1 in 5 and 1 in 2 adults [2,4].

HF is associated with high morbidity and mortality, similar to many cancers. Although survival after the initial manifestation of HF has improved because of expanding evidence-based treatments, improved patient surveillance, and management of complications [5,6], the death rate remains high, particularly among patients who have been hospitalized for HF [7]. As the survival rates following myocardial infarction have increased, the prevalence and identification of nonischemic cardiomyopathies rises, and as the population ages, the impact of HF on the health care system will increase [8].

Presently, the total expense related to HF nationally is estimated to be \$39.2 to \$60 billion, with most of this cost attributable to direct medical costs [3]. By 2030, the total annual expense of HF is projected to increase to \$70 billion [3]. The average annual cost per patient with HF is approximately \$30,000 per year in the United States, mostly for inpatient-related care [3].

HF is characterized by clinical signs and symptoms of impaired ventricular filling or function [1]. The signs and symptoms of HF are variable and can overlap with numerous other diseases, sometimes leading to delayed diagnosis and therapy, especially in older populations [9]. No single test exists for diagnosing HF. HF is a clinical diagnosis based on history, physical examination, laboratory, and imaging studies. However, cardiac imaging plays an important role in diagnosis, determination of the underlying etiology, guiding treatment decisions, establishing prognosis, and performing appropriate patient surveillance.

Because most patients with HF become symptomatic because of impaired myocardial function of the left ventricle (LV) [10], imaging plays an important supportive role including confirmation of HF as the cause of the patients' presenting signs and symptoms, especially by detecting LV dysfunction.

This diagnostic phase overlaps with reported approaches to appropriate use of imaging in other settings (see the updated ACR Appropriateness Criteria<sup>®</sup> topics on "[Dyspnea-Suspected Cardiac Origin \(Ischemia Already Excluded\)](#)" [11] and "[Nonischemic Myocardial Disease with Clinical Manifestations \(Ischemic Cardiomyopathy Already Excluded\)](#)" [12]).

Accurate determination of LV ejection fraction (EF) is important in the classification of HF due to differing patient demographics, comorbid conditions, prognosis, and response to therapies. Additionally, most clinical trials stratify patients based on LVEF [10]. Consequently, imaging has and continues to play a key role in the differentiation of HF phenotype categories that are used to guide therapeutic decisions. Symptomatic HF is often classified based on LVEF. Although the specific cut-points and definitions can vary by imaging modality, typical definitions include

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The American College of Radiology seeks and encourages collaboration with other organizations on the development of the ACR Appropriateness Criteria through representation of such organizations on expert panels. Participation on the expert panel does not necessarily imply endorsement of the final document by individual contributors or their respective organization.

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HF with preserved EF (HFpEF; LVEF  $\geq$ 50%), mildly reduced EF (HFmrEF; LVEF 41%-49%), reduced EF (HFrEF; LVEF  $\leq$ 40%), and improved EF (HFimpEF; LVEF initially  $\leq$ 40% with  $\geq$ 10 percentage-point increase to  $>$ 40%) [13].

There are multiple possible, and occasionally combined, causes for HF. These are inclusive of ischemic and nonischemic etiologies, the latter contributing known or identifiable causes such as hypertension, valvular heart disease, and amyloidosis, while also inclusive of idiopathic cardiomyopathy states without an identifiable cause despite exhaustive testing. The latter testing is typically aimed at identifying occult etiologies such as familial/hereditary cardiomyopathy, cardiac sarcoidosis, other forms of chronic inflammatory myocarditis, or myocardial iron overload. In clinical practice and multicenter HF trials, the etiology of HF has often been categorized into either ischemic cardiomyopathy or nonischemic cardiomyopathy [10,14].

Four stages of HF have been described [1], including 1) at risk (asymptomatic, underlying predisposing condition, but no objective findings of structural heart disease), 2) pre-HF (asymptomatic, with objective findings of impaired ventricular filling/function), 3) symptomatic, and 4) advanced (significantly interfering with daily function). The natural history of the disease is a progression between stages, although the disease course can be arrested at any stage, or potentially improve or go into remission. Higher stages are associated with progressively decreased survival.

Guideline-directed medical therapy is the standard of care for HF treatment, in conjunction with care delivery by a team specialized in HF management. Guideline-directed medical therapy includes both medical and procedural treatments (eg, coronary revascularization, cardiac resynchronization therapy) for HF and has resulted in reduced morbidity and mortality [1].

### Special Imaging Considerations

For the purposes of distinguishing between CT and CT angiography (CTA), ACR Appropriateness Criteria topics use the definition in the [ACR–NASCI–SIR–SPR Practice Parameter for the Performance and Interpretation of Body Computed Tomography Angiography \(CTA\)](#) [15]:

*“CTA uses a thin-section CT acquisition that is timed to coincide with peak arterial and/or venous enhancement, depending on the vascular structures to be analyzed. The resultant volumetric data set is interpreted using primary transverse reconstructions as well as multiplanar reformations and 3-D renderings.”*

All elements are essential: 1) timing, 2) reconstructions/reformats, and 3) 3-D renderings. Standard CTs with contrast also include timing issues and recons/reformats. Only in CTA, however, is 3-D rendering a **required** element. This corresponds to the definitions that the CMS has applied to the Current Procedural Terminology codes.

