New 2019

American College of Radiology
ACR Appropriateness Criteria®
Chest Pain-Possible Acute Coronary Syndrome

Variant: 1 Chest pain, low to intermediate probability for acute coronary syndrome. Initial imaging.

Procedure	Appropriateness Category	Relative Radiation Level
US echocardiography transthoracic stress	Usually Appropriate	O
Radiography chest	Usually Appropriate	☢
CTA coronary arteries with IV contrast	Usually Appropriate	☢☢☢
SPECT or SPECT/CT MPI rest and stress	Usually Appropriate	☢☢☢☢
US echocardiography transthoracic resting	May Be Appropriate	O
MRI heart function and morphology without and with IV contrast	May Be Appropriate	O
MRI heart with function and inotropic stress without and with IV contrast	May Be Appropriate	O
MRI heart with function and inotropic stress without IV contrast	May Be Appropriate	O
MRI heart with function and vasodilator stress perfusion without and with IV contrast	May Be Appropriate	O
CT coronary calcium	May Be Appropriate	☢☢☢
CTA chest with IV contrast	May Be Appropriate	☢☢☢
SPECT or SPECT/CT MPI rest only	May Be Appropriate	☢☢☢
Rb-82 PET/CT MPI rest and stress	May Be Appropriate (Disagreement)	☢☢☢☢
US echocardiography transesophageal	Usually Not Appropriate	O
Arteriography coronary	Usually Not Appropriate	☢☢☢
MRA coronary arteries without and with IV contrast	Usually Not Appropriate	O
MRA coronary arteries without IV contrast	Usually Not Appropriate	O
MRI heart function and morphology 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	☢☢☢

Variant: 2 Chest pain, high probability for acute coronary syndrome. Initial imaging.

Procedure	Appropriateness Category	Relative Radiation Level
Radiography chest	Usually Appropriate	☢
Arteriography coronary	Usually Appropriate	☢☢☢
US echocardiography transthoracic resting	May Be Appropriate	O
US echocardiography transthoracic stress	May Be Appropriate (Disagreement)	O
MRI heart function and morphology without and with IV contrast	May Be Appropriate (Disagreement)	O
CTA coronary arteries with IV contrast	May Be Appropriate	☢☢☢
SPECT or SPECT/CT MPI rest only	May Be Appropriate (Disagreement)	☢☢☢

SPECT or SPECT/CT MPI rest and stress	May Be Appropriate	☢☢☢☢
US echocardiography transesophageal	Usually Not Appropriate	O
MRA coronary arteries without and with IV contrast	Usually Not Appropriate	O
MRA coronary arteries without IV contrast	Usually Not Appropriate	O
MRI heart function and morphology without IV contrast	Usually Not Appropriate	O
MRI heart with function and inotropic stress without and with IV contrast	Usually Not Appropriate	O
MRI heart with function and inotropic stress without IV contrast	Usually Not Appropriate	O
MRI heart with function and vasodilator stress perfusion 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 chest with IV contrast	Usually Not Appropriate	☢☢☢
Rb-82 PET/CT MPI rest and stress	Usually Not Appropriate	☢☢☢☢

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Summary of Literature Review

Introduction/Background

Cardiovascular disease is the leading cause of death in the United States. Annually, there are more than 8 million visits to emergency departments by patients with acute chest pain [1], with estimated health care costs of $13 to $15 billion [2]. Approximately 5% to 13% of those patients who present with acute chest pain are eventually found to have an acute coronary syndrome (ACS) [1]. ACS includes ST-segment elevation myocardial infarction (MI), non-ST-segment elevation (NSTE) MI, and unstable angina (acute ischemia without necrosis) [3]. Once diagnosed with ACS, the patient may be urgently transferred to a cardiac catheterization laboratory for invasive angiography and potential coronary revascularization [4,5]. For patients not identified immediately with ACS, categorizing low, intermediate, and high probability for ACS helps identify increasing risk for downstream major adverse cardiac events (MACE). Patients are predominantly stratified by clinical suspicion (including risk scores and risk stratification models), the evaluation of prompt electrocardiogram (ECG; serially if necessary), and the use of cardiac biomarkers (eg, serial troponins and B-type natriuretic peptide) [6,7]. Commonly used risk scores include the Thrombolysis in Myocardial Infarction risk score (TIMI RS), Global Registry of Acute Cardiac Events risk score (GRACE RS), the History, Electrocardiogram, Age, Risk factors, Troponin (HEART) score [8], and the Platelet glycoprotein IIb/IIIa in Unstable angina: Receptor Suppression Using Integrilin

