American College of Radiology
ACR Appropriateness Criteria®
Evaluation of Cardiac Masses

Variant: 1 Adult. Suspected cardiac mass. No known cardiac mass. Initial imaging.

Procedure	Appropriateness Category	Relative Radiation Level
US echocardiography transthoracic resting	Usually Appropriate	O
MRI heart function and morphology without and with IV contrast	Usually Appropriate	O
CT heart function and morphology with IV contrast	Usually Appropriate	☢☢☢☢
US echocardiography transesophageal	May Be Appropriate (Disagreement)	O
MRI heart function and morphology without IV contrast	May Be Appropriate (Disagreement)	O
CTA chest with IV contrast	May Be Appropriate (Disagreement)	☢☢☢
Radiography chest	Usually Not Appropriate	☢
Arteriography coronary with ventriculography	Usually Not Appropriate	☢☢☢
MRA chest with IV contrast	Usually Not Appropriate	O
MRA coronary arteries without and with IV contrast	Usually Not Appropriate	O
MRI chest with IV contrast	Usually Not Appropriate	O
MRI chest without and with IV contrast	Usually Not Appropriate	O
MRI chest without 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	☢☢☢
CTA coronary arteries with IV contrast	Usually Not Appropriate	☢☢☢
DOTATATE PET/CT skull base to mid-thigh	Usually Not Appropriate	☢☢☢
FDG-PET/MRI heart	Usually Not Appropriate	☢☢☢
MIBG scan whole body with SPECT or SPECT/CT chest	Usually Not Appropriate	☢☢☢
FDG-PET/CT heart	Usually Not Appropriate	☢☢☢☢
FDG-PET/CT skull base to mid-thigh	Usually Not Appropriate	☢☢☢☢
Octreotide scan with SPECT or SPECT/CT chest and abdomen	Usually Not Appropriate	☢☢☢☢

Variant: 2 Adult. Known cardiac mass in echocardiography. Unknown etiology. Next imaging study.

Procedure	Appropriateness Category	Relative Radiation Level
US echocardiography transesophageal	Usually Appropriate	O
US echocardiography transthoracic resting	Usually Appropriate	O
MRI heart function and morphology without and with IV contrast	Usually Appropriate	O
FDG-PET/MRI heart	Usually Appropriate	☢☢☢
CT heart function and morphology with IV contrast	Usually Appropriate	☢☢☢☢
FDG-PET/CT heart	Usually Appropriate	☢☢☢☢
MRI heart function and morphology without IV contrast	May Be Appropriate	O
DOTATATE PET/CT skull base to mid-thigh	May Be Appropriate	☢☢☢
MIBG scan whole body with SPECT or SPECT/CT chest	May Be Appropriate	☢☢☢
Octreotide scan with SPECT or SPECT/CT chest and abdomen	May Be Appropriate	☢☢☢☢

Radiography chest	Usually Not Appropriate	☢
Arteriography coronary with ventriculography	Usually Not Appropriate	☢☢☢
MRA chest with IV contrast	Usually Not Appropriate	O
MRA coronary arteries without and with IV contrast	Usually Not Appropriate	O
MRI chest with IV contrast	Usually Not Appropriate	O
MRI chest without and with IV contrast	Usually Not Appropriate	O
MRI chest without 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	☢☢☢
CTA chest with IV contrast	Usually Not Appropriate	☢☢☢
CTA coronary arteries with IV contrast	Usually Not Appropriate	☢☢☢
FDG-PET/CT skull base to mid-thigh	Usually Not Appropriate	☢☢☢☢

Variant: 3 Adult. Known cardiac mass. Established etiology. Follow-up imaging.

Procedure	Appropriateness Category	Relative Radiation Level
US echocardiography transthoracic resting	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
FDG-PET/MRI heart	Usually Appropriate	☢☢☢
CT heart function and morphology with IV contrast	Usually Appropriate	☢☢☢☢
US echocardiography transesophageal	May Be Appropriate	O
DOTATATE PET/CT skull base to mid-thigh	May Be Appropriate	☢☢☢
FDG-PET/CT heart	May Be Appropriate	☢☢☢☢
Radiography chest	Usually Not Appropriate	☢
Arteriography coronary with ventriculography	Usually Not Appropriate	☢☢☢
MRA chest with IV contrast	Usually Not Appropriate	O
MRA coronary arteries without and with IV contrast	Usually Not Appropriate	O
MRI chest with IV contrast	Usually Not Appropriate	O
MRI chest without and with IV contrast	Usually Not Appropriate	O
MRI chest without 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	☢☢☢
CTA chest with IV contrast	Usually Not Appropriate	☢☢☢
CTA coronary arteries with IV contrast	Usually Not Appropriate	☢☢☢
FDG-PET/CT skull base to mid-thigh	Usually Not Appropriate	☢☢☢☢
Octreotide scan with SPECT or SPECT/CT chest and abdomen	Usually Not Appropriate	☢☢☢☢

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Introduction/Background

Cardiac masses are rare but are important contributors to morbidity and mortality [1]. Cardiac masses are broadly categorized as neoplastic and nonneoplastic. Cardiac neoplasms have a prevalence of 0.0017% to 0.33% [2,3]. Nonneoplastic cardiac masses include thrombus, vegetations, abscess, inflammatory pseudotumor, calcified amorphous tumor, caseating mitral annular calcification, lipomatous hypertrophy of the atrial septum, hematoma, focal myocardial hypertrophy, mitral annular calcifications, Lambl excrescences, atrial septal aneurysm, aneurysms of coronary arteries and bypass grafts, and pericardial cyst. Thrombus is the most common cardiac mass, with an estimated incidence of 3% to 25% in atrial fibrillation and 2% to 50% in left ventricular (LV) systolic dysfunction [1,4]. Metastasis is the most common cardiac neoplasm, 30 to 40 times more common than primary cardiac neoplasms [5-7]. Metastasis has a prevalence of 1.38 per 100,000 people, with an incidence of 1 in 100 in autopsies, compared with primary cardiac tumors, with an incidence of 1 in 2,000 in autopsies [5,6]. The most common metastatic tumors that spread to the heart are from lung, breast, esophagus and kidney cancer, melanoma, lymphoma, and leukemia. Tumors with the highest rate of cardiac metastasis are pleural mesothelioma (48.4%), melanoma (27.8%), lung adenocarcinoma (21%), undifferentiated carcinomas (19.5%), lung squamous cell carcinoma (18.2%), breast carcinoma (15.5%), ovarian carcinoma (10.3%), lympho-myeloproliferative neoplasms (9.4%), bronchoalveolar carcinomas (9.8%), gastric carcinomas (8%), renal carcinomas (7.3%), and pancreatic carcinomas (6.4%) [8].

Most primary cardiac neoplasms (75%-90%) are benign [9]. Fibroelastoma is the most common benign neoplasm, with other benign neoplasms including myxoma, fibroma, rhabdomyoma, adult rhabdomyoma, lipoma, lipomatous hypertrophy of atrial septum, hamartoma, hemangioma, paraganglioma, and cystic tumor of atrioventricular node [7,10]. Only 20% of primary cardiac neoplasms are malignant, with an incidence of 0.008% in the Surveillance, Epidemiology, and End Results registry [11]. The majority of primary cardiac malignancies are sarcomas, which account for just 1% of all soft tissue sarcomas [7,8]. Angiosarcoma and undifferentiated sarcoma account for up to 76% of cardiac sarcomas, with other types being leiomyosarcoma, synovial sarcoma, osteosarcoma, fibrosarcoma, myxoid sarcoma, liposarcoma, mesenchymal sarcoma, neurofibrosarcoma, and malignant fibrous histiocytoma [8,12]. Other malignant cardiac lesions include pericardial mesothelioma and hematolymphoid tumors [7]. Diffuse large B-cell lymphoma is the most common primary lymphoma of the heart [13]. Malignancies are more common in the right-sided chambers (28%), pericardium (32%), or pulmonary arteries (25%), whereas benign masses are more common in the left-sided chambers[14]. Normal variants that mimic cardiac masses include crista terminalis, taenia sagittalis, Chiari network, left atrial ridge (“coumadin ridge”), prominent Eustachian valve, interatrial septal aneurysm, moderator band, papillary muscles, and fibrous bands [15]. Extrinsic lesions that mimic cardiac mass include hiatal hernia, hematoma, bronchogenic cysts, intravascular lines, suture lines, mediastinal lymph nodes, epicardial fat, and infectious cysts.

Cardiac masses have nonspecific symptoms and presentations, which makes diagnosis challenging. A cardiac mass can present because of interference in cardiac structure, function, or blood flow, with symptoms such as palpitations, arrhythmias, syncope, cardiac failure, pericardial effusion, tamponade, upper extremity or neck swelling, chest discomfort, dyspnea, syncope, or presyncope [8,9]. Embolic manifestations include stroke, transient ischemic attack, infarcts of liver or spleen,

limb ischemia, venous thrombosis, or pulmonary embolism. Constitutional manifestations such as fever, bacteremia, fatigue, arthralgia, myalgia, or weight loss and paraneoplastic syndromes including erythematous rash can be rarely seen [9]. Other findings include cardiac murmur, tumor plop, clubbing, cyanosis, Raynaud phenomenon, anemia, thrombocytopenia and elevated gamma globulin, erythrocyte sedimentation ratio, and C-reactive protein [8,9]. Although histology is the reference standard in the evaluation of a cardiac mass, these masses are not always amenable to tissue sampling. Noninvasive imaging plays a key role in the evaluation of cardiac masses, including in the evaluation of a suspected cardiac mass, characterization of a known cardiac mass and follow-up of a cardiac mass, both before and after treatment.