The role of focused assessment with ultrasonography for trauma (FAST) (or extended-FAST or chest abdominal-FAST in evaluating chest injury) is primarily one of triage; a positive FAST and signs of hemodynamic instability may lead to immediate surgical intervention rather than CT [16,17]. Ultrasound (US) may be able to diagnose certain thoracic and abdominal injuries, but it is an insufficient test to fully exclude injuries to these areas because it has a relatively lower specificity compared with CT [18].

### Initial Imaging Definition

Initial imaging is defined as imaging at the beginning of the care episode for the medical condition defined by the variant. More than one procedure can be considered usually appropriate in the initial imaging evaluation when:

- There are procedures that are equivalent alternatives (ie, only one procedure will be ordered to provide the clinical information to effectively manage the patient’s care)

OR

- There are complementary procedures (ie, more than one procedure is ordered as a set or simultaneously where each procedure provides unique clinical information to effectively manage the patient’s care).

## **Discussion of Procedures by Variant**

### **Variant 1: Adult. Suspected heart failure. No history of heart failure. Initial imaging.**

The goal of imaging in this variant is to establish or confirm the diagnosis of HF in patients with suspected HF. This could include the evaluation of pulmonary edema or measurement of LVEF.

#### **Arteriography Coronary**

There is limited evidence to support the use of catheter coronary angiography as initial imaging to establish or confirm a diagnosis of HF.

#### **CT Chest With IV Contrast**

There is limited evidence to support the use of chest CT as initial imaging for the evaluation of patients with suspected HF, although this test can help to exclude pulmonary vascular or structural lung disease that could potentially mimic symptoms of HF.

#### **CT Chest Without and With IV Contrast**

There is limited evidence to support the use of chest CT as initial imaging for the evaluation of patients with suspected HF, although this test can help to exclude pulmonary vascular or structural lung disease that could potentially mimic symptoms of HF.

#### **CT Chest Without IV Contrast**

There is limited evidence to support the use of chest CT as initial imaging for the evaluation of patients with suspected HF, although this test can help to exclude structural lung disease that could potentially mimic symptoms of HF.

#### **CT Coronary Calcium**

There is limited evidence to support the use of coronary calcium CT as initial imaging for the evaluation of patients with suspected HF.

#### **CT Heart Function and Morphology With IV Contrast**

Cardiac CT is not considered a first-line test for quantification of cardiac function and morphology, but it can provide quantification of functional parameters (eg, volumes, function) and may be useful in providing some information in this clinical scenario such as evaluation of LVEF in situations in which other tests provide suboptimal diagnostic information [19].

#### **CTA Coronary Arteries With IV Contrast**

There is limited evidence to support the use of cardiac CTA as initial imaging to establish or confirm a diagnosis of HF.

#### **FDG-PET/CT Heart**

There is limited evidence to support the use of fluorine-18-2-fluoro-2-deoxy-D-glucose (FDG)-PET/CT as an initial imaging modality for suspected HF.

#### **MRA Coronary Arteries Without and With IV Contrast**

There is limited evidence to support the use of coronary artery MR angiography (MRA) as an initial imaging modality for suspected HF.

#### **MRI Heart Function and Morphology Without and With IV Contrast**

Cardiac MRI is considered the reference standard for the evaluation of ventricular size and EF and often plays a role in evaluation of the underlying cause of HF and its related prognosis. Cardiac MRI function and morphology may be useful in providing some information in this clinical scenario such as evaluation of LVEF. However, it is not usually part of the initial assessment process in acute HF, particularly in those who are critically unwell, due to reduced monitoring capability, relatively long examination times, patient inability to tolerate lying flat for prolonged periods, and potentially reduced image quality due to heart rhythm disturbances and challenges with breath-holds [20].

#### **MRI Heart Function and Morphology Without IV Contrast**

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capability, relatively long examination times, patient inability to tolerate lying flat for prolonged periods, and potentially reduced image quality due to heart rhythm disturbances and challenges with breath-holds [20].

### **MRI Heart Function with Stress Without and With IV Contrast**

There is limited evidence to support the use of stress cardiac MRI as an initial imaging modality to establish or confirm a diagnosis of HF.

### **Nuclear Medicine Ventriculography**

Nuclear medicine ventriculography can be used to estimate LVEF and may be useful in providing information in this clinical scenario in some circumstances, but not as a first-line imaging test.

### **Radiography Chest**

For patients presenting to the emergency department (ED) with supportive clinical and laboratory evidence of HF, the accuracy in identifying congestive HF on chest radiograph can vary from 78% for first-year emergency medicine residents, 85% for emergency medicine attendees, and 95% for radiologists [21].