Therapy risk score (PURSUIT RS), among many others [9,10]. Risk stratification of patients into low, intermediate, and high probability for ACS may therefore differ according to available institutional resources and practice, but these categories generally correspond to increasing likelihood of downstream MACE due to ACS. Historical risk scores such as the TIMI score, the GRACE score, and the PURSUIT score are being replaced by more accurate risk stratification tools such as the HEART score, which was designed specifically for evaluation of patients with chest pain in the emergency department without a diagnosis of ACS [8].

High-risk patients with a convincing clinical picture may quickly progress to an invasive strategy or to the presumption of obstructive coronary artery disease (CAD) treated medically. In the setting of confirmed ACS, "time is myocardium and time is outcomes," and prompt diagnosis can dramatically influence the downstream cardiovascular event rate [11-13]. However, ACS cannot be excluded in many patients with acute chest pain, even after initial clinical evaluation and diagnostic workup with ECG and cardiac biomarkers, and as many as 80% of these chest pain patients are admitted or observed for evaluation [14,15]. In the 1990s, studies showed 2% to 8% of emergency department patients were inappropriately discharged with a missed diagnosis of ACS, presenting a grave risk to those patients and the potential of litigation for physicians and healthcare facilities [16]. Although more recent studies have shown lower rates of missed diagnosis, appropriate identification of ACS remains an important issue.

Noninvasive imaging may therefore be indicated for risk stratification and clinical management in both low-risk and intermediate-risk patients [17]. This has continued to gain popularity since the first decade of the 2000s, with advanced medical imaging among chest pain patients quintupling [18]. This approach also serves to identify patients with a significant ischemic burden who could benefit from coronary revascularization [19-21]. Noninvasive imaging aids in the evaluation of the acute chest pain patients by either functionally determining a myocardial segment perfusion abnormality (eg, relative hypoperfusion, or a wall motion, or thickening abnormality, usually at stress testing) or anatomically visualizing an obstructive coronary artery stenosis. Although noninvasive imaging approaches have sensitivities and specificities in the 85% to 90% range, the corresponding false diagnosis rates are in the 10% to 15% range, and therefore consideration may be made to avoid diagnostic imaging altogether in patients at either end of the pretest probability spectrum [22]. Therefore, patient selection, as determined by clinical judgment and tools such as the HEART score, is critical because there has been historically a low yield of routine noninvasive cardiac imaging in low-risk patients [23-26].

Noncoronary etiologies for chest pain can also be established with imaging, the results of which may alter the patient's postdischarge care altogether. It is not uncommon for a patient to have acute chest pain occurring from other cardiovascular causes or noncardiac etiologies [17,27,28].

The available noninvasive cardiac imaging modalities include chest radiographs, rest single-photon emission computed tomography (SPECT) myocardial perfusion imaging (MPI), stress SPECT MPI, echocardiography (transthoracic and transesophageal), multidetector CT, PET (metabolic and perfusion), and MRI.

Special Imaging Considerations

For the purposes of distinguishing between CT and CT angiography (CTA), the 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) [29]:

> *"CTA uses a thin-section CT acquisition that is timed to coincide with peak arterial or venous enhancement. The resultant volumetric dataset is interpreted using primary transverse reconstructions as well as multiplanar reformations and 3-D renderings."*

All procedure elements are essential: 1) timing, 2) recons/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 CMS has applied to the CPT codes.

Discussion of Procedures by Variant

Variant 1: Chest pain, low to intermediate probability for acute coronary syndrome. Initial imaging.

Variant 1: Chest pain, low to intermediate probability for acute coronary syndrome. Initial imaging.

A. Arteriography Coronary

In patients with low to intermediate risk, arteriography is not the first-line evaluation or management. Patients with a nondiagnostic ECG and negative cardiac biomarkers should follow a clinical pathway beginning with a noninvasive approach [30].