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) [16]:

"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 reconstructions/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.

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 wherein each procedure provides unique clinical information to effectively manage the patient's care).

Discussion of Procedures by Variant

Variant 1: Adult. Suspected cardiac mass. No known cardiac mass. Initial imaging.

The goal of imaging in this variant is to establish the presence of cardiac mass. The symptoms of cardiac mass are nonspecific. However, a cardiac mass may be suspected or evaluated in some scenarios, such as in embolic stroke or sepsis. In patients with stroke, cardiac source of embolism is evaluated, including thrombus, vegetations, myxoma, fibroelastoma, mitral annular calcification,

atrial septal aneurysm, and Lambl excrescences. In patients with suspected infective endocarditis, see the ACR Appropriate Criteria® topic on "Infective Endocarditis" [17] for discussion on the evaluation of vegetations.

Variant 1: Adult. Suspected cardiac mass. No known cardiac mass. Initial imaging.
A. Arteriography coronary with ventriculography

There is no relevant literature to support the use of coronary arteriography as initial imaging for the evaluation of a suspected cardiac mass.

Variant 1: Adult. Suspected cardiac mass. No known cardiac mass. Initial imaging.
B. CT chest with IV contrast

There is no relevant literature to support the use of CT chest with intravenous (IV) contrast as initial imaging for the evaluation of suspected cardiac mass. Contrast timing and other technical parameters are not optimized for evaluation of a suspected cardiac mass.

Variant 1: Adult. Suspected cardiac mass. No known cardiac mass. Initial imaging.
C. CT chest without and with IV contrast

There is no relevant literature to support the use of CT chest without and with IV contrast as initial imaging for the evaluation of suspected cardiac mass. Contrast timing and other technical parameters are not optimized for evaluation of a suspected cardiac mass.

Variant 1: Adult. Suspected cardiac mass. No known cardiac mass. Initial imaging.
D. CT chest without IV contrast

There is no relevant literature to support the use of CT chest without IV contrast for evaluation of suspected cardiac mass. A small study showed that cardiac myxoma can be detected in noncontrast chest CT based on attenuation differences with blood pool (22.5 versus 44.6 Hounsfield units [HU]) [18].

Variant 1: Adult. Suspected cardiac mass. No known cardiac mass. Initial imaging.
E. CT heart function and morphology with IV contrast

CT heart function and morphology with IV contrast has several advantages in the evaluation of a cardiac mass, including high spatial resolution, good temporal resolution, multiplanar reconstruction, and large field of view to evaluate all cardiovascular and noncardiovascular structures. CT is a particularly effective modality in the evaluation of suspected cardiac thrombus in patients with embolic stroke [19]. In a study that used stroke recurrence as end point, CT had good accuracy (area under the curve [AUC] 0.63), comparable to MRI (AUC 0.53) and transthoracic echocardiography (TTE) (AUC 0.51) in the evaluation of cardiac source of embolic stroke (including cardiac thrombus, tumor, and valvular vegetation) [20]. Gated cardiac CT in the acute phase of ischemic stroke has a superior diagnostic yield compared with TTE for detection of embolic source, with CT showing an embolic source in 11.4% compared with 4.9% on TTE. Cardiac thrombus is the most frequent finding (in 7.1% versus 0.6%) [21].

The diagnostic certainty of CT is improved using spectral iodine maps [22]. Dual-energy CT (DECT)–derived iodine concentration and effective atomic number showed better diagnostic performance than attenuation values in early-phase cardiac CT for detecting left atrial appendage (LAA) thrombus and distinguishing it from the circulatory stasis [23]. Iodine concentration from DECT has a 97% sensitivity, 100% specificity, 100% positive predictive value (PPV), and 97% negative predictive value (NPV) in detecting thrombus and distinguishing it from contrast admixture artifact with transesophageal echocardiography (TEE) as the reference standard [24]. An

iodine cutoff value of 1.74 mg/mL has a 100% sensitivity, specificity, and AUC in diagnosing thrombus versus slow flow [24].

CT has a sensitivity of 97%, specificity of 88%, PPV of 97%, and NPV of 88% in diagnosis of vegetations and 100% accuracy in the evaluation of paravalvular complications such as pseudoaneurysm/abscess [25]. CT has been shown to provide complementary diagnostic information to TEE in suspected infective endocarditis and complications, including presurgical assessment and risk stratification. CT identifies an additional 11% vegetations and 14% fistulae compared with TEE [26].

Variant 1: Adult. Suspected cardiac mass. No known cardiac mass. Initial imaging.
F. CTA chest with IV contrast

CTA chest may be useful in the evaluation of suspected cardiac thrombus in patients with embolic stroke [19]. Nongated CTA can detect cardiac thrombus in 12% of patients presenting with stroke [22]. The diagnostic certainty of CT is improved using spectral iodine maps [22].The performance of CTA is improved using delayed phase and contrast optimization techniques. Delayed phase imaging improves the performance of CT (by distinguishing thrombus from stasis) with a pooled PPV of 92% for delayed phase compared with 41% for angiographic phase [27]. Note that CTA chest can be performed with or without electrocardiogram (ECG) triggering and generally uses thicker slices and larger field of view than a dedicated cardiac CT.

Variant 1: Adult. Suspected cardiac mass. No known cardiac mass. Initial imaging.
G. CTA coronary arteries with IV contrast

There is no relevant literature to support the use of CTA coronary arteries with IV contrast as initial imaging for the evaluation of suspected cardiac mass.

Variant 1: Adult. Suspected cardiac mass. No known cardiac mass. Initial imaging.
H. DOTATATE PET/CT skull base to mid-thigh

There is no relevant literature to support the use of DOTATATE PET/CT skull base to mid-thigh as initial imaging for the evaluation of suspected cardiac mass.

Variant 1: Adult. Suspected cardiac mass. No known cardiac mass. Initial imaging.
I. FDG-PET/CT heart

A dedicated cardiac fluorine-18-2-fluoro-2-deoxy-D-glucose (FDG)-PET/CT for cardiac masses involves a different prescan preparation to identify abnormal cardiac FDG uptake versus normal myocardial FDG uptake compared with whole body FDG-PET/CT. Cardiac FDG-PET/CT requires a low/no-carbohydrate, high-fat diet for at least 24 hours or at least 2 high-fat, no-carbohydrate meals before fasting for at least 4 hours and IV heparin 50 IU/kg 1 hour before imaging if only one high-fat meal was used before fasting, to shift metabolism from glucose to fatty acid [3]. There is no relevant literature to support the use of FDG-PET/CT heart as initial imaging for evaluation of suspected cardiac mass. A study of 389 surgically resected masses showed that FDG-PET/CT has a high sensitivity of 95.2%, comparable to that of TEE (95.2%) in the detection of cardiac masses, superior to MRI (93.1%) and CT (83.4%). FDG-PET/CT, TEE, and MRI have a 100% accuracy for primary malignant masses, with FDG-PET/CT and MRI having a 100% accuracy for metastatic masses [28].

Variant 1: Adult. Suspected cardiac mass. No known cardiac mass. Initial imaging.
J. FDG-PET/CT skull base to mid-thigh

FDG-PET/CT skull base to mid-thigh is typically referred to acquisition following standard

preparation that involves fasting for at least 4 to 6 hours and a high-protein, low-carbohydrate diet for 24 hours before scanning [29]. This technique is not used for evaluation of a cardiac mass due to normal, physiological myocardial uptake of FDG. There is no relevant literature to support the use of FDG-PET/CT skull base to mid-thigh as initial imaging modality in the evaluation of a suspected cardiac mass.

Variant 1: Adult. Suspected cardiac mass. No known cardiac mass. Initial imaging.
K. FDG-PET/MRI heart

FDG-PET/MRI heart is typically performed following a dedicated preparation of a low/no-carbohydrate, high-fat diet for at least 24 hours or at least 2 high-fat, no-carbohydrate meals before fasting for at least 4 hours and IV heparin 50 IU/kg 1 hour before imaging if only one high-fat meal was used before fasting, to shift metabolism from glucose to fatty acid [3].There is no relevant literature to support the use of FDG-PET/MRI heart as the initial imaging for the evaluation of a suspected cardiac mass.

Variant 1: Adult. Suspected cardiac mass. No known cardiac mass. Initial imaging.
L. MIBG scan whole body with SPECT or SPECT/CT chest

There is no relevant literature to support the use of metaiodobenzylguanidine (MIBG) whole body with single-photon emission CT (SPECT) or SPECT/CT chest scan as initial imaging for the evaluation of suspected cardiac mass.