In a systemic review and meta-analysis of suspected acute HF in the ED setting, pulmonary edema on chest radiography had a pooled positive likelihood ratio (LR+) of 4.8 (95% confidence interval [CI], 3.6-6.4) for affirming the diagnosis of acute HF and a pooled sensitivity of 56.9% (95% CI, 54.7%-59.1%) and specificity of 89.2% (95% CI, 87.9%-90.4%) based on 15 studies pooling 4,393 patients [22]. In patients presenting to an emergency setting with signs and symptoms of HF, those with sudden onset symptoms are more likely to demonstrate evidence of congestion on chest radiograph than those without sudden onset [23].

A recent systematic review and meta-analysis examined patients presenting with dyspnea to any clinical setting, undergoing both chest radiography and lung US to assess for acute decompensated HF, and compared with a reference standard of expert adjudication or B-type natriuretic peptide (BNP)/echocardiography. Chest radiography was found to have a pooled sensitivity of 73% (95% CI, 70%-76%) and a specificity of 90% (95% CI, 75%-97%) for the diagnosis of decompensated HF [24].

In a large cross-sectional study of ambulatory primary care patients undergoing a standardized diagnostic evaluation for suspected HF, NT-proBNP was found to have the greatest supplementary test yield, whereas the diagnostic contribution of chest radiograph towards the diagnosis of HF in multivariable regression models was incremental [25].

### **Rb-82 PET/CT Heart**

There is limited evidence to support the use of Rb-82 PET/CT as an initial imaging modality for suspected HF.

### **SPECT or SPECT/CT MPI Rest and Stress**

There is limited evidence to support the use of rest and stress single-photon emission computed tomography (SPECT)/CT myocardial perfusion imaging (MPI) as an initial imaging modality for suspected HF.

### **US Echocardiography Transesophageal**

There is limited evidence to support the use of transesophageal echocardiography (TEE) as an initial imaging modality to establish or confirm a diagnosis of HF.

### **US Echocardiography Transthoracic Resting**

Multiple studies have demonstrated the value of echocardiographic measures of cardiac structure and function as indicators of subclinical HF, and multisociety consensus guidelines list transthoracic echocardiography (TTE) as the preferred initial test in patients with suspected HF [1,26].

In a systemic review and meta-analysis of suspected acute HF in the ED setting, reduced EF on bedside echocardiogram had a pooled LR+ of 4.1 (95% CI = 2.4-7.2) for affirming the diagnosis of acute HF and a pooled sensitivity of 80.6% (95% CI, 72.9%-86.9%) and a specificity 80.6% (95% CI, 74.3%-86.0%) based on 3 studies pooling 325 patients [22].

In addition to LVEF, a variety of echocardiographic measures can provide robust information about the systolic and diastolic LV function that precedes drops in LVEF to below the lower limits of normal. These measures include measures of LV longitudinal deformation (ie, speckle tracking derived global longitudinal strain [GLS], or surrogates for GLS such as mitral annulus S' velocity or mitral annular plane systolic excursion), as well as diastolic measures such as E/A ratio, e', and E wave deceleration time [27,28].

Another enhancement that can improve 2-D echocardiography performance is the use of an intravenous (IV) contrast agent. In a retrospective study of almost 10,000 echocardiograms performed for an HF indication, routine use of intravascular contrast on a patient's admission TTE was shown to reduce the rate of repeat echocardiography during the index admission for presumed HF [29]. However, guidelines support use of echocardiographic contrast agents only in cases in which 2 or more contiguous LV segments are poorly visualized [30].

TTE also demonstrates value in the initial assessment of patients with HF and preserved LV function. In a large study of 2,671 patients free of heart disease at enrollment and followed longitudinally, as many as 57% had a normal or borderline low LVEF at the time of their first hospitalization for HF [26]. In a large cross-sectional study of elderly primary care patients with shortness of breath on exertion, many had unrecognized HF, most with preserved LVEF [31].

In a 2012 observational study of 322 patients including symptomatic patients with HFpEF and a control group of asymptomatic patients with diastolic dysfunction, the patients with HFpEF had worse systolic and diastolic LV function as assessed by speckle-tracking echocardiography, higher LV filling pressures, and lower cardiac output [32].

A 2016 systematic review and meta-analysis of 24 studies reporting  $E/e'$  and invasively-measured LV filling pressures in HFpEF determined that  $E/e'$  had poor correlation with LV filling pressures and had moderate sensitivity for excluding elevated LV filling pressures (summary sensitivity: 36%-64%), with better specificity (summary specificity: 73%-89%), concluding that  $E/e'$  should not be used in isolation to identify HFpEF [33].

Consensus clinical criteria for the diagnosis of HFpEF were assessed prospectively in the Alberta HEART cohort, and many patients met echocardiographic criteria for HFpEF despite expert adjudication into a non-HFpEF group [34].

Patients with HFpEF have lower longitudinal and circumferential strains using speckle tracking TTE compared with patients with hypertensive heart disease patients [27] and lower myocardial systolic and diastolic LV function compared with patients with asymptomatic LV diastolic dysfunction [32].

### **US Echocardiography Transthoracic Stress**

There is limited evidence to support the use of stress echocardiography as the initial imaging to establish or confirm a diagnosis of HF. This procedure may be useful in providing some information on diastolic function.

