

APPROPRIATE UTILIZATION OF CARDIOVASCULAR IMAGING

2015 ACR/ACC/AHA/AATS/ACEP/ASNC/NASCI/SAEM/SCCT/SCMR/SCPC/SNMMI/STR/STS Appropriate Utilization of Cardiovascular Imaging in Emergency Department Patients With Chest Pain



A Joint Document of the American College of Radiology Appropriateness Criteria Committee and the American College of Cardiology Appropriate Use Criteria Task Force

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The 2010 National Hospital Medical Care Survey reported nearly 130 million emergency department (ED) visits (1). The second largest component, 5.4%, were patients presenting with chest pain (CP) (1). In the patient presenting with undifferentiated CP, the spectrum of potential etiologies ranges from serious, immediate, life-threatening pathologies such as acute coronary syndromes (ACS), pulmonary embolism (PE), or acute aortic syndromes (AAS) to relatively benign illness without long-term consequences (such as costochondritis) and poses a great challenge to the caregiving physician. The initial strategy focuses on rapidly and accurately excluding diagnoses with the greatest short-term mortality risk. Much of the initial diagnosis is determined by the clinical presentation as assessed by the history, physical examination, and basic ancillary testing. However, diagnostic imaging may be used to identify or exclude a potential life-threatening condition when the clinical presentation does not reveal an obvious cause.

RATING GUIDE**Methods for Establishing Appropriate Use of Imaging in ED Patients With CP**

Clinicians, payers, and patients are interested in the incremental value offered by imaging to both the diagnosis and clinical management of disease conditions and, alternatively, when imaging does not offer this value. This document addresses the appropriate use of imaging in patients who present to an ED with CP. Imaging appropriateness explicitly considers two questions: 1) Is any imaging justified for 20 clinical scenarios that categorize patients after history, physical examination, and ancillary testing? and 2) If justified, what meaningful incremental information will an imaging procedure provide? This document combines evidence-based medicine, guidelines, and practice experience by engaging a rating panel in a modified Delphi exercise (2).

This document follows the methods as described in a joint publication by the American College of Cardiology and the ACR (3). When more than one imaging study is considered appropriate for a clinical scenario, the methods do not consider preferred individual modalities among all of those rated appropriate. Clinicians should include all factors including costs as well as local availability and expertise when ordering imaging studies.

Clinical Scenario and Indication Identification by Writing Group

The Emergency Department Patients With Chest Pain Writing Panel comprised practicing emergency medicine, cardiology, and radiology representatives from the relevant professional societies. The writing panel recognized key diagnoses related to patients who present to the ED with CP for which imaging may be relevant to diagnosis and management. Because the charge of the writing group is to describe common clinical scenarios seen in contemporary practice, the document is organized with respect to diagnostic algorithms from four key clinical entry points that direct imaging (see Figure 1):

1. Suspected non-ST-segment elevation ACS (clinical scenarios 1-10)
2. Suspected PE (clinical scenarios 11-15)
3. Suspected acute syndrome of the aorta (clinical scenarios 16-18)
4. Patients for whom a leading diagnosis is problematic or not possible (clinical scenarios 19 and 20)

Definition of Appropriateness

The ACR and American College of Cardiology definition of an “appropriate” imaging test is as follows (4):