Variant 1: Chest pain, low to intermediate probability for acute coronary syndrome. Initial imaging.

B. Radiography Chest

Chest radiography is primarily used for ruling out conditions that may masquerade as acute myocardial ischemia, as well as defining secondary findings that may accompany acute MI. Acute pulmonary edema can be seen on chest radiographs without enlargement of the cardiac silhouette in patients with acute MI and no prior history of ischemic damage or associated mitral valve disease. Although chest radiography is insufficient to confirm or exclude the presence of significant CAD, it may be useful in demonstrating clinically important pathology in a significant minority of ACS-suspected patients [31]. Other cardiovascular entities, such as aortic aneurysms, aortic dissections, and pulmonary embolism, may be suggested from the chest radiograph but with far lower sensitivity than in other imaging modalities, such as multidetector CT. Noncardiac findings associated with chest pain that can be identified on chest radiography include pneumothorax, fractured ribs, pleural effusions, and pneumonia, among others.

Variant 1: Chest pain, low to intermediate probability for acute coronary syndrome. Initial imaging.

C. SPECT or SPECT/CT MPI Rest Only

SPECT perfusion scintigraphy is an important test in the assessment for myocardial ischemia. In patients with active chest pain, an ECG with no ischemic changes, and an initial negative troponin, a promptly read rest SPECT has been demonstrated to be safe and clinically effective [32,33]. Rest-only MPI has been shown to be less sensitive than stress SPECT imaging if performed after the chest pain has subsided. The commonly used radionuclide agents are Tc-99m–labeled agents (eg, sestamibi, tetrofosmin). There is abundant literature describing the use of SPECT in ACS. The absence of a perfusion defect on an acute rest study is associated with a very high negative predictive value for ACS evaluation. As such, rest alone nuclear MPI has an American College of Cardiology/American Heart Association class I, level A recommendation for evaluation of suspected ACS [34] and has a well-established, well-supported track record in evaluating acute chest pain patients [35,36].

Variant 1: Chest pain, low to intermediate probability for acute coronary syndrome. Initial imaging.
D. SPECT or SPECT/CT MPI Rest and Stress

SPECT perfusion scintigraphy is an important test in the assessment for myocardial ischemia. Rest-only MPI has been shown to be less sensitive than stress SPECT imaging if performed after the chest pain has subsided. The commonly used radionuclide agents are Tl-201 (thallium) chloride and Tc-99m–labeled agents (eg, sestamibi, tetrofosmin). There is abundant literature describing the use of SPECT in ACS. A perfusion defect that becomes apparent or becomes larger during exercise stress or pharmacologic stress suggests ischemic myocardium. Patients with negative stress nuclear MPI can be safely discharged, and those with positive stress nuclear MPI have a higher likelihood of obstructive disease on subsequent coronary angiography compared with those evaluated by stress ECG [37]. In addition, trials in patients with stable ischemic heart disease suggest that the degree of ischemic myocardium may be more important than the presence of anatomic stenosis alone, using, for example, a threshold of 10% ischemic myocardium to identify patients likely to benefit from revascularization [38,39]. As such, vasodilator stress nuclear MPI has an American College of Cardiology/American Heart Association class I, level B recommendation for evaluation of suspected ACS [34] and has a well-established, well-supported track record in evaluating acute chest pain patients [35,36].

Variant 1: Chest pain, low to intermediate probability for acute coronary syndrome. Initial imaging.
E. US Echocardiography Transthoracic Stress

Stress echocardiography has been shown to be a modality equivalent to stress SPECT MPI in the acute setting in low- to intermediate-risk patients, with either exercise or a stress pharmacologic agent (such as dobutamine) inducing focal wall-motion abnormalities in the region(s) of ischemia [40-42]. When compared with stress ECG, stress echocardiography of acute chest pain patients in the emergency department has been shown to lead to fewer late events, including rehospitalization and late percutaneous coronary intervention [43,44], as well as excellent accuracy in predicting obstructive CAD on coronary angiography or subsequent cardiovascular events [45]. Positive stress echocardiography has been shown to identify incrementally more patients requiring revascularization in patients suspected of ACS when compared with a standard of care without use of imaging [46,47].