#### **Variant 2: Adult. Known heart failure. Unknown etiology. Initial imaging.**

In patients with known HF but unknown underlying etiology/cause, the intent of this variant is to guide initial imaging with respect to investigation of the underlying disease process including both ischemic and nonischemic causes.

### **Arteriography Coronary**

Angiography coronary may be useful in providing some information on the etiology of HF in this clinical scenario, such as obstructive coronary artery disease (CAD), depending on the pretest probability of disease. Contemporary multisociety guidelines suggest that invasive coronary angiography (ICA) can be used to test for CAD especially in intermediate- to high-risk patients [1]. In a study of 107 patients presenting with new-onset HFpEF, a subgroup of about half were symptomatic but had risk factors predisposing to CAD, and ICA in this subgroup did not detect any cases of obstructive disease [35].

### **CT Chest With IV Contrast**

There is limited evidence to support the use of chest CT as initial imaging for the evaluation of patients with known HF of undetermined etiology. The role of chest CT, with or without IV contrast, is mostly limited to evaluating extracoronary and extracardiac findings, for example, to quantify pericardial thickening or calcification, or to assess for thoracic findings of multisystem cardiac disease processes (eg, lymphadenopathy in sarcoidosis).

### **CT Chest Without and With IV Contrast**

There is limited evidence to support the use of chest CT as initial imaging for the evaluation of patients with known HF of undetermined etiology. The role of chest CT, with or without IV contrast, is mostly limited to evaluating extracoronary and extracardiac findings, for example, to quantify pericardial thickening or calcification, or to assess for thoracic findings of multisystem cardiac disease processes (eg, lymphadenopathy in sarcoidosis).

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There is limited evidence to support the use of chest CT as initial imaging for the evaluation of patients with known HF of undetermined etiology. The role of chest CT, with or without IV contrast, is mostly limited to evaluating extracoronary and extracardiac findings, for example, to quantify pericardial thickening or calcification, or to assess for thoracic findings of multisystem cardiac disease processes (eg, lymphadenopathy in sarcoidosis).

### **CT Coronary Calcium**

Several studies [36-39] have shown that a negative coronary calcium score CT has a high sensitivity and negative predictive value for excluding ischemic cardiomyopathy with modest specificity. However, coronary calcium score CT does not detect noncalcified or low-attenuation plaque or provide detail about the anatomical degree of coronary artery stenosis. Therefore, there is limited evidence to support the use of CT coronary calcium as initial imaging for the evaluation of patients with known HF of undetermined etiology.

### **CT Heart Function and Morphology With IV Contrast**

There is limited evidence to support the use of functional cardiac CT as initial imaging for the evaluation of patients with known HF of undetermined etiology. Cardiac CT is not considered a first-line test for quantification of cardiac function and morphology, but it can provide quantification of functional parameters (eg, volumes, function) [19].

More recent CT techniques for myocardial blood flow and tissue characterization include CT perfusion for evaluation of ischemia and late iodine enhancement and CT extracellular volume fraction for the evaluation of fibrosis and infarct [40]. However, there is limited evidence for these techniques in patients with HF, and cardiac MRI is more commonly used as a reference standard technique for tissue characterization [41].

### **CTA Coronary Arteries With IV Contrast**

CAD is a contributing factor in approximately half of all HF cases, and coronary CTA is indicated for the exclusion of obstructive CAD in low- to intermediate-risk patients as well as assessing potential coronary artery anomalies [19].

In a prospective study of patients with newly diagnosed undifferentiated HF undergoing CTA coronary arteries, coronary CTA showed high sensitivity at excluding obstructive CAD if patients had a nonzero coronary calcium score [39].

In a population of 100 patients with HFrEF undergoing CTA coronary arteries to exclude coexistent CAD, coronary CTA excluded an ischemic etiology in 73% of cases, as a “gatekeeper” for ICA [38].

### **FDG-PET/CT Heart**

Cardiac FDG-PET/CT may be useful to establish the etiology of HF in some circumstances, such as suspected cardiac sarcoidosis or for evaluation of myocardial viability. FDG-PET/CT is useful in identification of myocardial inflammation with appropriate dietary preparation to suppress physiologic myocardial glucose metabolism if the suspected underlying etiology is sarcoidosis or other inflammatory cardiomyopathy [42,43]. FDG-PET/CT can also be used for evaluation of myocardial viability, typically performed and interpreted in conjunction with a perfusion study [44].

### **MRA Coronary Arteries Without and With IV Contrast**

There is limited evidence to support the use of MRA of the coronary arteries as initial imaging for the evaluation of patients with known HF of undetermined etiology.

### **MRI Heart Function and Morphology Without and With IV Contrast**

Cardiac MRI can provide diagnostic and etiologic information in HF [45].

In a 2014 study of patients referred to a tertiary center for workup of undifferentiated HF with both echocardiography and MRI, MRI confirmed or led to a new diagnosis in 20% of cases and affected management decisions in approximately half of patients [46].

For the differentiation between ischemic and nonischemic etiologies of new-onset nonacute HFrEF using MRI, the presence of myocardial late gadolinium enhancement (LGE) alone has good discriminative power (c-statistic 0.85; 95% CI, 0.76-0.94) for the detection of an ischemic cause; the presence of an ischemic pattern on both LGE and cine imaging has a specificity of 87%, although the absence of both has a specificity of 94% for a nonischemic cause [47].

