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	O
Radiography chest	Usually Appropriate	☢
US echocardiography transthoracic stress	May Be Appropriate	O
MRI heart function and morphology without and with IV contrast	May Be Appropriate	O
MRI heart function and morphology without IV contrast	May Be Appropriate	O
Nuclear medicine ventriculography	May Be Appropriate	☢☢☢
CT heart function and morphology with IV contrast	May Be Appropriate	☢☢☢☢
US echocardiography transesophageal	Usually Not Appropriate	O
Arteriography coronary	Usually Not Appropriate	☢☢☢
MRA coronary arteries without and with IV contrast	Usually Not Appropriate	O
MRI heart function with stress without and with IV contrast	Usually Not Appropriate	O
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 MPI rest and stress	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	O
US echocardiography transthoracic stress	Usually Appropriate	O
MRI heart function and morphology without and with IV contrast	Usually Appropriate	O
MRI heart function and morphology without IV contrast	Usually Appropriate	O
MRI heart function with stress without and with IV contrast	Usually Appropriate	O
CTA coronary arteries with IV contrast	Usually Appropriate	☢☢☢
SPECT or SPECT/CT MPI rest and stress	Usually Appropriate	☢☢☢☢
US echocardiography transesophageal	May Be Appropriate	O
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 MPI rest and stress	May Be Appropriate	☢☢☢☢
Radiography chest	Usually Not Appropriate	☢
MRA coronary arteries without and with IV contrast	Usually Not Appropriate	O
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	O
US echocardiography transthoracic stress	Usually Appropriate	O
MRI heart function and morphology without and with IV contrast	Usually Appropriate	O
MRI heart function and morphology without IV contrast	Usually Appropriate	O
MRI heart function with stress without and with IV contrast	Usually Appropriate	O
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 MPI rest and stress	May Be Appropriate	☢☢☢☢
SPECT or SPECT/CT MPI rest and stress	May Be Appropriate	☢☢☢☢
US echocardiography transesophageal	Usually Not Appropriate	O
Arteriography coronary	Usually Not Appropriate	☢☢☢
MRA coronary arteries without and with IV contrast	Usually Not Appropriate	O
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	☢☢☢

Panel Members

Kate Hanneman, MD, MPH[a], James Roberts, MD, MSc[b], Prabhakar Shantha Rajiah, MD[c], Shawn Ahmad, MD, MBA[d], Ryan Avery, MD[e], William M. Brown, MD[f], Ahmed H. El-Sherief, MD[g], Joe Y. Hsu, MD[h], Veronica Lenge de Rosen, MD[i], Fay Lin, MD[j], Gurusher Panjrath, MBBS[k], Rahul D. Renapurkar, MD, MBBS[l], James A. White, MD[m], Michael A. Bolen, MD[n]

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® 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 HF with preserved EF (HFpEF; LVEF ≥50%), mildly reduced EF (HFmrEF; LVEF 41%-49%), reduced EF (HFrEF; LVEF ≤40%), and improved EF (HFimpEF; LVEF initially ≤40% with ≥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.

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

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

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

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

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

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

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

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

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

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

Variant 1: Adult. Suspected heart failure. No history of heart failure. Initial imaging. K. MRI heart function and morphology without 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. 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].

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

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

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

Variant 1: Adult. Suspected heart failure. No history of heart failure. Initial imaging.
O. Rb-82 PET/CT MPI rest and stress

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

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

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

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

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

Variant 2: Adult. Known heart failure. Unknown etiology. Initial imaging.
A. 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 HFrEF, 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].

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

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

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

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

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

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

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

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

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

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

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

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

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

Variant 2: Adult. Known heart failure. Unknown etiology. Initial imaging.
O. Rb-82 PET/CT MPI rest and stress

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Variant 3: Adult. Known heart failure. Follow-up imaging.
O. Rb-82 PET/CT MPI rest and stress

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

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

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

Variant 3: Adult. Known heart failure. Follow-up imaging.
R. 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 morality [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].

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

- **Variant 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.
- **Variant 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.
- **Variant 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, please go to the ACR website at https://www.acr.org/Clinical-Resources/Clinical-Tools-and-Reference/Appropriateness-Criteria.

Gender Equality and Inclusivity Clause

The ACR acknowledges the limitations in applying inclusive language when citing research studies that predates 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.

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.