Variant 1: Chest pain, low to intermediate probability for acute coronary syndrome. Initial imaging.
F. US Echocardiography Transthoracic Resting

Conventional resting echocardiography in the emergency department has some limited benefit for detection of ischemic myocardium with abnormal wall motion and thereby risk stratification of suspected ACS patients [48,49]; however, it is more widely used for the evaluation of heart failure, valvular dysfunction, and pericardial effusion [41]. Advances in contrast echocardiography to evaluate ischemic changes in wall thickening [50-53] and strain echocardiography to evaluate abnormal myocardial deformation [54-57] may provide an expanded role for resting echocardiography in the evaluation of ACS, particularly in patients with active chest pain at the time of imaging.

Variant 1: Chest pain, low to intermediate probability for acute coronary syndrome. Initial imaging.
G. US Echocardiography Transesophageal

The primary usefulness of resting transesophageal echocardiography (TEE) in the setting of acute chest pain is in ruling out aortic dissection in unstable patients. TEE is also used to further define valvular dysfunction or intracardiac thrombus, which can be sequelae of ischemic events in the subacute setting. Because of the semi-invasive nature of TEE and because there is limited information that can be added in the setting of acute chest pain, this modality is generally not indicated in the workup of patients with acute chest pain [58].

Variant 1: Chest pain, low to intermediate probability for acute coronary syndrome. Initial imaging.
H. CTA Coronary Arteries

In stable patients with suggested ACS at low or intermediate risk of adverse events, a noninvasive coronary imaging test (ie, coronary CTA [CCTA]) is a proven alternative to stress testing or selective coronary angiography [19,59,60]. CCTA has a very high negative predictive value for the detection of coronary atherosclerosis with or without significant stenosis and is an alternative to stress imaging in the emergency department and inpatient settings in patients at low to intermediate risk for CAD [59,61-64]. Large randomized controlled trials (eg, CT-STAT, ROMICAT I and II, ACRIN-PA, PROSPECT, CT-COMPARE, CATCH, and CATCH-2) have amply established the high negative predictive value (eg, safe discharge) and good prognosis of a negative CCTA in low- to intermediate-risk patients suspected of ACS when compared with standard pathways that predominantly involve stress nuclear MPI [65-72]. Normal CCTA has been shown to allow safe discharge from the emergency department without further workup, in both academic and community settings, with a negative predictive value for ACS over 95% [1,73-75], with equal or superior diagnostic performance when compared with stress echocardiography or nuclear MPI [76]. High-sensitivity troponin use has increased in Europe and in the United States to stratify patients with suspected ACS [77], but a CCTA strategy has still been found to be useful to avoid unnecessary downstream testing even when patients were first stratified by high-sensitivity troponin [78-80]. In a large multicenter study comparing CCTA with multiple other modalities used for ACS (stress cardiac MR [CMR], stress echocardiography, stress nuclear MPI, and stress PET), CCTA was found to have the highest diagnostic accuracy in finding patients with a significant coronary artery stenosis [81].

Novel applications of CT technology include stress CT perfusion imaging and CT–fractional flow reserve (FFR), both of which have well-established research support and are beginning to supplement anatomic CCTA information in daily clinical practice at certain centers. Stress CT perfusion imaging allows functional assessment of myocardial segments and has been shown to have similar diagnostic performance and predictive values when compared with stress MPI [82-85]. Although stress CT perfusion represents the typical approach to CT diagnosis of inducible ischemia, resting CT perfusion interpretation of myocardial segments from a routine resting CCTA has also shown utility in the diagnosis of ACS [86,87]. FFR is an invasively derived ratio comparing flow at hyperemia proximal and distal with a stenosis at catheterization, with powerful discriminatory value in determining the hemodynamic significance of the stenosis. CT-FFR uses computational fluid dynamic modeling techniques and/or machine learning to simulate the FFR process, using resting CCTA data and yield a CT-FFR number shown to correlate reasonably well with catheter-derived FFR values and deliver equivalent clinical outcomes when using a CT-FFR-guided management pathway [88-92]. Research into the additive value of CT perfusion and CT-FFR is ongoing, particularly in chest pain patients presenting acutely to the emergency department rather than as stable outpatients [93].