Variant 1: Adult. Suspected cardiac mass. No known cardiac mass. Initial imaging.
M. MRA chest with IV contrast

There is no relevant literature to support the use of MR angiography (MRA) chest with IV contrast as initial imaging for the evaluation of suspected cardiac mass.

Variant 1: Adult. Suspected cardiac mass. No known cardiac mass. Initial imaging.
N. MRA coronary arteries without and with IV contrast

There is no relevant literature to support the use of MRA coronary arteries without and with IV contrast as initial imaging for the evaluation of suspected cardiac mass.

Variant 1: Adult. Suspected cardiac mass. No known cardiac mass. Initial imaging.
O. MRI chest with IV contrast

There is no relevant literature to support the use of MRI chest with IV contrast as initial imaging for the evaluation of suspected cardiac mass.

Variant 1: Adult. Suspected cardiac mass. No known cardiac mass. Initial imaging.
P. MRI chest without and with IV contrast

There is no relevant literature to support the use of MRI chest without and with IV contrast as initial imaging for the evaluation of suspected cardiac mass.

Variant 1: Adult. Suspected cardiac mass. No known cardiac mass. Initial imaging.
Q. MRI chest without IV contrast

There is no relevant literature to support the use of MRI chest without IV contrast as initial imaging for the evaluation of suspected cardiac mass.

Variant 1: Adult. Suspected cardiac mass. No known cardiac mass. Initial imaging.
R. MRI heart function and morphology without and with IV contrast

MRI is useful in evaluating patients with suspected cardiac cause of embolic stroke [19]. MRI has comparable accuracy (AUC 0.53) as TTE (AUC 0.51) and less accuracy than CT (AUC 0.63) in the

evaluation of cardiac source of embolic stroke [20]. In a study of 160 patients, MRI showed the highest sensitivity and specificity (88% ± 9% and 99% ± 2%, respectively) for thrombus detection, compared with TTE (23% ± 12% and 96% ± 3.6%, respectively) and TEE (40% ± 14% and 96% ± 3.6%, respectively) [30]. MRI is particularly useful in the evaluation of small, mural, and apical thrombi. In 171 patients with coronary artery disease (CAD), MRI was superior to echocardiography in the detection of thrombus or neoplasm in patients with LV ejection fraction <30%, with TTE missing 30% of these thrombi [31]. However, the performance of MRI and echocardiography were similar in patients with LV ejection fraction >30% [31]. In a study of 201 patients, delayed-enhanced (DE)-MRI had a 100% sensitivity and NPV in the detection of LV thrombus following myocardial infarction. Compared with this, TTE showed a limited sensitivity of 35% using noncontrast technique and 64% using contrast agents [32].

With DE-MRI as the reference standard, a study of 121 patients showed that cine MRI had an accuracy of 95%, sensitivity of 79%, specificity of 99%, accuracy of 95%, and PPV of 95% in the detection of LV thrombus [33]. DE-MRI detects twice as many thrombi as noncontrast cine MRI in patients with infarct or ischemic cardiomyopathy. Nonvisualized thrombi were very small and frequently seen in the LV apex [34]. Another study in patients with LV systolic dysfunction showed that DE-MRI detects more thrombi than noncontrast cine MRI (7% versus 4.7%), with cine MRI missing small intracavitary and small/large mural thrombus [35]. For the detection of catheter-associated right atrial thrombus, the accuracy of cine MRI (sensitivity of 90%, specificity of 98%) and TTE (sensitivity 75%, specificity 90%) were lower than DE-MRI [36]. A meta-analysis showed that DE-MRI is the most accurate modality for the detection of LV thrombi (sensitivity 88%, specificity 99%), followed by cine MRI (sensitivity 58%-79%, specificity 99%, accuracy 95%, PPV 93%-95%, and NPV 95%-96%), contrast TTE (sensitivity 23%-61%, specificity 96%-99%, accuracy 92%, PPV 93%, and NPV 91%), and noncontrast TTE (sensitivity 24%-33%, specificity 94%-95%, accuracy 82%, PPV 57%, and NPV 85%) [37].

A study of 389 surgically resected mases showed that MRI had an accuracy of 93.1% in detecting cardiac mass, compared with 95.2% for FDG-PET/CT and TEE, 83% for CT, and 69.2% for TTE. MRI had a 100% accuracy for detecting primary malignant and metastatic masses [28].

Variant 1: Adult. Suspected cardiac mass. No known cardiac mass. Initial imaging.
S. MRI heart function and morphology without IV contrast

Cardiac masses can also be visualized in noncontrast MRI sequences, including cine MRI and noncontrast MRA such as 3-D steady-state free precession. With DE-MRI as the reference standard, a study of 121 patients showed that cine MRI had an accuracy of 95%, sensitivity of 79%, specificity of 99%, and PPV of 95% in detection of LV thrombus [33]. DE-MRI detects twice as much as thrombi as noncontrast cine MRI in patients with infarct or ischemic cardiomyopathy. Nonvisualized thrombi were small and frequently in LV apex [34]. Another study in LV systolic dysfunction showed that detection of thrombi is less with noncontrast cine MRI than DE-MRI (4.7% versus 7.0%) [35]. For detection of catheter-associated right atrial thrombus, the accuracy of cine MRI (sensitivity of 90%, specificity of 98%) and TTE (sensitivity 75%, specificity 90%) were lower than DE-MRI [36]. A meta-analysis showed cine MRI (sensitivity 58%-79%, specificity 99%, accuracy 95%, PPV 93%-95%, and NPV 95%-96%) had lower performance in the detection of LV thrombi than DE-MRI (sensitivity 88%, specificity 99%) [37].

Variant 1: Adult. Suspected cardiac mass. No known cardiac mass. Initial imaging.
T. Octreotide scan with SPECT or SPECT/CT chest and abdomen

There is no relevant literature to support the use of octreotide scan with SPECT or SPECT/CT chest and abdomen as initial imaging for the evaluation of suspected cardiac mass.

Variant 1: Adult. Suspected cardiac mass. No known cardiac mass. Initial imaging.
U. Radiography chest

There is no relevant literature to support the use of radiography chest as initial imaging for the evaluation of suspected cardiac mass.

Variant 1: Adult. Suspected cardiac mass. No known cardiac mass. Initial imaging.
V. US echocardiography transesophageal

TEE is used in the evaluation of cardiovascular source of embolus with no known cardiac source after inconclusive TTE [38]. A study of 160 patients with LV thrombus showed higher sensitivity and specificity of TEE (40% ± 14% and 96% ± 3.6%, respectively) than of TTE (23% ± 12% and 96% ± 3.6%, respectively) but lower sensitivity and specificity than MRI (88% ± 9% and 99% ± 2%, respectively) [30]. For infective endocarditis, TEE is used when there is moderate or high pretest probability (staphylococcus bacteremia, fungemia, prosthetic heart valve or intracardiac device), despite negative or nondiagnostic TTE or evaluation of paravalvular complications [19]. TEE has a specificity of 90% for the diagnosis of vegetations, with a sensitivity of 96% for native valves and 92% for prosthetic valves. TEE has a detection rate of 90% compared with 58% for TTE [39]. A single-institute study on 389 surgically removed masses showed that TEE has a 100% accuracy for the detection of primary malignant mass, similar to FDG-PET/CT and MRI, whereas TTE had an accuracy of 78.3% [28].

Variant 1: Adult. Suspected cardiac mass. No known cardiac mass. Initial imaging.
W. US echocardiography transthoracic resting

TTE is a first-line imaging modality in patients with suspected cardiac source of embolic stroke, suspected cardiac mass, and suspected infective endocarditis with positive blood culture or new murmur [19,38]. TTE techniques useful in the evaluation of cardiac mass include 2-D, 3-D, color Doppler, spectral Doppler, agitated saline, and ultrasound enhancement agents. Because of a high temporal resolution, TTE is particularly good for the evaluation of small, mobile masses, especially those attached to the valves [9]. TTE is also excellent in assessing the hemodynamic effect of cardiac mass, including valvular or vascular obstruction or valvular regurgitation [9]. For detecting vegetations, TTE has a sensitivity of 70% in native valves and 50% in prosthetic valves, with a specificity of 90% in both settings. Detection rate of vegetation with TTE is lower than TEE (58% versus 90%) [39].

In a study of 121 patients with DE-MRI as the reference standard, contrast-enhanced echocardiography had a higher sensitivity (61% versus 33%) and accuracy (92% versus 82%) compared with noncontrast-enhanced echocardiography for detection of thrombus [33]. Compared with DE-MRI, TTE is likely to miss small size or mural thrombus. In another study on 2,432 patients with LV dysfunction with DE-MRI as reference, the sensitivity, specificity, PPV, and NPV of TTE for detection of thrombus were 33%, 91%, 29%, and 93%, respectively [40]. Among patients who had possible LV thrombus as the clinical indication for echocardiography, sensitivity and PPV were markedly higher (60%, 75%), possibly because of dedicated imaging around LV apex [40]. In a study of 160 patients, TTE had a lower sensitivity and specificity (23% ± 12% and 96% ± 3.6%, respectively) compared with TEE (40% ± 14% and 96% ± 3.6%, respectively) and MRI (88% ± 9% and 99% ± 2%, respectively) [30]. For right atrial thrombus, TTE had an accuracy of 86%, sensitivity of 75%, specificity of 90%, PPV of 75%, and NPV of 90% with DE-MRI as the reference

standard [36].