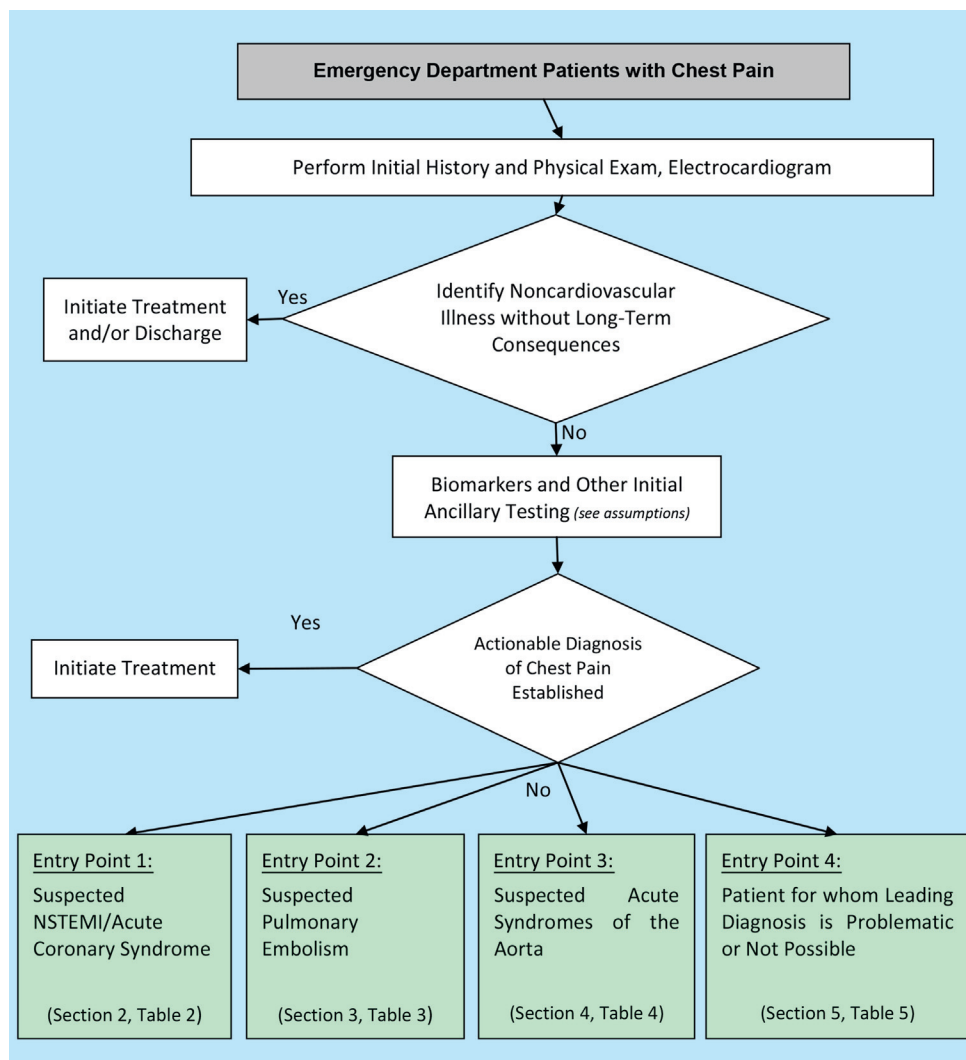
The concept of appropriateness, as applied to health care, balances risk and benefit of a treatment, test, or procedure in the context of available resources for an individual patient with specific characteristics. Appropriateness criteria provide guidance to supplement the clinician’s judgment as to whether a patient is a reasonable candidate for the given treatment, test or procedure.

This definition highlights the central pursuit of the greatest yield of clinically valuable diagnostic information from imaging with the least negative impact on the patient.

On the basis of available evidence, the Emergency Department Patients With Chest Pain Rating Panel members assigned a rating to each imaging procedure for each of the 20 clinical scenarios on a scale ranging from 1 to 9 as follows:

Appropriate rating 7, 8, or 9: An appropriate option for the management of patients in this population because of benefits generally outweighing risks; an effective option for individual care plans although not always

FIGURE 1 Entry Points for Clinical Scenarios Under Consideration



necessary depending on physician judgment and patient specific preferences (i.e., the procedure is generally acceptable and is generally reasonable for the indication).

May be appropriate rating 4, 5, or 6: At times an appropriate option for the management of patients in this population because of variable evidence or agreement regarding the benefit/risk ratio, potential benefit on the basis of practice experience in the absence of evidence, and/or variability in the population; effectiveness for individual care must be determined by a patient's physician in consultation with the patient on the basis of additional clinical variables and judgment along with patient preferences (i.e., the procedure may be acceptable and may be reasonable for the indication).