Variant 1: Chest pain, low to intermediate probability for acute coronary syndrome. Initial imaging.
I. CT Coronary Calcium

The role of the calcium score as a standalone test in the acute setting has not been established [94]. Limited studies have been performed demonstrating that the absence of coronary artery calcium (CAC) has a high negative predictive value for ACS among lower-risk patients with chest pain [95]. Several studies have suggested that in young patients with chest pain, a calcium score of zero is not a reliable test to exclude CAD, and adverse events have been shown to occur in up to 6% of acute chest pain patients without coronary artery calcium [96]. The ability of a zero calcium score to allow safe discharge of low-risk acute chest pain patients continues to be actively studied [97-100].

Variant 1: Chest pain, low to intermediate probability for acute coronary syndrome. Initial imaging.
J. CT Chest

Nongated chest CT, although useful for evaluating noncardiac thoracic pathology, does not currently have a role in the evaluation of possible ACS, although perfusion defects can be seen on contrast-enhanced nongated chest CT in patients with ACS [101,102].

Variant 1: Chest pain, low to intermediate probability for acute coronary syndrome. Initial imaging.
K. CTA Chest

CTA of the chest has a well-established role for evaluating other etiologies that may mimic ACS, such as aortic dissection, acute pericarditis, pneumonia, and pneumothorax [27,103]. Nongated chest CTA intended to evaluate a patient for aortic dissection or pulmonary embolism may depict incidental coronary artery pathology, such as anomalous coronary arteries, obstructive CAD, and involvement of the coronary arteries by aortic dissection [104]. In particular, CTA for aortic dissection or pulmonary embolism may be performed with ECG-gating without specific intent to evaluate the coronary arteries (ie, gating intended to reduce pulsation artifact in the great vessels but the examination not otherwise tailored to the coronary arteries), and in those cases, coronary abnormalities may be even more readily apparent as an unexpected finding. Therefore, there is insufficient evidence to support nongated (or incidentally gated) CTA for the evaluation of ACS.

Variant 1: Chest pain, low to intermediate probability for acute coronary syndrome. Initial imaging.
L. Rb-82 PET/CT Heart

A stress PET examination can reliably demonstrate myocardial blood flow using rubidium-82 (Rb-82) or nitrogen-13 (N-13) ammonia. Limited data are available for PET perfusion studies in the setting of acute chest pain, although there is growing evidence for diagnostic and prognostic applications in chronic coronary disease [105,106]. PET can also document anaerobic metabolism using fluorine-18-2-fluoro-2-deoxy-D-glucose and other metabolic tracers. This technology is less well studied in the workup of the acute chest pain patient but may have a role when combined with CTA [105,107,108]. Meta-analysis has shown PET to demonstrate excellent diagnostic performance when compared with other methods of evaluating ischemic myocardium [109].

Variant 1: Chest pain, low to intermediate probability for acute coronary syndrome. Initial imaging.

M. MRI Heart with Function and Inotropic Stress

Although early ACS approaches of CMR included high-risk patients and tended to use rest-only CMR, more recent studies have demonstrated high negative predictive value and excellent diagnostic performance in a low- to intermediate-risk cohort when compared with nuclear MPI or stress echocardiography [110,111]. Multiple studies have shown that a vasodilator stress CMR strategy for chest pain patients can allow safe discharge and show similar clinical performance to other stress perfusion techniques [45,112-114]. However, inotropic stress agents like dobutamine, although useful for the characterization of stable ischemic heart disease [115,116], are relatively contraindicated in patients with recent or active chest pain, and so limited literature exists on the use of inotropic stress MRI for the evaluation of ACS.

Variant 1: Chest pain, low to intermediate probability for acute coronary syndrome. Initial imaging.