Variant 2: Adult. Known cardiac mass in echocardiography. Unknown etiology. Next imaging study.

In patients with a known cardiac mass on echocardiography, further imaging is often required to characterize the cardiac mass for treatment planning. Thrombus requires anticoagulants, whereas malignant tumors are managed by surgery, radiation, or chemotherapy. Benign neoplasms can be followed up with imaging or may be resected if there are significant symptoms or development of complications. Characterization involves distinguishing a true cardiac mass from a pseudomass caused by normal variants or extrinsic compression, nonneoplastic mass from neoplastic mass, and benign neoplasm from malignant neoplasm [41]. Characterization requires several factors including demographics (especially age), clinical probability (known malignancy or infection, presence of catheter, associated syndromes), presentation, location of mass, and imaging features. Imaging features include the size, location (chamber, myocardium, pericardium, extracardiac), number, morphology (margins, attachment, appearance, infiltration), and tissue characteristics (signal/attenuation, contrast enhancement, calcification, fat, vascularity). Imaging also provides information for surgical planning such as relationship to adjacent structures, preferred surgical approach, and reconstruction of chambers [10,41]. The staging of a primary cardiac malignancy is beyond the scope of this document.

Variant 2: Adult. Known cardiac mass in echocardiography. Unknown etiology. Next imaging study.

A. Arteriography coronary with ventriculography

There is no relevant literature to support the use of coronary arteriography for the characterization of a known cardiac mass. Coronary angiography may be performed for assessment of a feeding artery in myxoma and paraganglioma, which helps in surgical planning [42,43].

Variant 2: Adult. Known cardiac mass in echocardiography. Unknown etiology. Next imaging study.

B. CT chest with IV contrast

There is no relevant literature to support the use of CT chest with IV contrast for the characterization of a known cardiac mass. Contrast timing and other technical parameters are not optimized for the evaluation of a suspected cardiac mass.

Variant 2: Adult. Known cardiac mass in echocardiography. Unknown etiology. Next imaging study.

C. CT chest without and with IV contrast

There is no relevant literature to support the use of CT chest without and with IV contrast for the characterization of a known cardiac mass. Contrast timing and other technical parameters are not optimized for the evaluation of a suspected cardiac mass.

Variant 2: Adult. Known cardiac mass in echocardiography. Unknown etiology. Next imaging study.

D. CT chest without IV contrast

There is no relevant literature to support the use of CT chest without IV contrast for the characterization of suspected cardiac mass. One small study showed that cardiac myxoma can be detected in noncontrast chest CT based on differences in attenuation with blood pool (22.5 versus 44.6 HU) with a sensitivity of 88.8%/86.1%, specificity of 95.0%/100%, PPV of 96.9%/100%, NPV of 82.6%/80.0%, and accuracy of 91.1%/91.1%, for reader 1 and reader 2, respectively [18].

Variant 2: Adult. Known cardiac mass in echocardiography. Unknown etiology. Next imaging study.

E. CT heart function and morphology with IV contrast

CT heart function and morphology with IV contrast has several advantages in the evaluation of cardiac masses including high spatial resolution, good temporal resolution, multiplanar reconstruction, and large field of view. Tissue characterization is limited compared with MRI and is based on the presence of fat, fluid, calcification, and contrast enhancement. CT is used in the evaluation of calcified masses, feeding arteries, involvement of adjacent structures, particularly coronary arteries, and CAD before interventional or surgical procedures. In 40 patients with surgical confirmation, CT was concordant with surgical findings for location, appearance, size, pedicle diameter, and origin in 100% of cases [44].

CT is effective in distinguishing thrombus from artifacts and cardiac neoplasms. In a meta-analysis of 15 trials with 2,550 patients with TEE as the reference standard, CT had pooled sensitivities of 0.957, specificities of 0.917, and AUC of 0.9883 in the diagnosis of LAA thrombus with further improved performance using delayed imaging, ECG gating, and heart rate control (sensitivities 0.991, specificities 0.989, AUC 0.9972) [45]. DECT-derived iodine concentration and effective atomic number showed better diagnostic performance than attenuation values in early-phase cardiac CT in detecting LAA thrombus and distinguishing it from the circulatory stasis [23]. The iodine concentration in DECT has a sensitivity of 97%, specificity of 100%, PPV of 100%, and NPV of 97% in detecting thrombus and distinguishing circulatory stasis with TEE as the reference standard [24]. An iodine cutoff value of 1.74 mg/mL has a 100% sensitivity, specificity, and AUC in distinguishing thrombus from slow flow [24].

Studies have evaluated the usefulness of various CT features in characterization of a cardiac mass. Presence of ≥5 CT features including size >3 cm, solid component, calcification, isodensity with cardiac muscle, irregular margins, contrast enhancement, invasion, and pericardial effusion indicates malignancy with 100% PPV, whereas a cutoff of ≤2 CT features had a 100% NPV [46]. In a study of 119 patients, CT increased the decision-making rate from 23% before CT to 62% after, particularly effective for the evaluation of LV masses and malignant masses [47]. A small DECT study shows that mean iodine concentration was significantly different between thrombus and myxoma. An iodine cutoff of 2.37 mg/mL had a sensitivity, specificity, and AUC of 94%, 100%, and 99.7%, respectively, for diagnosing a cardiac mass [48]. The diagnostic performance of iodine concentration was better than attenuation value in postcontrast CT (AUC 0.77 versus 0.51) but worse than signal-intensity ratio in MRI (AUC of 0.89) for differentiating cardiac thrombi and tumors [49]. The optimal cutoff value of iodine concentration for differentiation between tumor and thrombus was 2.55 mg/mL, with a sensitivity and specificity of 66.7% and 79%, respectively [49].

A volume perfusion CT technique has been shown to reliably distinguish metastasis from thrombus in oncological patients with cardiac mass [50]. A CT radiomics model had a higher accuracy than the clinical model (AUC 0.973 versus 0.970) in distinguishing thrombus from cardiac tumor in a study that had 192 training data sets. A combined radiomics-clinical model has an even larger AUC than the clinical model (AUC 0.911 versus 0.802) in a 63-patient external validation model [51].

Variant 2: Adult. Known cardiac mass in echocardiography. Unknown etiology. Next imaging study.

F. CTA chest with IV contrast

There is no relevant literature to support the use of CTA chest with IV contrast for the characterization of a known cardiac mass. The technical parameters such as slice thickness, contrast timing, field of view, and ECG synchronization are not optimized for the evaluation of a suspected cardiac mass.

Variant 2: Adult. Known cardiac mass in echocardiography. Unknown etiology. Next imaging study.

G. CTA coronary arteries with IV contrast

There is no relevant literature to support the use of CTA coronary arteries with IV contrast for the characterization of a suspected cardiac mass. CTA may provide assessment feeding artery in myxoma and paraganglioma, which helps in surgical planning.

Variant 2: Adult. Known cardiac mass in echocardiography. Unknown etiology. Next imaging study.

H. DOTATATE PET/CT skull base to mid-thigh

A DOTATATE scan may be used in the detection of cardiac metastasis from neuroendocrine tumors, carcinoid tumors, and paragangliomas due to expression of somatostatin receptors 2 subtype [52-54]. DOTATATE has a 100% sensitivity in the detection of cardiac paragangliomas compared with 57.1% for FDG-PET/CT [52]. Concomitant CT showed a sensitivity of 19% and specificity of 100% [54].

^{18}F-6-fluoro-L-DOPA PET/CT, which targets paragangliomas via a large amino-acid transporter system, also has a 100% sensitivity for the detection of cardiac paragangliomas, but DOTATATE has higher sensitivity for succinate dehydrogenase mutations, which are seen in 80% of cardiac paragangliomas [55]. DOTATATE is also used for staging of cardiac paragangliomas because of the sensitivity of detection of metastasis [55]. ^{68}Ga-DOTA-Phe1-Tyr3-octreotide (DOTATOC),^{68}Ga-DOTA-Tyr3-octreotate (DOTANOC), ^{18}F-FDOPA, and ^{18}F-fluorodopamine (^{18}F-FDA) have also been shown to be sensitive in the detection of cardiac metastasis from serotonin-producing neuroendocrine tumors, unrelated to the development of carcinoid syndrome [56-58]. $^{123/131}$I-MIBG or ^{18}F-FDA also target the norepinephrine transporter system found in paragangliomas [52].

Variant 2: Adult. Known cardiac mass in echocardiography. Unknown etiology. Next imaging study.