In a study of 100 patients with new-onset HFrEF without prior clinical evidence of CAD, ischemic-pattern LGE by cardiac MRI had a sensitivity of 86% (95% CI, 80-91) and a specificity of 92% (95% CI, 87-96) for the diagnosis of significant CAD, defined as a stenosis of >70% in any coronary artery at time of ICA [48].

In patients presenting with new-onset HFrEF of uncertain etiology, LGE MRI has a diagnostic sensitivity of 67% to 100% and a specificity of 96% to 100% for detecting ischemic cardiomyopathy, comparable to the detection of obstructive disease at ICA, suggesting that MRI with LGE is a safe, effective, and potentially economical gatekeeper to coronary angiography in patients presenting with HFrEF [49]. However, given the overall moderate sensitivity, an ischemic etiology cannot be excluded when LGE is absent [50]. In a 2022 retrospective study of patients referred for cardiac MRI due to HF of unknown etiology in a tertiary center, cardiac MRI was shown to lead to a new etiological diagnosis in 39% of the 243 patients [51].

In a 2018 study of 154 patients with newly diagnosed HfpEF, cardiac MRI diagnosed new pathology (namely, CAD including previous myocardial infarction, hypertrophic cardiomyopathy, and constrictive pericarditis) in 27% of patients, and these patients were at risk of increased morbidity and mortality [52].

In a 2020 prospective study randomizing 500 patients with nonischemic HF to either echocardiography plus routine cardiac MRI or echocardiography plus selective cardiac MRI according to the clinical presentation, a selective approach to MRI was found to be just as effective as routine MRI for determining a specific HF etiology [53].

A retrospective study of 83 patients undergoing cardiac MRI with LGE for the evaluation of new-onset HfrEF showed that myocardial LGE alone has good discriminative power (c-statistic 0.85; 95% CI, 76%-94%) for the detection of an ischemic cause; the presence of an ischemic pattern on both LGE and cine imaging has specificity of 87%, although the absence of both has specificity of 94% for a nonischemic cause [47]. The addition of resting first-pass perfusion imaging did not improve diagnosis performance.

#### **MRI Heart Function and Morphology Without IV Contrast**

Cardiac MRI without IV contrast can be used in cases in which precise information about biventricular function and volumes is required. Non-LGE-based tissue characterization methods, for example, native T1 and T2 mapping, can provide important quantitative information about the myocardium including fibrosis and edema [45].

#### **MRI Heart Function with Stress Without and With IV Contrast**

Stress perfusion cardiac MRI, most often performed with a pharmaceutical vasodilator, can be used to identify and assess severity of segments of myocardial ischemia and infarction.

In a small prospective study of patients with HFpEF, exercise stress MRI showed promise for the diagnosis of diastolic dysfunction compared with the reference standard of right heart catheterization using exercise stress [54].

#### **Nuclear Medicine Ventriculography**

Resting nuclear medicine ventriculography can be used to estimate LVEF and ventricular volumes, however, there is limited evidence to support the use of nuclear medicine ventriculography for determining HF etiology.

#### **Radiography Chest**

Although radiography may play a role in diagnosing HF, there is limited evidence to support the use of chest radiography for determining a specific HF etiology.

#### **Rb-82 PET/CT Heart**

Rb-82 PET/CT may be useful to establish the etiology of HF in some circumstances including evaluation of suspected myocardial ischemia [55].

#### **SPECT or SPECT/CT MPI Rest and Stress**

Radionuclide imaging has shown usefulness in distinguishing ischemic from nonischemic HF etiologies and identify potential candidates for coronary revascularization [56].

Studies of patients with HFrEF and without known CAD undergoing both SPECT and coronary angiography showed that SPECT was sensitive for the detection of ischemic cardiomyopathy and CAD in this patient group [57,58].

In a prospective multinational trial of 201 patients hospitalized with a first HF episode undergoing SPECT Tc-99m sestamibi MPI, SPECT demonstrated excellent negative predictive value (96%) for significant CAD [59].

In a 2019 study of 503 patients from tertiary centers with elevated cardiac biomarkers, MPI was shown to be able to risk stratify patients with recently elevated cardiac biomarkers, and the severity of the perfusion defect correlated with increased risk of mortality [60].

A 2021 study comparing echocardiography and MPI showed significant discrepancies between calculated LVEFs [61]. Additionally, MPI suffers from false-positive results in some nonischemic cardiomyopathies, as well as false-negative results in global balanced ischemia [62]. In dyspneic patients with HFrEF without chest pain, the nonglobal resting LV dysfunction and high-summed stress MPI-deficiency score on gated rest and stress SPECT served as independent predictors of an ischemic etiology, and despite low sensitivity, specificity was modest [63].

### **US Echocardiography Transesophageal**

TEE can provide additional information over TTE and may be useful to establish the etiology of HF for specific indications, including evaluation of valvular disease, but is typically not performed as the initial imaging modality.