Relative Radiation Level Designations

Relative Radiation Level*	Adult Effective Dose Estimate Range	Pediatric Effective Dose Estimate Range
O	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 (e.g., region of the body exposed to ionizing radiation, the imaging guidance that is used). The RRLs for these examinations are designated as "Varies."

References

1. Heidenreich PA, Bozkurt B, Aguilar D, et al. 2022 AHA/ACC/HFSA Guideline for the Management of Heart Failure: A Report of the American College of Cardiology/American Heart Association Joint Committee on Clinical Practice Guidelines. Circulation 2022;145:e895-e1032.
2. Correction to: Heart Disease and Stroke Statistics-2023 Update: A Report From the American Heart Association. Circulation 2023;147:e622.
3. Heidenreich PA, Fonarow GC, Opsha Y, et al. Economic Issues in Heart Failure in the United States. J Card Fail 2022;28:453-66.
4. Lloyd-Jones DM, Larson MG, Leip EP, et al. Lifetime risk for developing congestive heart failure: the Framingham Heart Study. Circulation. 2002;106(24):3068-3072.
5. Merlo M, Pivetta A, Pinamonti B, et al. Long-term prognostic impact of therapeutic strategies in patients with idiopathic dilated cardiomyopathy: changing mortality over the last 30 years. Eur J Heart Fail. 2014;16(3):317-324.
6. Roger VL, Weston SA, Redfield MM, et al. Trends in heart failure incidence and survival in a community-based population. JAMA. 2004;292(3):344-350.
7. Shah KS, Xu H, Matsouaka RA, et al. Heart Failure With Preserved, Borderline, and Reduced Ejection Fraction: 5-Year Outcomes. J Am Coll Cardiol 2017;70:2476-86.
8. Roger VL. Epidemiology of Heart Failure: A Contemporary Perspective. Circ Res 2021;128:1421-34.
9. Hancock HC, Close H, Mason JM, et al. High prevalence of undetected heart failure in long-term care residents: findings from the Heart Failure in Care Homes (HFinCH) study. Eur J Heart Fail. 2013;15(2):158-165.
10. Yancy CW, Jessup M, Bozkurt B, et al. 2013 ACCF/AHA guideline for the management of heart failure: a report of the American College of Cardiology Foundation/American Heart Association Task Force on Practice Guidelines. J Am Coll Cardiol 2013;62:e147-239.
11. Bolen MA, Bin Saeedan MN, Rajiah P, et al. ACR Appropriateness Criteria® Dyspnea-Suspected Cardiac Origin (Ischemia Already Excluded): 2021 Update. J Am Coll Radiol 2022;19:S37-S52.
12. Rajiah P, Kirsch J, Bolen MA, et al. ACR Appropriateness Criteria® Nonischemic Myocardial Disease with Clinical Manifestations (Ischemic Cardiomyopathy Already Excluded). J Am Coll Radiol 2021;18:S83-S105.
13. Bozkurt B, Coats AJS, Tsutsui H, et al. Universal definition and classification of heart failure: a report of the Heart Failure Society of America, Heart Failure Association of the European Society of Cardiology, Japanese Heart Failure Society and Writing Committee of the Universal Definition of Heart Failure: Endorsed by the Canadian Heart Failure Society, Heart Failure Association of India, Cardiac Society of Australia and New Zealand, and Chinese

Heart Failure Association. Eur J Heart Fail 2021;23:352-80.

14. Richardson P, McKenna W, Bristow M, et al. Report of the 1995 World Health Organization/International Society and Federation of Cardiology Task Force on the Definition and Classification of cardiomyopathies. Circulation. 1996;93(5):841-842.

15. American College of Radiology. ACR–NASCI–SIR–SPR Practice Parameter for the Performance and Interpretation of Body Computed Tomography Angiography (CTA). Available at: https://gravitas.acr.org/PPTS/GetDocumentView?docId=164+&releaseId=2.

16. Akoglu H, Celik OF, Celik A, Ergelen R, Onur O, Denizbasi A. Diagnostic accuracy of the Extended Focused Abdominal Sonography for Trauma (E-FAST) performed by emergency physicians compared to CT. American Journal of Emergency Medicine. 36(6):1014-1017, 2018 Jun.Am J Emerg Med. 36(6):1014-1017, 2018 Jun.