I. FDG-PET/CT heart

Cardiac FDG-PET/CT provides characterization of a cardiac and pericardiac mass as malignant versus benign/nonneoplastic based on standardized uptake value (SUV) [59]. FDG-PET/CT can also help in planning before biopsy. Compared with the more commonly performed whole body FDG-PET/CT, a dedicated cardiac PET/CT for cardiac masses requires a different prescan preparation to identify abnormal FDG uptake versus normal myocardial FDG uptake. Cardiac FDG-PET/CT requires a low/no-carbohydrate, high-fat diet for at least 24 hours or at least 2 high-fat, no-carbohydrate meals before fasting for at least 4 hours and IV heparin 50 IU/kg 1 hour before imaging if only one high-fat meal was used before fasting, to shift metabolism from glucose to fatty acid [3,29].

Various SUV values have been proposed as cutoffs to distinguish benign from malignant lesions with additional CT features improving the performance of FDG-PET/CT. The SUV values are also affected by technology, acquisition parameters, and ECG gating. A study of 65 cardiac masses that used standard diet preparation, but with prolonged fasting, showed that an SUV_{max} of ≥6.75 can distinguish benign from malignant masses, with a sensitivity, specificity, accuracy, PPV, and NPV of

92.11%, 88.89%, 90.77%, 92.11%, and 88.89%, respectively [60]. The addition of ≥3 CT features (infiltration of surrounding tissues, necrosis, multiple chamber/vascular involvement, distal metastasis) to SUV_{max} of ≥6.75 improved the performance to 94.74%, 88.89%, 92.31%, 92.31%, and 92.31%, respectively [60]. Another study of 38 patients showed that an SUV_{max} cutoff of 3.44 has a 100% sensitivity and specificity, and a maximum tumor-to-background ratio of 1.55 has a 95.8% sensitivity and 92.9% specificity in distinguishing malignancy from benign lesions [61]. A study of 59 patients showed that SUV_{max} of 3.8 has a 96.6% sensitivity and 93.9% specificity for the diagnosis of malignancy [62]. Rahbar et al [63], in a study of 24 patients, showed that an SUV_{max} of 4.2 can distinguish benign from malignant masses, with a sensitivity and specificity of 94% and 100%, respectively, although they could not be distinguished based only on metabolism. The presence of ≥3 morphological CT criteria (contrast uptake, tumor infiltration to surrounding tissue, infiltration into epicardium, irregular margin, necrosis, pericardial effusion, involvement of >1 chamber) has a specificity of 100% and a sensitivity of 70%. A lower SUV_{max} cutoff of 3.5 has a sensitivity of 100% and specificity of 86% (accuracy, 96%) [63]. In a study of 60 masses, D'Angelo et al [46] showed that an SUV_{max} ≥4.9 has an 86.8% sensitivity, 94.4% specificity, and 89.3% accuracy; total lesion glycolysis ≥29 has a 90% sensitivity, 100% specificity, and 91.7% accuracy; and metabolic tumor volume ≥8.2 has a 83.3% sensitivity, 100% specificity, and 86.1% accuracy. The presence of ≥5 CT signs (of irregular margins, pericardial effusion, invasion, solid nature, diameter >3 cm, CT contrast uptake) and precontrast characteristics (solid component, isoattenuating lesion, calcification) has a 100% PPV for malignancy, and the presence of ≤2 CT features has 100% NPV. Three or 4 CT features have a PPV of 87%, which can be increased to 100% with the presence of at least one abnormal FDG-PET/CT parameter. Irregular margins have an accuracy of 92%. Liu et al [64], in a study of 46 patients using FDG-PET/CT and dual-phase contrast CTA, showed a diagnostic accuracy of FDG-PET of 85%, CT of 83%, and combined FDG-PET/CT of 93%. PET used SUV, SUV adjusted for serum glucose, and tumor-to-background ratio. Malignant CT features in this study included involvement of right heart or multiple chambers, mediastinum or great vessels, broad-based attachment (>5 cm), and at least moderate enhancement, whereas benign CT features included internal calcification, smooth boundary, and lack of enhancement. A meta-analysis of 7 studies of 469 patients showed that higher SUV_{max} (>10) indicates malignancy versus benign lesions (SUV_{max} <3.5), with FDG-PET/CT having 92% to 100% sensitivities and 84% to 92% specificities [65]. Higher SUV_{max} also correlates with poor survival [65].

FDG-PET/CT can distinguish diffuse large B-cell lymphoma from other cardiac tumors based on greater FDG uptake, location in right atrioventricular groove, encasement without stenosis of coronary arteries, and presence of a large pericardial effusion [13]. R-kurtosis (PET-derived tumor expansion pattern) of ≥0.444 had an 88.9% probability of lymphoma versus sarcoma, and R-kurtosis >0.044 plus conduction disorders had an 80% probability [66]. In a 17-patient study, Liu et al [64] showed that an SUV_{mean} of >5.17 and contrast-enhanced CT morphological features (homogeneity of enhancement, focal/diffuse) can distinguish primary cardiac lymphoma and angiosarcoma, with a 100% accuracy, sensitivity, and diagnostic accuracy. PET/CT alone showed an 89% sensitivity, 75% specificity, and 82% accuracy, whereas thoracic contrast-enhanced CT alone showed a 78% sensitivity, 100% specificity, and 88% diagnostic accuracy [64].

FDG-PET/CT had superior sensitivity than echocardiography for the detection of malignant cardiac/pericardiac masses (96.6% versus 72.4%) and malignant cardiac neoplasms (95.6% versus 78.3%) [62]. A study on 119 patients with cardiac masses showed that PET/CT increased decision-making rate from 49% before PET to 100% after and is the most efficient technique to distinguish

benign and malignant masses, with AUC of 0.89 for benign and 0.94 for malignant lesions [47]. A meta-analysis of 6 studies of 408 patients showed that FDG-PET/CT had a higher pooled sensitivity over conventional imaging modalities (MRI, CT, TEE) (0.89 versus 0.7), lower pooled specificity (0.89 versus 0.96), higher diagnostic odds ratio (64 versus 52), and similar AUC [14]. Limitations of FDG-PET/CT include dependency of results on FDG uptake time, blood glucose levels, insulin medication, highly variable and nonuniform cardiac FDG uptake in fasted patients, limited scanner spatial resolution, and lack of cardiac and breathing motion correction [14].

Variant 2: Adult. Known cardiac mass in echocardiography. Unknown etiology. Next imaging study.

J. FDG-PET/CT skull base to mid-thigh

FDG-PET/CT skull base to mid-thigh typically involves standard preparation, which involves fasting for at least 4 to 6 hours and a high-protein, low-carbohydrate diet for 24 hours before scanning [29]. This technique is not used for the evaluation of a cardiac mass due to normal, physiological myocardial uptake of FDG. A study of 66 cardiac masses showed that FDG-PET with standard 4- to 6-hour fasting has a sensitivity and specificity of 70% to 83% and 75% to 88% in the diagnosis of cardiac mass with MRI as the reference standard, which dropped to 49% when thrombus is included. FDG activity was related to the degree of contrast enhancement. Lesions missed in PET/CT were mostly mobile lesions below the temporal resolution of PET/CT [67]. Standard preparation FDG-PET/CT is typically used in the detection of a primary extracardiac tumor in a known cardiac metastasis or the detection of extracardiac malignancy in a known cardiac primary (i.e., staging) [3,60]. Metastasis is usually more amenable to biopsy [3]. For staging, FDG-PET outperformed contrast-enhanced CT on a per-patient (66.7% versus 55.6% correct diagnosis, respectively), per-organ (10 versus 7 organs, respectively), and per-lesion basis (>29 versus >25 lesions, respectively) [68].

Variant 2: Adult. Known cardiac mass in echocardiography. Unknown etiology. Next imaging study.

K. FDG-PET/MRI heart

FDG-PET/MRI is a hybrid technique that combines the strengths of PET and MRI (i.e., metabolic and blood flow information from the former and morphological and functional information from the latter). FDG-PET/MRI heart is typically performed following a dedicated preparation of a low/no-carbohydrate, high-fat diet for at least 24 hours or at least 2 high-fat, no-carbohydrate meals before fasting for at least 4 hours and IV heparin 50 IU/kg 1 hour before imaging if only one high-fat meal was used before fasting, to shift metabolism from glucose to fatty acid [3]. A small study of 28 patients that used histology for malignancy and response to anticoagulation for thrombus as the reference standards showed that FDG-PET/CT with standard preparation had a lower specificity (84.6% versus 100%), lower PPV (87.5% versus 100%) and lower accuracy (89.3% versus 92.9%) than MRI but higher sensitivity (93.3% versus 86.7%) for distinguishing benign from malignant lesions. Combining FDG-PET with MRI combines the high sensitivity of PET with the high specificity of MRI [68]. In a study of 72 patients, Aghayev et al [69] showed that FDG uptake with SUV_{max}/blood pool ≥3.0 had a high specificity of 88%, and cardiac MR features (size, location, T1and T2 signal intensity, fat suppression, pericardial effusion, first-pass perfusion, late gadolinium enhancement [LGE], mobility, shape) had a high specificity of 98%. Combining multiple (>4) MRI features and FDG uptake (SUV_{max}/blood pool ratio ≥3.0) yielded a sensitivity of 85% and a specificity of 88% to diagnose malignant masses. In a study of 20 patients, FDG-PET/MRI showed that an SUV cutoff ≥5.2 can distinguish benign and malignant tumors, with a 100% sensitivity and 92% specificity. MRI T2-signal and contrast had a sensitivity of 100% and specificities of 54% and

46%, respectively; morphological cine features had an 86% sensitivity and 92% specificity; and all available MRI features yield a 100% sensitivity and 92% specificity, whereas a Boolean "AND" combination of an SUV_{max} of ≥5.2, providing 100% sensitivity and specificity [70].