N. MRI Heart with Function and Vasodilator Stress Perfusion

Although early ACS approaches of CMR included high-risk patients and tended to use rest-only CMR, more recent studies have demonstrated high negative predictive value and excellent diagnostic performance in a low- to intermediate-risk cohort when compared with nuclear MPI or stress echocardiography [110,111]. Multiple studies have shown that a stress CMR strategy for chest pain patients can allow safe discharge and show similar clinical performance to other stress-perfusion techniques [45,112-114]. In particular, CMR has been shown to have similar or better performance to nuclear MPI in determining the degree of ischemic myocardium, which may be an important predictor of outcomes after revascularization [117,118]. For example, several studies on outpatients with suspected CAD (eg, MR-IMPACT, CE-MARC, MR-INFORM) demonstrated superior performance of stress CMR when compared with nuclear SPECT MPI [119,120] and have recently reported noninferiority when compared with invasive FFR [121].

Variant 1: Chest pain, low to intermediate probability for acute coronary syndrome. Initial imaging.

O. MRI Heart Function and Morphology

CMR with delayed postcontrast imaging and edema-weighted imaging provides assessment of the size, distribution, and transmural extent of acute or remote MI. Cine CMR has usefulness in demonstrating wall-motion abnormalities, which may accompany acute or chronic ischemic heart disease, and first-pass contrast-enhanced perfusion CMR can demonstrate myocardial perfusion abnormalities [110,111,122-124]. The use of T2-weighted CMR to identify myocardial edema can help predict outcomes in patients with NSTE-ACS without affecting time to catheterization [125]. In addition, CMR has a role in elucidating the cause of myocardial necrosis in patients with elevated cardiac biomarkers presumed to have ACS but with nonobstructive coronary arteries by CT or catheter angiography [126,127]. MRI, like CT, can also identify noncardiac reasons for chest pain. Both contrast-enhanced and nonenhanced time-of-flight angiographic techniques can be used for aortic pathology, and CMR can be used for the evaluation of other mimics of ACS with troponin elevation, including pericarditis, myocarditis, and Takotsubo cardiomyopathy [128,129]. New techniques in CMR, for example, myocardial mapping, may provide additional methods that can be used to evaluate patients with acute chest pain [130,131].

Variant 1: Chest pain, low to intermediate probability for acute coronary syndrome. Initial imaging.

P. MRA Coronary Arteries

Although coronary MR angiography (MRA) has not been established in general practice, both angiographic and phase-contrast flow continue to be developed for coronary artery assessment in research centers [132]. Noncontrast angiographic whole-heart acquisition with 3-D steady-state free precession MRI technique can provide imaging of the coronary arteries and is particularly useful in the evaluation of coronary anomalies, bypass graft assessment, and coronary aneurysm formation [133]. Trials have demonstrated high sensitivity and moderate specificity of coronary MRA for the evaluation of obstructive coronary artery stenosis, particularly when used in combination with nonangiographic CMR sequences [119,134]. Future avenues of clinical use include reliable evaluation of coronary artery stenosis and characterization of plaque composition for the identification of vulnerable or high-risk plaques [135].

Variant 2: Chest pain, high probability for acute coronary syndrome. Initial imaging.

Variant 2: Chest pain, high probability for acute coronary syndrome. Initial imaging.
A. Arteriography Coronary

Prompt coronary angiography is the mainstay of diagnosis and management of patients at high risk for ACS, in particular those with an ischemic pattern on ECG [7]. By American College of Cardiology/American Heart Association guidelines, there is a class I, level A recommendation to direct ST-segment elevation patients suspected of ACS to the catheterization laboratory with a "door-to-device” time of ≤90 min [136-138]. The emphasis of timeliness in arteriography and reperfusion of the coronary arteries for ECG-positive ACS is such that the use of other modalities in the evaluation of high-risk ACS patients, particularly modalities with a significant time penalty (eg, MRI, PET, MPI), is limited.

In patients without ST-segment elevation, positive cardiac biomarkers may nonetheless suggest myocardial necrosis, and the ECG may demonstrate a NSTE ischemic pattern, including ST depression, transient ST-segment elevation, or prominent T-wave inversions [139]. ACS patients with unstable angina may have similar ECG patterns but demonstrate no biomarker evidence of myocardial necrosis (eg, troponin level within normal limits), though biomarker negativity in these patients may grow rarer as high-sensitivity biomarker tests become more widely available [140]. Patients with NSTE-ACS do not require immediate emergent evaluation in the catheterization laboratory in the absence of shock or medically refractory symptoms but are admitted for inpatient stabilization, relief of ischemic symptoms, and guideline-directed medical therapy. NSTE-ACS patients may then be managed with an ischemia-guided strategy (ie, only proceed to catheterization if ischemic signs or symptoms persist despite aggressive medical therapy) or an invasive strategy (ie, routine catheterization with the goal of revascularization, either as an early invasive strategy within 24 h or a delayed invasive strategy in the 24–72 h time frame) [139,141-143]. The optimal timing and choice of invasive angiography in patients with ST-segment or non-ST-segment ACS continues to be an active area of research.