17. Becker A, Lin G, McKenney MG, Marttos A, Schulman CI. Is the FAST exam reliable in severely injured patients?. Injury. 41(5):479-83, 2010 May.

18. Laselle BT, Byyny RL, Haukoos JS, et al. False-negative FAST examination: associations with injury characteristics and patient outcomes. Ann Emerg Med. 60(3):326-34.e3, 2012 Sep.

19. Aziz W, Claridge S, Ntalas I, et al. Emerging role of cardiac computed tomography in heart failure. [Review]. ESC Heart Fail. 6(5):909-920, 2019 10.

20. Peterzan MA, Rider OJ, Anderson LJ. The Role of Cardiovascular Magnetic Resonance Imaging in Heart Failure. Card Fail Rev 2016;2:115-22.

21. Kennedy S, Simon B, Alter HJ, Cheung P. Ability of physicians to diagnose congestive heart failure based on chest X-ray. J Emerg Med 2011;40:47-52.

22. Martindale JL, Wakai A, Collins SP, et al. Diagnosing Acute Heart Failure in the Emergency Department: A Systematic Review and Meta-analysis. [Review]. Acad Emerg Med. 23(3):223-42, 2016 Mar.

23. Collins SP, Lindsell CJ, Yealy DM, et al. A comparison of criterion standard methods to diagnose acute heart failure. Congest Heart Fail. 2012;18(5):262-271.

24. Maw AM, Hassanin A, Ho PM, et al. Diagnostic Accuracy of Point-of-Care Lung Ultrasonography and Chest Radiography in Adults With Symptoms Suggestive of Acute Decompensated Heart Failure: A Systematic Review and Meta-analysis. JAMA netw. open. 2(3):e190703, 2019 03 01.

25. Kelder JC, Cramer MJ, van Wijngaarden J, et al. The diagnostic value of physical examination and additional testing in primary care patients with suspected heart failure. Circulation. 2011;124(25):2865-2873.

26. Aurigemma GP, Gottdiener JS, Shemanski L, Gardin J, Kitzman D. Predictive value of systolic and diastolic function for incident congestive heart failure in the elderly: the cardiovascular health study. J Am Coll Cardiol. 2001;37(4):1042-1048.

27. Esposito R, Sorrentino R, Galderisi M. The use of transthoracic echocardiography for the assessment of left ventricular systolic and diastolic function in patients with suspected or ascertained chronic heart failure. Expert Rev Cardiovasc Ther. 2016;14(1):37-50.

28. Nagueh SF, Smiseth OA, Appleton CP, et al. Recommendations for the Evaluation of Left Ventricular Diastolic Function by Echocardiography: An Update from the American Society of Echocardiography and the European Association of Cardiovascular Imaging. J Am Soc

Echocardiogr. 29(4):277-314, 2016 Apr.

29. Lee KC, Liu S, Callahan P, et al. Routine Use of Contrast on Admission Transthoracic Echocardiography for Heart Failure Reduces the Rate of Repeat Echocardiography during Index Admission. J Am Soc Echocardiogr. 34(12):1253-1261.e4, 2021 12.

30. Mulvagh SL, Rakowski H, Vannan MA, et al. American Society of Echocardiography Consensus Statement on the Clinical Applications of Ultrasonic Contrast Agents in Echocardiography. J Am Soc Echocardiogr 2008;21:1179-201; quiz 281.

31. van Riet EE, Hoes AW, Limburg A, Landman MA, van der Hoeven H, Rutten FH. Prevalence of unrecognized heart failure in older persons with shortness of breath on exertion. Eur J Heart Fail. 2014;16(7):772-777.

32. Morris DA, Boldt LH, Eichstadt H, Ozcelik C, Haverkamp W. Myocardial systolic and diastolic performance derived by 2-dimensional speckle tracking echocardiography in heart failure with normal left ventricular ejection fraction. Circ Heart Fail. 2012;5(5):610-620.

33. Sharifov OF, Schiros CG, Aban I, Denney TS, Gupta H. Diagnostic Accuracy of Tissue Doppler Index E/e' for Evaluating Left Ventricular Filling Pressure and Diastolic Dysfunction/Heart Failure With Preserved Ejection Fraction: A Systematic Review and Meta-Analysis. [Review]. J Am Heart Assoc. 5(1), 2016 Jan 25.