Variant 2: Adult. Known cardiac mass in echocardiography. Unknown etiology. Next imaging study.
L. MIBG scan whole body with SPECT or SPECT/CT chest

MIBG scintigraphy has a 54.5% to 75% detection rate of cardiac paragangliomas and may be useful in the evaluation of neuroendocrine tumors [52].

Variant 2: Adult. Known cardiac mass in echocardiography. Unknown etiology. Next imaging study.
M. MRA chest with IV contrast

There is no relevant literature to support the use of MRA chest with IV contrast for the characterization of suspected cardiac mass.

Variant 2: Adult. Known cardiac mass in echocardiography. Unknown etiology. Next imaging study.
N. MRA coronary arteries without and with IV contrast

There is no relevant literature to support the use of MRA coronary arteries without and with IV contrast for the characterization of suspected cardiac mass.

Variant 2: Adult. Known cardiac mass in echocardiography. Unknown etiology. Next imaging study.
O. MRI chest with IV contrast

There is no relevant literature to support the use of MRI chest with IV contrast for the characterization of suspected cardiac mass.

Variant 2: Adult. Known cardiac mass in echocardiography. Unknown etiology. Next imaging study.
P. MRI chest without and with IV contrast

There is no relevant literature to support the use of MRI chest without and with IV contrast for the characterization of suspected cardiac mass.

Variant 2: Adult. Known cardiac mass in echocardiography. Unknown etiology. Next imaging study.
Q. MRI chest without IV contrast

There is no relevant literature to support the use of MRI chest without IV contrast for the characterization of suspected cardiac mass.

Variant 2: Adult. Known cardiac mass in echocardiography. Unknown etiology. Next imaging study.
R. MRI heart function and morphology without and with IV contrast

MRI provides comprehensive assessment and characterization of cardiac masses, using morphological features and tissue characteristics. Morphological features include size, number, location, extension, and invasion of adjacent structures. The signal characteristics of the mass are evaluated in multiple sequences such as steady-state free precession and/or spoiled gradient-echo cine imaging, T1-weighted and T2-weighted black-blood sequences with and without fat saturation, diffusion, parametric mapping (T1, T2, T2*), perfusion, and early gadolinium

enhancement and LGE, including at long inversion times. MRI does not have adequate spatial or temporal resolution for the evaluation of mobile, small lesions, or feeding arteries, and it offers limited characterization of calcification [41,71].

DE-MRI can reliably differentiate LA thrombus from tumor in suspected cardioembolic stroke [72]. A study of 261 patients that used TEE as the reference standard showed an accuracy, sensitivity, and specificity of 99.2%, 100%, and 99.2%, respectively, for DE-MRI; 94.3%, 66.7%, and 95.2%, respectively, for MRA; and 91.6%, 66.7%, and 92.5%, respectively, for cine MRI in the diagnosis of left atrial and LAA thrombus [73]. In 43 masses, the diagnostic performance of signal intensity of MRI was better than dual-energy iodine concentration and postcontrast attenuation values (0.89 versus 0.77 versus 0.51) for differentiating cardiac thrombi and tumors [49]. A study of 116 patients showed that MRI had a higher accuracy (95%) of differentiating thrombus from neoplasm using low/similar signal intensity as myocardium—short T1 and low signal at high T1. The ability of MRI tissue features (signal intensity, homogeneity, first-pass perfusion, LGE, postcontrast T1) to distinguish benign and malignant tumors was moderate (79%) [31]. A study of 101 patients showed that MRI had an accuracy, sensitivity, specificity, PPV, and NPV of 96.6%, 98%, 86.6%, 96.2%, and 96.6%, respectively, for cardiac masses and 93.6%, 86.7%, 98.04%, 92.9%, and 97%, respectively, for thrombus [74].

MRI can reliably exclude a pseudotumor and characterize a mass as benign or malignant with 95% accuracy compared with histology using tumor perfusion, invasiveness, localization, and pericardial fluid [5]. Morphological features that distinguish a malignant from benign lesion include bulky mass (>5 cm), broad-base, heterogeneous signal (due to hemorrhage and necrosis), contrast enhancement, indistinct margins, infiltrative signs (crossing tissue planes), involvement of adjacent structures, and distal metastasis. Absence of these features does not necessarily exclude cardiac neoplasm [71]. In a study of 249 patients, MRI can differentiate thrombus and myxoma in 88.4% of cases and accurately diagnose malignant masses, with missed or misdiagnosis of a few benign masses [75]. A heterogeneous pattern of enhancement is seen in 59% of cardiac metastasis, with poorer survival in patients with cancer with cardiac metastasis than those without cardiac metastasis [76]. A retrospective study on 66 patients that used a decision-tree algorithm (based on classification and regression tree analysis) using first-pass perfusion, tumor invasion, LGE, and pericardial effusion had a 90% diagnostic accuracy in differentiating benign from malignant, with the cost of misclassifying a malignant tumor as benign twice that of classifying benign as malignant [77]. A 145-patient study with histological correlation showed that readers were able to correctly diagnose cardiac mass as benign or malignant using MRI in 89% to 94% of cases, with a 95% agreement rate [78]. In a multicenter study of 903 patients, MRI was accurate in 98.4% in distinguishing benign from malignant masses, with an MRI diagnosis of pseudotumor or benign mass having similar outcomes as those of no mass, whereas those with malignant tumor (hazard ratio [HR] 3.31) and thrombus (HR 1.46) had greater mortality. Long T1 MRI had a 98.7% accuracy in distinguishing thrombus from tumor. MRI diagnosis provided incremental prognostic value over LV ejection fraction, CAD, and extracardiac malignancy. Importantly, half the patients were referred for evaluation of a suspected cardiac mass, and MRI was accurate in excluding a mass or identifying a pseudomass, which was confirmed by an almost 5-year follow-up [76]. In masses followed up without histology, no adverse event occurred in 5 years [79]. A study on 119 patients showed that MRI increased decision-making rate from 31% before MRI to 85% after [47].

A 125-patient study showed that MRI had more concordance with histology than TTE (76% versus

58%), with malignant lesions being larger, infiltrative, having higher LGE and isointense signal in T1-weighted images, with similar perfusion and T2 black-blood signal intensity. In another study on 50 patients, MRI had a higher accuracy than echocardiography (77% versus 43%) with histological reference standard in distinguishing nonneoplasm versus benign versus malignant. MRI used location outside right atrium T2-hyperintensity and contrast enhancement for benign tumor and location outside cardiac chambers, nonmobility, pericardial effusion, myocardial invasion, and contrast enhancement for malignancy, identifying 6 cases missed in TTE [80]. MRI correctly classified benign versus malignant in 98% versus 57% in TTE [81]. In a small study of 28 patients, MRI detected 4 additional masses compared with echocardiography, correctly characterized the mass in 75% of cases compared with 29% in echocardiography, and provided additional information compared with echocardiography in up to 46% of cases [82]. In a small study of 28 patients that used histology for malignancy and response to anticoagulation for thrombus as the reference standards, MRI had better specificity than FDG-PET/CT with standard preparation (100% versus 84.6%), PPV (100% versus 87.5%), and accuracy (92.9% versus 89.3%), albeit lower sensitivity (86.7% versus 93.3%) for distinguishing benign from malignant masses [68]. MRI-derived model including mass localization (nonleft heart chamber, pericardial effusion), morphology (sessile, polylobate, infiltration), and tissue characterization (first-pass perfusion and heterogeneity) (scores 0-8, cutoff ≥5) has a high accuracy with AUC of 0.976 in predicting malignancy (sensitivity 92%, specificity 96%), higher than echocardiography (which used infiltration, pericardial effusion, sessile, polylobate mass, inhomogeneity, and nonleft localization and a cutoff of ≥3) with AUC of 0.932 (sensitivity 93%, specificity 80%), and predicted higher risk of mortality using histology as reference standard [83].

Several novel parameters are also being evaluated. A 42-patient study showed that MRI can characterize masses based on T1- and T2-mapping. Thrombus has similar signal as myocardium, with recent thrombus having lower signal than chronic thrombus. Lipoma, calcifications, and melanoma have lower T1 values than myocardium, with other masses have higher T1 values than myocardium; T2 values were high for most masses including thrombus [84]. Calcifications have short T1/short T2, lipoma and melanoma have short T1/long T2; most tumors have long T1/long T2, similar to myocardium for rhabdomyoma and long/very long T1 for myxoma or fibroelastoma. Postcontrast T1 values of thrombus were 30% lower than precontrast [84]. Radiomics features from native T1 maps had higher AUC than mean native T1 and LGE ratio (0.98 versus 0.86 versus 0.82, P = .001) for distinguishing thrombus from neoplasms. Combining radiomics score and native T1 improved the diagnostic performance over mean T1 or LGE. With an optimal cutoff value of –6.5, radiomics score showed a sensitivity, specificity, and accuracy of 95.4%, 95.2%, and 95.2%, respectively [85]. With a cutoff value of 1540.3 ms, native T1 showed a sensitivity, specificity, and accuracy of 81.8%, 81.0%, and 81.4%, respectively. The LGE ratio also demonstrated a lower diagnostic performance than that of the radiomics score (AUC 0.82). With a cutoff value of 3.4, it showed a sensitivity, specificity, and accuracy of 68.2%, 95.2%, and 81.4%, respectively [85].