Variant 2: Chest pain, high probability for acute coronary syndrome. Initial imaging.
B. Radiography Chest

Chest radiography is primarily used for ruling out conditions that may masquerade as acute myocardial ischemia as well as defining secondary findings that may accompany acute MI. Acute pulmonary edema can be seen on chest radiographs without enlargement of the cardiac silhouette in patients with acute MI and no prior history of ischemic damage or associated mitral valve disease. Although chest radiography is insufficient to confirm or exclude the presence of significant

CAD, it may be useful in demonstrating clinically important pathology in a significant minority of ACS-suspected patients [31]. Other cardiovascular entities, such as aortic aneurysms, aortic dissections, and pulmonary embolism, may be suggested from the chest radiography but with far lower sensitivity than other imaging modalities such as multidetector CT. Noncardiac findings associated with chest pain that can be identified on the chest radiograph include pneumothorax, fractured ribs, pleural effusions, and pneumonia, among others.

Variant 2: Chest pain, high probability for acute coronary syndrome. Initial imaging.
C. CTA Coronary Arteries

There is no relevant literature regarding the use of CCTA in the evaluation of ACS in high-probability patients.

Variant 2: Chest pain, high probability for acute coronary syndrome. Initial imaging.
D. CT Chest

Nongated chest CT, although useful for evaluating noncardiac thoracic pathology, does not currently have a role in the evaluation of possible ACS, although perfusion defects can be seen on nongated chest CT in patients with ACS [101,102]

Variant 2: Chest pain, high probability for acute coronary syndrome. Initial imaging.
E. CTA Chest

CTA of the chest has a well-established role for evaluating other etiologies that may mimic ACS, such as aortic dissection, acute pericarditis, pneumonia, and pneumothorax [27,103].

Variant 2: Chest pain, high probability for acute coronary syndrome. Initial imaging.
F. CT Coronary Calcium

There is no relevant literature regarding the use of CT calcium scoring in the evaluation of ACS in high-probability patients.

Variant 2: Chest pain, high probability for acute coronary syndrome. Initial imaging.
G. MRA Coronary Arteries

There is no relevant literature regarding the use of coronary MRA in the evaluation of ACS in high-risk patients.

Variant 2: Chest pain, high probability for acute coronary syndrome. Initial imaging.
H. MRI Heart Function and Morphology

The use of T2-weighted CMR to identify myocardial edema can help predict outcomes in patients with NSTE-ACS, without impacting time to catheterization, and a combination of noncontrast and postcontrast resting CMR sequences can help inform prognosis and identify myocardial areas at risk [125,144]. In addition, CMR has a role in elucidating the cause of myocardial necrosis in patients with elevated cardiac biomarkers presumed to have ACS but with nonobstructive coronary arteries by CT or catheter angiography [126-128,145].

Variant 2: Chest pain, high probability for acute coronary syndrome. Initial imaging.
I. MRI Heart with Function and Inotropic Stress

There is no relevant literature regarding the use of stress CMR in the evaluation of ACS in high-probability patients.

Variant 2: Chest pain, high probability for acute coronary syndrome. Initial imaging.
J. MRI Heart with Function and Vasodilator Stress Perfusion

There is no relevant literature regarding the use of stress perfusion CMR in the evaluation of ACS in high-probability patients.

Variant 2: Chest pain, high probability for acute coronary syndrome. Initial imaging.
K. Rb-82 PET/CT Heart

There is no relevant literature regarding the use of stress PET/CT in the evaluation of ACS in high-probability patients.