### **US Echocardiography Transthoracic Resting**

TTE is a diagnostic tool used for assessing LV structure and function.

A pilot study of 3-D speckle tracking echocardiography in 40 patients showed promise in noninvasively discriminating between ischemic and nonischemic HF etiology [64].

### **US Echocardiography Transthoracic Stress**

Stress TTE can be useful in identifying inducible wall motion abnormalities in the assessment of ischemic heart disease [65]. The assessment of longitudinal systolic and diastolic LV and right ventricle function during a submaximal exercise stress TTE can confirm LV dysfunction related to HFpEF and might be used as a diagnostic test for difficult clinical situations [66].

When combined with exercise, peak mitral annular systolic velocity with tissue doppler imaging is a significant independent predictor of HFpEF and may increase the diagnostic value of models using the variables recommended by the European Society of Cardiology guidelines [67].

A pilot study to assess the usefulness of stress echocardiography for the assessment of diastolic dysfunction in patients with suspected HFpEF showed good discrimination between a group of patients with suspected HFpEF and healthy and hypertensive control groups based on a stress echocardiogram [68].

### **Variant 3: Adult. Known heart failure. Follow-up imaging.**

Follow-up imaging performed in the course of ongoing care for patients with established HF to assess for change in left ventricular function, response to therapy, and prognostication. Investigation of new symptoms is not included in this variant and could be guided by other ACR Appropriateness Criteria.

### **Arteriography Coronary**

There is limited evidence to support the use of catheter angiography as follow-up imaging for the evaluation of patients with known HF.

### **CT Chest With IV Contrast**

There is limited evidence to support the use of chest CT as follow-up imaging for the evaluation of patients with known HF.

### **CT Chest Without and With IV Contrast**

There is limited evidence to support the use of chest CT as follow-up imaging for the evaluation of patients with known HF.

### **CT Chest Without IV Contrast**

There is limited evidence to support the use of chest CT as follow-up imaging for the evaluation of patients with known HF.

### **CT Coronary Calcium**

There is limited evidence to support the use of coronary calcium score CT as follow-up imaging for the evaluation of patients with known HF.

### **CT Heart Function and Morphology With IV Contrast**

Cardiac CT can be used to evaluate and follow ventricular volumes and function in situations in which other tests provide suboptimal diagnostic information.

### **CTA Coronary Arteries With IV Contrast**

There is limited evidence to support the use of coronary CTA as follow-up imaging for the evaluation of patients with known HF in the absence of new ischemic-type signs or symptoms.

### **FDG-PET/CT Heart**

Cardiac FDG-PET/CT may be useful for follow-up imaging of known HF related to sarcoidosis or other causes of myocardial inflammation or for re-evaluation of myocardial viability.

In a retrospective single-center cohort study of 254 patients with ischemic HF undergoing stress and rest MPI and viability testing, quantitative PET metrics of myocardial blood demonstrated modest prognostic value [69].

In the Positron Emission Tomography and Recovery Following Revascularization (PARR-2) study of almost 400 patients randomized to either standard care or an FDG-PET–assisted strategy for determining revascularization in patients with suspected ischemic cardiomyopathy, there were fewer adverse cardiac events when PET-strategy revascularization recommendations were followed [70,71].

### **MRA Coronary Arteries Without and With IV Contrast**

There is limited evidence to support the use of coronary MRA as follow-up imaging for the evaluation of patients with known HF, ischemia already excluded, in the absence of new ischemic-type signs or symptoms.

### **MRI Heart Function and Morphology Without and With IV Contrast**

A 2021 meta-analysis showed that cardiac MRI is useful for the prognostication of patients with HFpEF and that myocardial LGE, elevated T1 mapping times, ischemia, and right ventricular systolic dysfunction are associated with worse prognosis [72]. A 2017 meta-analysis similarly showed that LGE is strongly and independently associated with ventricular arrhythmias and sudden cardiac death [73].

In a multicenter study of 1,561 patients with known or suspected heart disease undergoing routine cardiac MRI for a wide range of indications, both LVEF and LGE are independent predictors of all-cause mortality [74].

Contemporary studies have demonstrated the role of LGE in the risk stratification of patients with dilated cardiomyopathy, including a multicenter study of 1,672 patients with dilated cardiomyopathy that showed strong prognostic value of LGE for the end points (including all-cause mortality, heart transplantation, and left ventricular assist device implant) [75].

### **MRI Heart Function and Morphology Without IV Contrast**

Cardiac MRI function and morphology without IV contrast is useful to quantify LVEF and follow changes over time.

### **MRI Heart Function with Stress Without and With IV Contrast**

In a multicenter study of 582 patients with reduced LVEF and suspected myocardial ischemia, the presence of ischemia, LGE, or both was associated with higher outcome rates (including death and nonfatal myocardial infarction) [76]. Even in patients without known CAD, a study of 1,203 patients with HFpEF found that inducible myocardial ischemia on stress cardiac MRI and LGE have long-term prognostic to predict major adverse cardiac events [77].

In a study of 200 patients with reduced LVEF undergoing dobutamine stress cardiac MRI, worsening left ventricular wall motion score index with stress was prognostically significant and associated with increased future cardiac events [78].