Variant 2: Adult. Known cardiac mass in echocardiography. Unknown etiology. Next imaging study.

S. MRI heart function and morphology without IV contrast

Without IV contrast, MRI can still provide some assessment and characterization of cardiac masses, using morphological features and tissue characteristics. Morphological features include size, number, location, extension, and invasion of adjacent structures. The signal characteristics of the mass are evaluated in multiple sequences such as steady-state free precession, T1-weighted and T2-weighted black-blood sequences with and without fat saturation, diffusion, and parametric

mapping (T1, T2, T2*).

A study of 261 patients that used TEE as the reference standard showed an accuracy, sensitivity, and specificity of 91.6%, 66.7% and 92.5%, respectively, for cine MRI in the diagnosis of left atrial and LAA thrombus [73]. In 43 masses, the diagnostic performance of signal intensity of MRI was better than dual-energy iodine concentration and postcontrast attenuation values (0.89 versus 0.77 versus 0.51) for differentiating cardiac thrombi and tumors [49]. A study of 116 patients showed that MRI had a higher accuracy (95%) of differentiating thrombus from neoplasm using low/similar signal intensity as myocardium—short T1 and low signal at high T1 [31]. A 42-patient study showed that MRI can characterize masses based on T1- and T2-mapping. Thrombus has a similar signal as myocardium, with recent thrombus having lower signal than chronic thrombus. Lipoma, calcifications, and melanoma have lower T1 values than myocardium, with other masses have higher T1 than myocardium; T2 values were high for most masses, including thrombus [84]. Calcifications have short T1/short T2, lipoma and melanoma have short T1/long T2, and most tumors have long T1/long T2, such as myocardium for rhabdomyoma and long/very long T1 for myxoma or fibroelastoma. Postcontrast T1 values of thrombus were 30% lower than precontrast [84]. Radiomics features from native T1 maps had higher AUC than mean native T1 and LGE ratio (0.98 versus 0.86 versus 0.82, P = .001) for distinguishing thrombus from neoplasms. Combining radiomics score and native T1 improved the diagnostic performance over mean T1 or LGE. With an optimal cutoff value of –6.5, radiomics score showed a sensitivity, specificity, and accuracy of 95.4%, 95.2%, and 95.2%, respectively [85]. With a cutoff value of 1540.3 ms, native T1 showed a sensitivity, specificity, and accuracy of 81.8%, 81.0%, and 81.4%, respectively. The LGE ratio also demonstrated a lower diagnostic performance than that of the radiomics score (AUC 0.82). With a cutoff value of 3.4, it showed a sensitivity, specificity, and accuracy of 68.2%, 95.2%, and 81.4%, respectively [85].

Variant 2: Adult. Known cardiac mass in echocardiography. Unknown etiology. Next imaging study.

T. Octreotide scan with SPECT or SPECT/CT chest and abdomen

Octreotide scan may be useful in the evaluation of neuroendocrine tumors [52].

Variant 2: Adult. Known cardiac mass in echocardiography. Unknown etiology. Next imaging study.

U. Radiography chest

There is no relevant literature to support the use of radiography chest for the characterization of suspected cardiac mass.

Variant 2: Adult. Known cardiac mass in echocardiography. Unknown etiology. Next imaging study.

V. US echocardiography transesophageal

TEE can provide further evaluation of the morphology of a cardiac mass, including the attachment, extension, and hemodynamic effects, particularly useful in the evaluation of atrial and valvular lesions, especially left atrium or mitral valve. Three-dimensional TEE provides incremental value in accurate assessment of the size, shape, composition, and relationship with adjacent structures [86]. Ultrasound contrast agents improve the capabilities of TEE, with malignant tumors demonstrating greater enhancement than benign tumors and thrombus [87]. A small study of 24 patients showed that TEE was superior to TTE in the assessment of cardiac masses in all sites in the heart and vessels, with a 100% accuracy for TEE compared with 70% for TTE [82]. A study on 119 patients

showed that TEE increased the decision-making rate from 2% before TEE to 54% after. TEE is particularly efficient for atrial masses, with the decision rate for left atrial mass increasing from 0% to 74% [47].

Variant 2: Adult. Known cardiac mass in echocardiography. Unknown etiology. Next imaging study.

W. US echocardiography transthoracic resting

TTE can assess the location and morphological features of cardiac mass including size, mobility, and involvement of adjacent structures such as pericardium. TTE is particularly good for the evaluation of small, mobile masses, especially those attached to the valves [9]. TTE is also excellent in assessing the hemodynamic effect including valvular or vascular obstruction or regurgitation [9]. Tissue characterization of the mass is limited, with texture homogeneity found to be useful [88]. Echocardiography is limited by acoustic windows, and small field of view for the evaluation of extracardiac extension. Nonleft localization, sessile, polylobate shape, inhomogeneity, infiltration, and moderate/severe pericardial effusion are independent predictors of malignancy. The malignant predictive ability of the unweighted echocardiographic score of ≥3 was very high, with a sensitivity of 93%, specificity of 80%, and AUC of 0.932, compared with 92%, 96%, and 0.932, respectively, for MRI [89]. Another study on 86 patients that used morphological features showed that a maximum diameter >28 mm and a minimum diameter >19.5 mm are cutoff values for the differentiation of benign and malignant tumors. TTE had better diagnostic accuracy than CT and MRI (84%, 81%, 76%, respectively) in a single-center retrospective review [68]. A study on 95 patients showed an accuracy of 80% for TTE compared with histology [90]. A study on 86 patients showed that TTE and abdominal sonography can evaluate the vascularity of thrombus in the right heart extending from malignancies [53].

Ultrasound contrast agents improve the capabilities of TTE for tissue characterization, with malignant tumors demonstrating greater enhancement than benign tumors and thrombus [87,91]. However, movement of contrast media can interfere with enhancement of the mass, resulting in up to 25% nondiagnostic scans. Benign lesions show regular morphology, clear-boundary, and uniform enhancement that is less than adjacent myocardium, whereas malignant lesions show irregular shape, unclear boundary, and uneven enhancement, which is higher than normal myocardium. Thrombus shows no enhancement [92]. Quantitative real-time perfusion (blood volume, blood flow velocity, microvascular blood flow) can distinguish thrombus (no perfusion) from benign and malignant tumors. Blood flow volume >3.28 dB at peak dipyridamole stress predicted malignancy (AUC 0.75), with 5.8 times higher chance of being malignant than benign tumors [93]. Novel methods such as artificial intelligence, including a fully automatic classification method based on sparse representation, was shown to have a high accuracy of 96.91%, sensitivity of 100%, and specificity of 93.02% in classifying cardiac tumors and thrombus [94].

Variant 3: Adult. Known cardiac mass. Established etiology. Follow-up imaging.

Follow-up imaging is performed during ongoing care for patients with established and characterized cardiac masses. Follow-up imaging is required for untreated benign masses to assess any interval growth or compromise of adjacent structures such as valves. Follow-up imaging is also required for masses treated with anticoagulants, surgery, radiotherapy, or chemotherapy to evaluate response to therapy and for any residual or recurrent masses.

Variant 3: Adult. Known cardiac mass. Established etiology. Follow-up imaging.

A. Arteriography coronary with ventriculography

There is no relevant literature to support the use of coronary arteriography with ventriculography for the follow-up of a known and characterized cardiac mass.

Variant 3: Adult. Known cardiac mass. Established etiology. Follow-up imaging.
B. CT chest with IV contrast

There is no relevant literature to support the use of CT chest with IV contrast for the follow-up of a known and characterized cardiac mass. Contrast timing and other technical parameters are not optimized for follow-up of a known cardiac mass.

Variant 3: Adult. Known cardiac mass. Established etiology. Follow-up imaging.
C. CT chest without and with IV contrast

There is no relevant literature to support the use of CT chest without and with IV contrast for the follow-up of a known and characterized cardiac mass. Contrast timing and other technical parameters are not optimized for follow-up of a known cardiac mass.

Variant 3: Adult. Known cardiac mass. Established etiology. Follow-up imaging.
D. CT chest without IV contrast

There is no relevant literature to support the use of CT chest without IV contrast for the follow-up of a known and characterized cardiac mass.

Variant 3: Adult. Known cardiac mass. Established etiology. Follow-up imaging.
E. CT heart function and morphology with IV contrast

In an already characterized mass, CT heart function and morphology with IV contrast is an effective technique for evaluating change in size or internal characteristics and any residual or recurrent mass [5]. CT with ECG gating, heart rate control, and delayed imaging has pooled sensitivities of 0.991, specificities of 0.989, and AUC of 0.9972 in diagnosis of cardiac thrombus [45].