34. Ezekowitz JA, McAlister FA, Howlett J, et al. A prospective evaluation of the established criteria for heart failure with preserved ejection fraction using the Alberta HEART cohort. ESC Heart Fail. 2018;5(1):19-26.

35. Melo RM, Melo EF, Biselli B, Souza GE, Bocchi EA. Clinical usefulness of coronary angiography in patients with left ventricular dysfunction. Arq Bras Cardiol. 2012;98(5):437-441.

36. Abunassar JG, Yam Y, Chen L, D'Mello N, Chow BJ. Usefulness of the Agatston score = 0 to exclude ischemic cardiomyopathy in patients with heart failure. Am J Cardiol. 2011;107(3):428-432.

37. Premaratne M, Shamsaei M, Chow JD, et al. Using coronary calcification to exclude an ischemic etiology for cardiomyopathy: A validation study and systematic review. Int J Cardiol. 2017;230:518-522.

38. Sousa PA, Bettencourt N, Dias Ferreira N, et al. Role of cardiac multidetector computed tomography in the exclusion of ischemic etiology in heart failure patients. Rev Port Cardiol. 2014;33(10):629-636.

39. ten Kate GJ, Caliskan K, Dedic A, et al. Computed tomography coronary imaging as a gatekeeper for invasive coronary angiography in patients with newly diagnosed heart failure of unknown aetiology. Eur J Heart Fail. 2013;15(9):1028-1034.

40. Assen MV, Vonder M, Pelgrim GJ, Von Knebel Doeberitz PL, Vliegenthart R. Computed tomography for myocardial characterization in ischemic heart disease: a state-of-the-art review. Eur Radiol Exp 2020;4:36.

41. Pattanayak P, Bleumke DA. Tissue characterization of the myocardium: state of the art characterization by magnetic resonance and computed tomography imaging. Radiol Clin North Am 2015;53:413-23.

42. Aitken M, Chan MV, Urzua Fresno C, et al. Diagnostic Accuracy of Cardiac MRI versus FDG

PET for Cardiac Sarcoidosis: A Systematic Review and Meta-Analysis. Radiology 2022;304:566-79.

43. Martineau P, Gregoire J, Harel F, Pelletier-Galarneau M. Assessing cardiovascular infection and inflammation with FDG-PET. Am J Nucl Med Mol Imaging 2021;11:46-58.

44. Khalaf S, Al-Mallah MH. Fluorodeoxyglucose Applications in Cardiac PET: Viability, Inflammation, Infection, and Beyond. [Review]. Methodist Debakey Cardiovasc J. 16(2):122-129, 2020 Apr-Jun.

45. Contaldi C, Dellegrottaglie S, Mauro C, et al. Role of Cardiac Magnetic Resonance Imaging in Heart Failure. [Review]. Heart Fail Clin. 17(2):207-221, 2021 Apr.

46. Lum YH, McKenzie S, Brown M, Hamilton-Craig C. Impact of cardiac magnetic resonance imaging on heart failure patients referred to a tertiary advanced heart failure unit: improvements in diagnosis and management. Intern Med J. 49(2):203-211, 2019 Feb.

47. Won E, Donnino R, Srichai MB, et al. Diagnostic Accuracy of Cardiac Magnetic Resonance Imaging in the Evaluation of Newly Diagnosed Heart Failure With Reduced Left Ventricular Ejection Fraction. Am J Cardiol. 2015;116(7):1082-1087.

48. Valle-Munoz A, Estornell-Erill J, Soriano-Navarro CJ, et al. Late gadolinium enhancement-cardiovascular magnetic resonance identifies coronary artery disease as the aetiology of left ventricular dysfunction in acute new-onset congestive heart failure. Eur J Echocardiogr. 2009;10(8):968-974.

49. Assomull RG, Shakespeare C, Kalra PR, et al. Role of cardiovascular magnetic resonance as a gatekeeper to invasive coronary angiography in patients presenting with heart failure of unknown etiology. Circulation. 2011;124(12):1351-1360.

50. Hamilton-Craig C, Strugnell WE, Raffel OC, Porto I, Walters DL, Slaughter RE. CT angiography with cardiac MRI: non-invasive functional and anatomical assessment for the etiology in newly diagnosed heart failure. Int J Cardiovasc Imaging. 2012;28(5):1111-1122.