Rarely appropriate rating 1, 2, or 3: Rarely an appropriate option for the management of patients in this population because of the lack of a clear benefit/risk advantage; rarely an effective option for individual care plans; exceptions should have documentation of the clinical reasons for proceeding with this care option (i.e., the procedure is not generally acceptable and is not generally reasonable for the indication).

Consensus was reached when 60% or greater of the panel members assigned a rating within one of the three categories: appropriate (A), may be appropriate (M), or rarely appropriate (R). When consensus was not reached for a study within a particular clinical scenario, regardless of the rating panel scores, the rating was assigned M*, or may be appropriate*, with the asterisk referring to the fact that the rating of M* was from absence of consensus as

opposed to M, indicating that consensus was reached in the may be appropriate category.

DEFINITIONS

Non-ST-Segment Elevation ACS

Any group of clinical symptoms compatible with acute myocardial ischemia, including unstable angina and non-ST-segment elevation myocardial infarction (NSTEMI).

AAS

Any group of clinical symptoms compatible with aortic dissection, intramural hematoma, and symptomatic aortic ulceration.

CP Related to ACS

Any constellation of anginal or anginal-equivalent symptoms that the physician feels may represent a condition resulting from obstructive coronary artery disease (CAD). Examples of such symptoms include but are not exclusive to CP, chest tightness, burning, shoulder pain, and jaw pain or “angina equivalents” such as dyspnea.

ABBREVIATIONS

See [Appendix 1](#).

ASSUMPTIONS

General Clinical Assumptions

To limit inconsistencies in interpretation, specific assumptions were considered by the writing group in development and were used by the rating panel. Assumptions associated with specific presentations are also reviewed in the following respective sections.

Practice Parameters/Standard of Care

All imaging is performed by qualified personnel in an accredited laboratory using standardized imaging protocols.

Clinicians should consider ionizing radiation when choosing an imaging modality for a patient in a specific clinical scenario. Radiation exposure should be minimized in all patients according to the principle of “as low as reasonably achievable.” Tests involving radiation should use protocols (5) that deliver the least possible radiation dose but preserve image quality and sensitivity (6).

Cost/Value

From the standpoint of the practicing emergency medicine physician caring for an individual patient, the potential clinical benefits of an appropriate imaging study should be the highest priority, and these are weighed against potential risks of performing either no imaging study or an alternative study.

As related to societal benefits, costs should also be considered in relation to potential benefits in order to better understand comparative value. However, there is a relative paucity of data to assess cost-effectiveness among multiple studies. When available, these data are noted by the writing panel, and cost/value data are considered, if deemed appropriate, by rating panel members.

Guidance Specifically for Appropriate Use Criteria Users

Reducing imaging that is “rarely appropriate” is considered a potentially valuable means to reduce costs and population risks in cardiovascular imaging among patients who present to emergency medicine physicians with CP.

The category “may be appropriate” should be used when insufficient clinical data are available for a definitive categorization or there are substantial differences in opinion regarding the appropriateness of that indication. The absence of definitive data supporting a specific imaging study for a particular subset of patients does not imply a lack of benefit, and in such cases, careful investigation of the particulars of the clinical scenario is warranted. The designation “may be appropriate” should not be used as the sole grounds for denial of reimbursement for a given examination for a specific clinical scenario.

Entry Criteria Into Algorithms

1. All adult patients presenting to EDs with potential CP syndromes will undergo evaluations that generally include history and physical examination, immediate electrocardiography (ECG) to identify or exclude ST-segment elevation myocardial infarction (STEMI), and cardiac and/or pulmonary biomarker analysis (troponin and/or D-dimer) ([Figure 1](#)). Some patients will be diagnosed with noncardiovascular illnesses that exclude ACS, PE, and AAS, and in general, no imaging is required. Patients with evidence of STEMI on initial ECG or initial biomarkers and/or ECG clearly consistent with ACS or NSTEMI are admitted and treated according to evidence-based guidelines. These patients are, in general, not the subjects of this document.
2. [Table 1](#) evaluates the role of imaging in the process of the initial workup, with two common scenarios that include patients for whom ECG is diagnostic for STEMI and patients for whom an alternative, noncardiac diagnosis is likely.
3. After the initial evaluation, it is assumed that the physician will be able to clinically risk-stratify the majority of those remaining patients into one of the three suspected diagnoses of concern: ACS ([Section 2](#)), PE ([Section 3](#)), and AAS ([Section 4](#)). [Section 5](#) includes the minority of patients for whom a leading diagnosis is not possible. [Sections 2 through 5](#) assume that the initial