Variant 3: Adult. Known cardiac mass. Established etiology. Follow-up imaging.
F. CTA chest with IV contrast

There is no relevant literature to support the use of CTA chest with IV contrast for follow-up of a known cardiac mass. The technical parameters such as slice thickness, contrast timing, field of view, and ECG synchronization are not optimized for the evaluation of a suspected cardiac mass.

Variant 3: Adult. Known cardiac mass. Established etiology. Follow-up imaging.
G. CTA coronary arteries with IV contrast

There is no relevant literature to support the use of CTA coronary arteries with IV contrast for the follow-up of a known and characterized cardiac mass.

Variant 3: Adult. Known cardiac mass. Established etiology. Follow-up imaging.
H. DOTATATE PET/CT skull base to mid-thigh

DOTATATE scan is useful in the detection of cardiac metastasis from neuroendocrine tumors, carcinoid tumors, and paragangliomas [52-54].

Variant 3: Adult. Known cardiac mass. Established etiology. Follow-up imaging.
I. FDG-PET/CT heart

FDG-PET/CT of the heart with dedicated preparation maybe useful for follow-up of known cardiac mass, assessing response to therapy, and assessing any residual or recurrent lesion [5,8]. FDG-PET/CT is particularly useful when the cardiac mass had FDG uptake. FDG-PET/CT has a high sensitivity of 95.2% in the detection of cardiac masses, which is superior to that of MRI (93.1%) and CT (83.4%). FDG-PET/CT captures early changes of glucose metabolism that accompany response

to treatment, which often precedes anatomical changes. Response assessment criteria define optimal thresholds for response categories [95]. Although there is no specific evidence for cardiac masses, the role of FDG-PET/CT in the assessment of response to surgery, chemotherapy, radiation, immunotherapy, and hormonal therapy has been well established for multiple other types of malignancies. There is limited evidence that positive response to therapy of cardiac mass results in a decrease or resolution of FDG uptake [13].

Variant 3: Adult. Known cardiac mass. Established etiology. Follow-up imaging.
J. FDG-PET/CT skull base to mid-thigh

There is no relevant literature to support the use of FDG-PET/CT skull base do mid-thigh for the follow-up of a known and characterized cardiac mass. FDG-PET/CT skull base to mid-thigh with standard preparation involves fasting for at least 4 to 6 hours and a high-protein, low-carbohydrate diet for 24 hours before scanning [29]. This technique is not used for follow-up of a known cardiac mass due to normal, physiological myocardial uptake of FDG. However, this technique can be used for assessing responses at other sites of metastatic disease. Some centers may perform FDG-PET/CT skull base to mid-thigh with preparation to suppress myocardial uptake and evaluate noncardiac tumors as well.

Variant 3: Adult. Known cardiac mass. Established etiology. Follow-up imaging.
K. FDG-PET/MRI heart

FDG-PET/MRI heart is useful in the follow-up of cardiac masses after treatment, based on metabolic information and morphological characteristics [96]. Even with non–FDG-avid masses, MRI can provide sufficient information for follow-up of cardiac masses.

Variant 3: Adult. Known cardiac mass. Established etiology. Follow-up imaging.
L. MRA chest with IV contrast

There is no relevant literature to support the use of MRA chest with IV contrast for follow-up of known and characterized cardiac mass.

Variant 3: Adult. Known cardiac mass. Established etiology. Follow-up imaging.
M. MRA coronary arteries without and with IV contrast

There is no relevant literature to support the use of MRA coronary arteries without and with IV contrast for follow-up of known and characterized cardiac mass.

Variant 3: Adult. Known cardiac mass. Established etiology. Follow-up imaging.
N. MRI chest with IV contrast

There is no relevant literature to support the use of MRI Chest with IV contrast for follow-up of known and characterized cardiac mass.

Variant 3: Adult. Known cardiac mass. Established etiology. Follow-up imaging.
O. MRI chest without and with IV contrast

There is no relevant literature to support the use of MRI Chest without and with IV contrast for follow-up of known and characterized cardiac mass.

Variant 3: Adult. Known cardiac mass. Established etiology. Follow-up imaging.
P. MRI chest without IV contrast

There is no relevant literature to support the use of MRI Chest without IV contrast for follow-up of known and characterized cardiac mass.

Variant 3: Adult. Known cardiac mass. Established etiology. Follow-up imaging.

Q. MRI heart function and morphology without and with IV contrast

MRI is a useful modality in the follow-up of cardiac mass, including thrombus after anticoagulant therapy, benign masses without therapy, and malignant tumors following treatment to assess for residual/recurrent tumor. MRI can reliably exclude a pseudotumor and characterize a mass as benign or malignant with 95% accuracy compared with histology using tumor perfusion, invasiveness, localization, and pericardial fluid [5].

Variant 3: Adult. Known cardiac mass. Established etiology. Follow-up imaging.
R. MRI heart function and morphology without IV contrast

MRI without IV contrast can evaluate the change in size and signal characteristics of a known cardiac mass. For differentiating cardiac thrombi and tumors, the diagnostic performance of signal intensity of MRI was better than dual-energy iodine concentration and postcontrast attenuation values (0.89 versus 0.77 versus 0.51) [49]. MRI had a higher accuracy (95%) of differentiating thrombus from neoplasm using low/similar signal intensity as myocardium—short T1 and low signal at high T1 [31].

Variant 3: Adult. Known cardiac mass. Established etiology. Follow-up imaging.
S. Octreotide scan with SPECT or SPECT/CT chest and abdomen

There is no relevant literature to support the use of octreotide scan with SPECT or SPECT/CT chest and abdomen or the follow-up of a known and characterized cardiac mass.

Variant 3: Adult. Known cardiac mass. Established etiology. Follow-up imaging.
T. Radiography chest

There is no relevant literature to support the use of radiography chest for the follow-up of a known and characterized cardiac mass.

Variant 3: Adult. Known cardiac mass. Established etiology. Follow-up imaging.
U. US echocardiography transesophageal

TEE maybe useful for the follow-up of a known and characterized cardiac mass in some circumstances, particularly if the mass was previously characterized by TEE and in some locations such as left atrium/atrial appendage. A study of 389 surgically resected masses showed that TEE had a high sensitivity of 95.2%, comparable to that of FDG-PET/CT in the detection of cardiac masses, which is superior to that of MRI (93.1%) and CT (83.4%) [28]. A small study of 24 patients showed that TEE was superior to TTE in the assessment of cardiac masses in all sites in heart and vessels, with a 100% accuracy for TEE compared with 70% for TTE [82].

Variant 3: Adult. Known cardiac mass. Established etiology. Follow-up imaging.
V. US echocardiography transthoracic resting

TTE is the first-line imaging modality used in the follow-up of cardiac masses. In the detection of thrombus, TTE with contrast echocardiography has a higher sensitivity (61% versus 33%) and accuracy (92% versus 82%) compared with noncontrast-enhanced echocardiography [33]. TTE has a high sensitivity of 93%, specificity of 80% and AUC of 0.932 in prediction of malignancy [89].

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**: For initial imaging in an adult with suspected cardiac mass, TTE resting, CT heart

function and morphology with IV contrast, and MRI heart function and morphology without and with IV contrast are the recommended studies to establish the presence or absence of cardiac mass. These studies are equivalent alternatives, but often echocardiography is obtained along with either CT or MRI, because they may provide complementary information. CTA chest with IV contrast, MRI heart function and morphology without IV contrast, and TEE may be appropriate in some circumstances with suspected cardiac thrombus.

- **Variant 2**: For initial imaging in an adult with a known cardiac mass detected on echocardiography, MRI heart function and morphology without and with IV contrast, CT heart function and morphology with IV contrast, FDG-PET/CT heart, FDG-PET/MRI heart, TTE resting, and TEE are the recommended studies to characterize the mass and plan treatment that provide complementary information. MRI provides comprehensive assessment and characterization of cardiac masses, using morphological features and tissue characteristics. FDG-PET/CT with dedicated preparation is a complementary modality that provides metabolic information. FDG-PET/MRI combines the metabolic information from FDG and morphological and functional information of MRI. CT is used in the evaluation of calcified masses, feeding arteries, involvement of adjacent structures, particularly coronary arteries, and CAD before interventional or surgical procedures. TEE can provide further evaluation of the morphology of a cardiac mass, including the attachment, extension, and hemodynamic effects, which are particularly useful in the evaluation of atrial and valvular lesions, especially left atrium or mitral valve.

- **Variant 3**: For follow-up imaging in an adult with a known cardiac mass and established etiology, TTE resting, MRI heart function and morphology without and with IV contrast, MRI heart function and morphology without IV contrast, CT heart function and morphology with IV contrast, and FDG-PET/MRI heart are recommended to evaluate interval changes and response to therapy. These studies are equivalent alternatives, but often echocardiography is obtained along with CT, MRI, or FDG-PET/MRI, because they may provide complementary information.

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.”

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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.

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