51. Ojrzynska-Witek N, Marczak M, Mazurkiewicz L, et al. Role of cardiac magnetic resonance in heart failure of initially unknown etiology: A 10-year observational study. Kardiol Pol. 80(3):278-285, 2022.

52. Kanagala P, Cheng ASH, Singh A, et al. Diagnostic and prognostic utility of cardiovascular magnetic resonance imaging in heart failure with preserved ejection fraction - implications for clinical trials. J Cardiovasc Magn Reson. 20(1):4, 2018 01 11.

53. Paterson DI, Wells G, Erthal F, et al. OUTSMART HF: A Randomized Controlled Trial of Routine Versus Selective Cardiac Magnetic Resonance for Patients With Nonischemic Heart Failure (IMAGE-HF 1B). Circulation. 141(10):818-827, 2020 03 10.

54. Backhaus SJ, Lange T, George EF, et al. Exercise Stress Real-Time Cardiac Magnetic Resonance Imaging for Noninvasive Characterization of Heart Failure With Preserved Ejection Fraction: The HFpEF-Stress Trial. Circulation. 143(15):1484-1498, 2021 04 13.

55. Byrne C, Hasbak P, Kjaer A, Thune JJ, Kober L. Impaired myocardial perfusion is associated with increasing end-systolic- and end-diastolic volumes in patients with non-ischemic systolic heart failure: a cross-sectional study using Rubidium-82 PET/CT. BMC Cardiovasc Disord 2019;19:68.

56. Gulati V, Ching G, Heller GV. The role of radionuclide imaging in heart failure. J Nucl Cardiol.

2013;20(6):1173-1183.

57. Danias PG, Ahlberg AW, Clark BA, 3rd, et al. Combined assessment of myocardial perfusion and left ventricular function with exercise technetium-99m sestamibi gated single-photon emission computed tomography can differentiate between ischemic and nonischemic dilated cardiomyopathy. Am J Cardiol 1998;82:1253-8.

58. Danias PG, Papaioannou GI, Ahlberg AW, et al. Usefulness of electrocardiographic-gated stress technetium-99m sestamibi single-photon emission computed tomography to differentiate ischemic from nonischemic cardiomyopathy. Am J Cardiol 2004;94:14-9.

59. Soman P, Lahiri A, Mieres JH, et al. Etiology and pathophysiology of new-onset heart failure: evaluation by myocardial perfusion imaging. J Nucl Cardiol 2009;16:82-91.

60. Gowdar S, Ahlberg AW, Rai M, et al. Risk stratification with vasodilator stress SPECT myocardial perfusion imaging in patients with elevated cardiac biomarkers. J Nucl Cardiol. 27(6):2320-2331, 2020 12.

61. Jacobson AF, Narula J, Tijssen J. Analysis of Differences in Assessment of Left Ventricular Function on Echocardiography and Nuclear Perfusion Imaging. Am J Cardiol. 156:85-92, 2021 10 01.

62. Travin MI. Cardiac radionuclide imaging to assess patients with heart failure. Semin Nucl Med. 2014;44(4):294-313.

63. Beton O, Kurmus O, Asarcikli LD, Alibazoglu B, Alibazoglu H, Yilmaz MB. The practical value of technetium-99m-MIBI SPET to differentiate between ischemic and non-ischemic heart failure presenting with exertional dyspnea. Hellenic Journal of Nuclear Medicine. 19(2):147-54, 2016 May-Aug.Hellenic J Nucl Med. 19(2):147-54, 2016 May-Aug.

64. Vachalcova M, Valocik G, Kurecko M, et al. The three-dimensional speckle tracking echocardiography in distinguishing between ischaemic and non-ischaemic aetiology of heart failure. ESC Heart Fail. 7(5):2297-2304, 2020 10.

65. Sicari R, Cortigiani L. The clinical use of stress echocardiography in ischemic heart disease. Cardiovasc Ultrasound 2017;15:7.

66. Donal E, Thebault C, Lund LH, et al. Heart failure with a preserved ejection fraction additive value of an exercise stress echocardiography. Eur Heart J Cardiovasc Imaging. 2012;13(8):656-665.

67. Meluzin J, Sitar J, Kristek J, et al. The role of exercise echocardiography in the diagnostics of heart failure with normal left ventricular ejection fraction. Eur J Echocardiogr. 2011;12(8):591-602.