### **Nuclear Medicine Ventriculography**

Resting nuclear medicine ventriculography can be used to evaluate LVEF and ventricular volumes and may be useful to follow-up patients with established HF in some circumstances.

### **Radiography Chest**

Chest radiography may have value for in the acute setting for following pulmonary edema or for detecting HF exacerbations characterized by pulmonary edema, but chest radiographic findings are insensitive for monitoring HF and detecting changes in LVEF [79].

### **Rb-82 PET/CT Heart**

PET/CT using the perfusion tracer Rb-82 can be used to assess myocardial perfusion and metabolism and can help inform myocardial viability [80].

### **SPECT or SPECT/CT MPI Rest and Stress**

SPECT or SPECT/CT MPI may be useful for follow-up of myocardial ischemia and response to medical management, as well as for assessment of myocardial viability following infarction. SPECT using Tc-99m–labeled compounds may be indicated for viability imaging with high sensitivity although modest specificity [80].

### **US Echocardiography Transesophageal**

There is limited evidence to support the use of TEE for routine follow-up of patients with known HF. TEE can provide additional information over TTE evaluation for specific indications, in particular valvular structure and function, but is typically not performed for routine follow-up imaging.

### **US Echocardiography Transthoracic Resting**

In patients with a change in clinical status or patients who have received guideline-directed medical treatment and are being considered for a cardiac implantable electronic device or invasive procedure, there are data to support the use of TTE. TTE can be used to identify high-risk parameters associated with adverse outcomes that can guide therapy and follow-up management of patients with HF [81].

A 2005 multicenter trial of 336 patients with advanced HF and severe LV dysfunction showed the LV end-diastolic volume index, mitral deceleration time, and vena contracta width of mitral regurgitation predicted adverse events including death and HF hospitalization [82].

In a study of 468 patients admitted with HF undergoing echocardiography at the time of their first HF admission, TTE-derived GLS was associated with 30-day HF readmission independent of other clinical or echocardiographic parameters [83]. Similarly, in a cohort of 2,440 patients with HF, a lower echocardiography-derived GLS was associated with a worse prognosis including increased cardiac mortality [84]. A retrospective review of the TOPCAT study cohort showed that after multivariate adjustment, GLS was also a significant predictor of sudden cardiac death and cardiac arrest [85].

In a 2020 study of 436 patients with HFrEF randomized into clinical follow-up either with or without routine echocardiography every 6 months, there were similar adverse event rates between the 2 groups [86].

Echocardiography can also demonstrate beneficial LV remodeling that occurs after initiation of guideline-directed medical therapy [87].

Diastolic dysfunction grading as determined by contemporary guidelines has prognostic significance in HF, with the primary end points of readmission for HF and cardiovascular death rising with worsening diastolic dysfunction grade [88].

Within individual HFpEF cases, TTE with Doppler indexes of LV filling pressures (ie, early diastolic mitral annular velocity and E/Vp) do not reliably track directly measured filling pressures, limiting the use of these techniques in the titration of medical therapy for HFpEF [89].

In addition to estimating EF, it has been shown that the LV longitudinal function (as assessed by speckle-tracking GLS, S' velocity of the mitral annulus, and/or mitral annular plane systolic excursion) as well as LV diastolic dysfunction and filling pressures (estimated through use of E/A ratio, E velocity deceleration time, and E/e' ratio) can precede drops in EF [27].

### **US Echocardiography Transthoracic Stress**

Dobutamine stress echocardiography (DSE) has a good sensitivity and specificity for predicting LV function improvement after coronary revascularization [80].

In a study of 528 patients with HF and CAD, myocardial ischemia detected by DSE (as determined by new or worsening wall motion abnormalities or biphasic response) was associated with increased risk of cardiac death [90].

In another study of 235 patients with ischemic cardiomyopathy undergoing low-dose DSE, stress-induced wall motion abnormalities were again shown to be an independent predictor of cardiac death and similar to high-dose DSE [91].

In a study of 731 patients with 2 or more akinetic LV segments at rest undergoing high-dose DSE, akinesia becoming dyskinesia at peak stress was also associated with increased risk of cardiac events and death [92].

In a 2016 observational study of 60 patients, an elevated tricuspid peak velocity during exercise was associated with HF-related hospitalization and/or death, and this measure may have prognostic value in HF [93].

A 2019 prospective study of stress echocardiography in a cohort of patients with HF showed an association between adverse outcomes (including HF hospitalizations and death) with pulmonary congestion (as determined by lung US) and low cardiac index at peak exercise [94].

### Summary of Highlights

This is a summary of the key recommendations from the variant tables. Refer to the complete narrative document for more information.