Variant 2: Chest pain, high probability for acute coronary syndrome. Initial imaging.
L. SPECT or SPECT/CT MPI Rest Only

There is no relevant literature regarding the use of rest-only MPI in the evaluation of ACS in high-probability patients.

Variant 2: Chest pain, high probability for acute coronary syndrome. Initial imaging.
M. SPECT or SPECT/CT MPI Rest and Stress

Noninvasive stress testing with nuclear SPECT-MPI may be helpful in NSTE-ACS patients for risk stratification before discharge in patients with an ischemia-guided strategy. High NSTE-ACS patients (eg, patients with left main disease, age >70, multivessel disease, diabetes mellitus, prior MI or revascularization, or depressed left ventricular function) may benefit from routine revascularization, but low-to intermediate-risk NSTE-ACS patients may receive less benefit from routine revascularization and therefore may benefit from risk stratification according to provocative testing with stress. In particular, nuclear MPI with stress can be used to identify low-risk patients suitable for early discharge [146,147].

Variant 2: Chest pain, high probability for acute coronary syndrome. Initial imaging.
N. US Echocardiography Transthoracic Stress

There is no relevant literature regarding the use of stress echocardiography in the evaluation of ACS in high-probability patients.

Variant 2: Chest pain, high probability for acute coronary syndrome. Initial imaging.
O. US Echocardiography Transthoracic Rest

Conventional resting echocardiography in the emergency department has some limited benefit for detection of ischemic myocardium with abnormal wall motion and thereby risk stratification of suspected ACS patients [48,49]; however, it is more widely used for the evaluation of heart failure, valvular dysfunction, and pericardial effusion [41]. Assessment of left ventricle function is necessary in patients with confirmed ACS in order to guide pharmacological therapies and help determine revascularization choices (eg, percutaneous coronary intervention versus bypass graft surgery). Advances in contrast echocardiography to evaluate ischemic changes in wall thickening [50-53] and strain echocardiography to evaluate abnormal myocardial deformation [54-57] may provide a new role for resting echocardiography in the evaluation of ACS.

Variant 2: Chest pain, high probability for acute coronary syndrome. Initial imaging.
P. US Echocardiography Transesophageal

The primary usefulness of TEE in the setting of acute chest pain is in ruling out aortic dissection in unstable patients. TEE is also used to further define valvular dysfunction or intracardiac thrombus, which can be sequelae of ischemic events in the subacute setting. Because of the semi-invasive nature of TEE and because there is limited information that can be added in the setting of acute chest pain, this modality is generally not indicated in the workup of patients with acute chest pain [58].

Summary of Recommendations

- **Variant 1:** CTA coronary arteries with IV contrast, Tc-99m SPECT or SPECT/CT MPI rest and stress, or ultrasound echocardiography transthoracic stress is usually appropriate for the initial imaging of chest pain in adults with low to intermediate probability for ACS. These procedures are equivalent alternatives (ie, only one procedure will be ordered to provide the clinical information to effectively manage the patient's care). Radiography chest is a complementary procedure used for rapid triage in chest pain patients who may then benefit from more definitive imaging with regard to ACS. The panel did not agree on recommending Rb-82 PET/CT heart for the initial imaging of chest pain in adults with low to intermediate probability for ACS. There is insufficient medical literature to conclude whether or not these patients would benefit from Rb-82 PET/CT heart for this clinical scenario. Rb-82 PET/CT heart in this patient population is controversial but may be appropriate.
- **Variant 2:** Arteriography coronary is usually appropriate for the initial imaging of chest pain in adults with high probability for ACS. Radiography chest is a complementary procedure used for rapid triage in chest pain patients who may then benefit from more definitive imaging with regard to ACS. The panel did not agree on recommending MRI heart function and morphology without and with IV contrast or SPECT or SPECT/CT MPI rest only or ultrasound echocardiography transthoracic stress for the initial imaging of chest pain with high probability for ACS. There is insufficient medical literature to conclude whether or not these patients would benefit from these examinations for this clinical scenario. MRI heart function and morphology without and with IV contrast or SPECT or SPECT/CT MPI rest only or ultrasound echocardiography transthoracic stress in this patient population is controversial but may be appropriate.

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.

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	5	The individual ratings are too dispersed from the

(Disagreement)		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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