68. Belyavskiy E, Morris DA, Url-Michitsch M, et al. Diastolic stress test echocardiography in patients with suspected heart failure with preserved ejection fraction: a pilot study. ESC Heart Fail. 6(1):146-153, 2019 02.

69. Benz DC, Kaufmann PA, von Felten E, et al. Prognostic Value of Quantitative Metrics From Positron Emission Tomography in Ischemic Heart Failure. JACC Cardiovasc Imaging. 14(2):454-464, 2021 02.

70. Bock A, Estep JD. Myocardial viability: heart failure perspective. [Review]. Curr Opin Cardiol. 34(5):459-465, 2019 09.

71. Mc Ardle B, Shukla T, Nichol G, et al. Long-Term Follow-Up of Outcomes With F-18-

Fluorodeoxyglucose Positron Emission Tomography Imaging-Assisted Management of Patients With Severe Left Ventricular Dysfunction Secondary to Coronary Disease. Circ Cardiovasc Imaging 2016;9.

72. Assadi H, Jones R, Swift AJ, Al-Mohammad A, Garg P. Cardiac MRI for the prognostication of heart failure with preserved ejection fraction: A systematic review and meta-analysis. Magn Reson Imaging. 76:116-122, 2021 02.

73. Di Marco A, Anguera I, Schmitt M, et al. Late Gadolinium Enhancement and the Risk for Ventricular Arrhythmias or Sudden Death in Dilated Cardiomyopathy: Systematic Review and Meta-Analysis. [Review]. JACC Heart Fail. 5(1):28-38, 2017 01.

74. Klem I, Shah DJ, White RD, et al. Prognostic value of routine cardiac magnetic resonance assessment of left ventricular ejection fraction and myocardial damage: an international, multicenter study. Circ Cardiovasc Imaging 2011;4:610-9.

75. Alba AC, Gaztanaga J, Foroutan F, et al. Prognostic Value of Late Gadolinium Enhancement for the Prediction of Cardiovascular Outcomes in Dilated Cardiomyopathy: An International, Multi-Institutional Study of the MINICOR Group. Circ Cardiovasc Imaging 2020;13:e010105.

76. Ge Y, Antiochos P, Steel K, et al. Prognostic Value of Stress CMR Perfusion Imaging in Patients With Reduced Left Ventricular Function. JACC Cardiovasc Imaging 2020;13:2132-45.

77. Pezel T, Hovasse T, Sanguineti F, et al. Long-Term Prognostic Value of Stress CMR in Patients With Heart Failure and Preserved Ejection Fraction. JACC Cardiovasc Imaging 2021;14:2319-33.

78. Dall'Armellina E, Morgan TM, Mandapaka S, et al. Prediction of cardiac events in patients with reduced left ventricular ejection fraction with dobutamine cardiovascular magnetic resonance assessment of wall motion score index. J Am Coll Cardiol 2008;52:279-86.

79. Madsen EB, Gilpin E, Slutsky RA, Ahnve S, Henning H, Ross J, Jr. Usefulness of the chest x-ray for predicting abnormal left ventricular function after acute myocardial infarction. Am Heart J. 1984;108(6):1431-1436.

80. Kandolin RM, Wiefels CC, Mesquita CT, et al. The Current Role of Viability Imaging to Guide Revascularization and Therapy Decisions in Patients With Heart Failure and Reduced Left Ventricular Function. [Review]. Can J Cardiol. 35(8):1015-1029, 2019 08.

81. Prastaro M, D'Amore C, Paolillo S, et al. Prognostic role of transthoracic echocardiography in patients affected by heart failure and reduced ejection fraction. Heart Fail Rev. 2015;20(3):305-316.

82. Grayburn PA, Appleton CP, DeMaria AN, et al. Echocardiographic predictors of morbidity and mortality in patients with advanced heart failure: the Beta-blocker Evaluation of Survival Trial (BEST). J Am Coll Cardiol. 2005;45(7):1064-1071.

83. Saito M, Negishi K, Eskandari M, et al. Association of left ventricular strain with 30-day mortality and readmission in patients with heart failure. J Am Soc Echocardiogr. 2015;28(6):652-666.

84. Trobs SO, Prochaska JH, Schwuchow-Thonke S, et al. Association of Global Longitudinal Strain With Clinical Status and Mortality in Patients With Chronic Heart Failure. JAMA Cardiol. 6(4):448-456, 2021 04 01.