- **Variation 1:** Chest radiography and transthoracic resting echocardiography is usually appropriate for initial imaging assessment of an adult with suspected HF, but without history of HF. Chest radiography can provide assessment of pulmonary edema. Transthoracic resting echocardiography helps in quantification of LVEF.
- **Variation 2:** TEE (resting or stress), MRI heart function and morphology without or without and with IV contrast, MRI heart function with stress without and with IV contrast, CTA coronary arteries with IV contrast, and SPECT or SPECT/CT MPI (resting and stress) is usually appropriate for initial imaging assessment of adults with known HF to establish the etiology. The initial choice of the imaging test should be guided by the clinical scenario and the most likely underlying disease process—including both ischemic and nonischemic causes. Transthoracic resting echocardiography evaluates LV structure and function. MRI provides structural and functional information as well as tissue characterization. Coronary CTA provides anatomical evaluation of CAD. Stress TEE, SPECT or SPECT/CT MPI, and MRI provide evaluation of myocardial ischemia.
- **Variation 3:** TEE (resting or stress), MRI heart function and morphology without or without and with IV contrast, or MRI heart function with stress without and with IV contrast is usually appropriate for initial imaging assessment of ongoing follow-up of adults with known HF without new symptoms. These tests help in assessment of longitudinal changes in left ventricular function, response to therapy, and prognostication.

### Supporting Documents

The evidence table, literature search, and appendix for this topic are available at <https://acsearch.acr.org/list>. The appendix includes the strength of evidence assessment and the final rating round tabulations for each recommendation.

For additional information on the Appropriateness Criteria methodology and other supporting documents go to [www.acr.org/ac](http://www.acr.org/ac).

### Gender Equality and Inclusivity Clause

The ACR acknowledges the limitations in applying inclusive language when citing research studies that pre-dates the use of the current understanding of language inclusive of diversity in sex, intersex, gender and gender-diverse people. The data variables regarding sex and gender used in the cited literature will not be changed. However, this guideline will use the terminology and definitions as proposed by the National Institutes of Health [95].

## Appropriateness Category Names and Definitions

Appropriateness Category Name	Appropriateness Rating	Appropriateness Category Definition
Usually Appropriate	7, 8, or 9	The imaging procedure or treatment is indicated in the specified clinical scenarios at a favorable risk-benefit ratio for patients.
May Be Appropriate	4, 5, or 6	The imaging procedure or treatment may be indicated in the specified clinical scenarios as an alternative to imaging procedures or treatments with a more favorable risk-benefit ratio, or the risk-benefit ratio for patients is equivocal.
May Be Appropriate (Disagreement)	5	The individual ratings are too dispersed from the panel median. The different label provides transparency regarding the panel's recommendation. "May be appropriate" is the rating category and a rating of 5 is assigned.
Usually Not Appropriate	1, 2, or 3	The imaging procedure or treatment is unlikely to be indicated in the specified clinical scenarios, or the risk-benefit ratio for patients is likely to be unfavorable.

## Relative Radiation Level Information

Potential adverse health effects associated with radiation exposure are an important factor to consider when selecting the appropriate imaging procedure. Because there is a wide range of radiation exposures associated with different diagnostic procedures, a relative radiation level (RRL) indication has been included for each imaging examination. The RRLs are based on effective dose, which is a radiation dose quantity that is used to estimate population total radiation risk associated with an imaging procedure. Patients in the pediatric age group are at inherently higher risk from exposure, because of both organ sensitivity and longer life expectancy (relevant to the long latency that appears to accompany radiation exposure). For these reasons, the RRL dose estimate ranges for pediatric examinations are lower as compared with those specified for adults (see Table below). Additional information regarding radiation dose assessment for imaging examinations can be found in the ACR Appropriateness Criteria® [Radiation Dose Assessment Introduction](#) document [96].

Relative Radiation Level Designations		
Relative Radiation Level*	Adult Effective Dose Estimate Range	Pediatric Effective Dose Estimate Range
○	0 mSv	0 mSv
⊕	<0.1 mSv	<0.03 mSv
⊕⊕	0.1-1 mSv	0.03-0.3 mSv
⊕⊕⊕	1-10 mSv	0.3-3 mSv
⊕⊕⊕⊕	10-30 mSv	3-10 mSv
⊕⊕⊕⊕⊕	30-100 mSv	10-30 mSv

\*RRL assignments for some of the examinations cannot be made, because the actual patient doses in these procedures vary as a function of a number of factors (eg, region of the body exposed to ionizing radiation, the imaging guidance that is used). The RRLs for these examinations are designated as "Varies."

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The ACR Committee on Appropriateness Criteria and its expert panels have developed criteria for determining appropriate imaging examinations for diagnosis and treatment of specified medical condition(s). These criteria are intended to guide radiologists, radiation oncologists and referring physicians in making decisions regarding radiologic imaging and treatment. Generally, the complexity and severity of a patient's clinical condition should dictate the selection of appropriate imaging procedures or treatments. Only those examinations generally used for evaluation of the patient's condition are ranked. Other imaging studies necessary to evaluate other co-existent diseases or other medical consequences of this condition are not considered in this document. The availability of equipment or personnel may influence the selection of appropriate imaging procedures or treatments. Imaging techniques classified as investigational by the FDA have not been considered in developing these criteria; however, study of new equipment and applications should be encouraged. The ultimate decision regarding the appropriateness of any specific radiologic examination or treatment must be made by the referring physician and radiologist in light of all the circumstances presented in an individual examination.