TABLE 1 Imaging of Patients for Whom the Initial Workup Is Diagnostic for STEMI or for Whom a Noncardiac Diagnosis Is Likely

Indication	Chest Radiography	Echocardiography Rest	CMR Rest	SPECT Rest	CCTA	CCath
1. Diagnostic ECG for STEMI	M	R	R	R	R	A
2. Initial history/physical examination and/or chest radiography identifies a likely noncardiac diagnosis (e.g., pneumothorax, costochondritis, lesion in the esophagus)		R	R	R	R	R

Appropriate use key: A = appropriate; M = may be appropriate with rating panel consensus; R = rarely appropriate.

CCath, catheter-based coronary angiography; CCTA, coronary CT angiography; CMR, cardiovascular MR; ECG, electrocardiogram; SPECT, single-photon emission computed tomography; STEMI, ST-segment elevation myocardial infarction.

workup and ancillary testing, including cardiac and/or pulmonary biomarkers, are completed (Figure 1).

- Some patients who enter the clinical scenarios and undergo imaging studies will have inconclusive data to confirm or exclude a leading diagnosis after imaging. Although ratings for Sections 2 through 5 may have more than one imaging study that may be considered appropriate, this document does not specifically address the appropriate use of a second imaging study. The writing group acknowledges that although such patients can present a diagnostic dilemma, there are limited or no data on which to establish appropriate use criteria for the second study, particularly because findings from the first study may influence the best choice for subsequent imaging.
- One-third of patients with confirmed acute myocardial infarction (AMI) will not have typical CP; Section 2 includes those patients.
- Imaging in the ED alone, or during evaluation in an observation unit, is considered in this document. Some patients may be candidates for outpatient referrals for follow-up imaging in lower intensity settings. The clinical scenarios in this document in general do not cover these referrals, nor does this document include imaging for patients who do not present to the ED.
- Miniaturization of ultrasound technology has enabled the use of focused cardiac ultrasound (FOCUS), or bedside ultrasonography performed by the emergency medicine physician, using highly portable equipment that lends itself well to use in an ED setting when a rapid evaluation is required. The writing panel gave specific consideration to FOCUS as an expedited method for bedside diagnoses (7). FOCUS is recognized as a universal part of emergency medicine training and practice. It is valuable in selected patients considered in this document, in particular those who present with CP or shortness of breath. Although it can assess left and right ventricular dysfunction, determine volume status, evaluate the fluid status of the lungs, and exclude some items in the initial differential diagnosis, its main utility for patients covered by the current guidelines is to detect pericardial fluid in patients with suspected cardiac tamponade (8).

With respect to ACS, although FOCUS can accurately estimate ejection fraction with good interrater reliability, FOCUS alone is not useful in ruling in or out an ACS. Echocardiographers have found that the absence of regional wall motion abnormalities has a negative predictive value (NPV) of 82% to 98% for AMI (9-12). One study reported that sensitivity among patients with NSTEMI was only 86% (10). Thus, like echocardiography, FOCUS is not considered sufficient to allow safe discharge from the ED. Similarly, FOCUS should not be used alone as the basis for decisions about the disposition of patients with possible ischemic CP. With respect to acute PE, a right ventricle larger in size than the left ventricle and paradoxical septal motion can suggest PE, but this observation on FOCUS should not preclude additional imaging. With respect to acute syndromes of the aorta, other than detecting tamponade, FOCUS is unlikely to provide diagnostic help in patients with suspected aortic dissection.

Although appropriate for patients who present to emergency medicine physicians with CP, FOCUS was not considered by the rating panel because it is inherently the initial examination performed by emergency medicine physicians, and subsequent imaging as noted in this document is also appropriate. FOCUS is indicated for the proper, rapid identification and exclusion of key cardiovascular diagnoses as indicated by existing guidelines (7).