85. Kalra R, Gupta K, Sheets R, et al. Cardiac Function and Sudden Cardiac Death in Heart

Failure With Preserved Ejection Fraction (from the TOPCAT Trial). Am J Cardiol. 129:46-52, 2020 08 15.

86. Bosso G, Valvano A, Guarnaccia F, et al. Adherence to guidelines in the management of patients with chronic heart failure follow-up: role of periodic echocardiographic examinations. J Cardiovasc Med (Hagerstown). 21(3):216-222, 2020 Mar.

87. Vizzardi E, D'Aloia A, Giubbini R, et al. Effect of spironolactone on left ventricular ejection fraction and volumes in patients with class I or II heart failure. Am J Cardiol. 2010;106(9):1292-1296.

88. Machino-Ohtsuka T, Seo Y, Ishizu T, et al. Clinical utility of the 2016 ASE/EACVI recommendations for the evaluation of left ventricular diastolic function in the stratification of post-discharge prognosis in patients with acute heart failure. Eur Heart J Cardiovasc Imaging. 20(10):1129-1137, 2019 Oct 01.

89. Bhella PS, Pacini EL, Prasad A, et al. Echocardiographic indices do not reliably track changes in left-sided filling pressure in healthy subjects or patients with heart failure with preserved ejection fraction. Circ Cardiovasc Imaging. 2011;4(5):482-489.

90. Elhendy A, Sozzi F, van Domburg RT, et al. Effect of myocardial ischemia during dobutamine stress echocardiography on cardiac mortality in patients with heart failure secondary to ischemic cardiomyopathy. Am J Cardiol. 2005;96(4):469-473.

91. Maskoun W, Mustafa N, Mahenthiran J, et al. Wall motion abnormalities with low-dose dobutamine predict a high risk of cardiac death in medically treated patients with ischemic cardiomyopathy. Clin Cardiol. 2009;32(7):403-409.

92. Sozzi FB, Elhendy A, Rizzello V, et al. Prognostic significance of akinesis becoming dyskinesis during dobutamine stress echocardiography. J Am Soc Echocardiogr. 2007;20(3):257-261.

93. Donal E, Lund LH, Oger E, et al. Value of exercise echocardiography in heart failure with preserved ejection fraction: a substudy from the KaRen study. Eur Heart J Cardiovasc Imaging. 2016;17(1):106-113.

94. Fabiani I, Pugliese NR, Galeotti GG, et al. The Added Value of Exercise Stress Echocardiography in Patients With Heart Failure. Am J Cardiol. 123(9):1470-1477, 2019 05 01.

95. Measuring Sex, Gender Identity, and Sexual Orientation.

96. American College of Radiology. ACR Appropriateness Criteria® Radiation Dose Assessment Introduction. Available at: https://edge.sitecorecloud.io/americancoldf5f-acrorgf92a-productioncb02-3650/media/ACR/Files/Clinical/Appropriateness-Criteria/ACR-Appropriateness-Criteria-Radiation-Dose-Assessment-Introduction.pdf.

Disclaimer

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.

[a]Toronto General Hospital, University of Toronto, Toronto, Ontario, Canada. [b]Research Author, St Paul's Hospital and University of British Columbia, Vancouver, British Columbia, Canada. [c]Panel Chair, Mayo Clinic, Rochester, Minnesota. [d]Dartmouth-Hitchcock Medical Center, Lebanon, New Hampshire; American Society of Echocardiography. [e]Feinberg School of Medicine, Northwestern University, Chicago, Illinois; Commission on Nuclear Medicine and Molecular Imaging. [f]University of Alabama at Birmingham, Birmingham, Alabama, Primary care physician. [g]VA Greater Los Angeles Healthcare System, Los Angeles, California. [h]Kaiser Permanente, Los Angeles, California. [i]Baylor College of Medicine, Houston, Texas. [j]Weill Cornell Medicine, New York, New York; Society of Cardiovascular Computed Tomography. [k]The George Washington University School of Medicine and Health Sciences, Washington, District of Columbia; American College of Cardiology. [l]Cleveland Clinic, Cleveland, Ohio. [m]University of Calgary Cummings School of Medicine, Calgary, Alberta, Canada; Society for Cardiovascular Magnetic Resonance. [n]Specialty Chair, Cleveland Clinic, Cleveland, Ohio.