Testing Considerations

- This report considers exercise treadmill testing without imaging and stress testing with imaging, including the following: echocardiography, cardiovascular MR (CMR), and nuclear imaging, including single-photon emission computed tomography (SPECT). This report considers CT for the coronary arteries (coronary CT angiography [CCTA]), for the pulmonary arteries (CT pulmonary angiography [CTPA]), and for the aorta (CT aortography [CTAo]). The report also considers CT scans tailored to identify all three diagnoses, or “triple-rule-out” (TRO) CT. This report considers invasive diagnostic catheterization that can be tailored to evaluate patients with clinically suspected ACS (CCath), PE (PCath), or AAS (catheter-based

aortography [AoCath]). Although invasive catheterization can be coupled with an intervention, for the purposes of this document, *catheterization* refers only to the diagnostic portion of an overall procedure.

- Although ratings for TRO studies (Table 5) include specific scenarios, it is acknowledged that more generally, no single test provides optimal performance for all three diagnoses (ACS, PE, and AAS).
- All tests considered in this document have multiple capabilities, both as stand-alone technologies and for use in combination during the evaluation of individual patients. This document is not intended to describe imaging technologies; descriptions are intended to reflect the capabilities of modern imaging for emergency medicine patients.
- The quality of the imaging data in clinical use will be reflective of the quality of the imaging data demonstrated in representative clinical trials. The quality of imaging data is a result of many steps, including data acquisition, processing, interpretation, and reporting.
- Improvements in the analytic performance of cardiac troponin (cTn) assays have resulted in improved sensitivity and precision, resulting in the ability to measure 10-fold lower concentrations of cTn with high precision. These “high-sensitivity” cTn assays, defined as those that can measure cTn in at least 50% of healthy individuals, are not currently available in the United States, although they are already in clinical use throughout most of the world (13). The increased sensitivity of newer cTn assays allows potentially more rapid diagnosis of patients with myocardial infarction (MI), particularly early after symptom onset, compared with contemporary assays currently in wide use. However, the higher sensitivity may lead to the detection of cTn in a substantial proportion of patients who do not have ACS but have other underlying cardiovascular diseases, such as heart failure (14).

Given the absence of widespread availability in the United States at the time of development of this document, recommendations contained herein regarding the use of troponins in the evaluation pathway of patients will generally reflect data from currently available assays (13,14). However, as literature on the use of this type of testing is emerging, this document includes one clinical scenario that incorporates high-sensitivity troponin testing, scenario 6 in Table 2.1. Several studies have shown that patients with Thrombolysis in Myocardial Infarction (TIMI) risk scores of 0 and negative results for high-sensitivity troponin at presentation or presentation after 2 hours are at very low risk for ACS (15).

Comorbidities and Contraindications

Patients under consideration for rating among imaging tests do not have specific comorbidities or contraindications as noted below.

- Unless otherwise stated, the following absolute or relative contraindications that would preclude certain types of imaging are assumed not to be present: claustrophobia, pregnancy, iodine allergy, renal dysfunction, and high resting heart rate.
- Imaging studies that deliver ionizing radiation are, in general, relatively contraindicated during pregnancy.
- Gadolinium-enhanced MRI is, in general, not performed in patients who are pregnant.

Availability and Expertise

- Geographic or regional variability: issues of local availability and of skill in conducting each potential imaging study are not considered by the rating panel. Specifically, it is assumed that credentialed laboratories staffed by skilled imagers are locally available.

TABLE 2.1 Suspected Non-ST-Segment Elevation ACS: Early Assessment Pathway Based on Initial ECG, Biomarker Analysis, and Symptoms

Indication	Echocardiography Rest	CMR Rest	SPECT Rest	CCTA	CCath
Positive initial diagnosis of NSTEMI/ACS					
3. Initial ECG and/or biomarker analysis unequivocally positive for ischemia	R	R	R	R	A
Equivocal initial diagnosis of NSTEMI/ACS					
4. Equivocal initial troponin or single troponin elevation without additional evidence of ACS	M*	M*	A	A	R
5. Ischemic symptoms resolved hours before testing	R	M	M*	A	R
Low/intermediate likelihood initial diagnosis of NSTEMI/ACS					
6. TIMI risk score = 0, early hsTrop negative	R	R	R	A	R
7. Normal or nonischemic on initial ECG, normal initial troponin	R	R	M*	A	R

Appropriate use key: A = appropriate; M = may be appropriate with rating panel consensus; M* = may be appropriate as determined by lack of consensus by rating panel; R = rarely appropriate.

ACS, acute coronary syndrome; CCath, catheter-based coronary angiography; CCTA, coronary CT angiography; CMR, cardiovascular MR; ECG, electrocardiography; hsTrop, high-sensitivity troponin T; NSTEMI, non-ST-segment elevation myocardial infarction; SPECT, single-photon emission computed tomography; TIMI, Thrombolysis in Myocardial Infarction.

2. Radiotracers for nuclear imaging studies and interpreting personnel may not be available at all hours for testing, although some centers with significant off-hours volume have set up mechanisms for 24/7 testing.
3. Although the technology and expertise are generally available on an institutional basis, a qualified technologist (e.g., a sonographer) may not be readily available to an ED, and it may be less likely that a reader is immediately available for studies performed after hours.
4. CCTA using 64-channel or greater cardiac CT systems (16) is now available for many emergency medicine services. Although CT scanners and expertise are generally available on an institutional basis and often include 24/7 service to the ED for CTPA and CTAo, specific capabilities for CCTA may not be readily available to the ED, especially for studies performed after hours.

Assessing the Risk for ACS in Patients With Suspected ACS

In many studies cited in this document and throughout Section 2, reference is made to “low”, “intermediate,” or “high” risk. Although the term *risk* is used, the term refers to the likelihood that an ACS is present given a certain set of clinical findings (or alternatively risk for short-term ACS “events”) (17). For patients with suspected ACS, determination of likelihood of disease on the basis of any of the traditional methods such as those recommended by the American Heart Association scientific statement can help direct further testing and imaging in this group.

From the literature, there are no widely agreed-upon, post hoc, numerical thresholds that distinguish these categories, as there are for categories of risk for coronary heart disease using the Framingham risk score, for instance. The Rule-Out Myocardial Infarction/Ischemia Using Computer Assisted Tomography trials aimed to enroll patients with suspected ACS at “low to intermediate” risk (18,19). The prevalence of a final diagnosis of ACS among the enrolled population was approximately 8%, and this was considered an intermediate-risk population. In a study of 2,271 patients presenting with CP to EDs, initial clinical criteria were able to identify what was termed a low-risk group, with a 30-day major cardiovascular event rate (death, MI, stroke, or revascularization) of 2.5% (20).

Clinical risk assessment involves evaluation of symptoms, initial ECG, and initial biomarkers (21). Several scoring systems have been developed and validated in this population to various degrees, including the Agency for Health Care Policy and Research (now the Agency for Healthcare Research and Quality) CP score (20) and the TIMI score (22,23). For the purpose of this document, reference is made to specific scoring systems in clinical scenarios on the basis of published literature that would inform ratings of imaging tests. Regarding these

scoring tools, it is important to note that initial validation often occurs in a population of patients from clinical trials for which the diagnosis of ACS is definitive. Whether these tools all translate into the lower risk population of ED patients with suspected ACS is not always as yet well validated (22).

SECTION 1: IMAGING OF PATIENTS FOR WHOM THE INITIAL WORKUP IS DIAGNOSTIC FOR STEMI OR FOR WHOM A NONCARDIAC DIAGNOSIS IS LIKELY

Clinical and Imaging Rationale

Much of the initial triaging of patients presenting with CP comes from defining the clinical presentation as assessed by the history and physical examination and initial ECG. Patients not easily placed into one of these scenarios from additional information and/or risks are considered in subsequent sections and tables.

Description of Clinical Scenarios

Clinical Scenario 1: Diagnostic Electrocardiogram for STEMI

In patients for whom ECG shows STEMI, CCath has been shown to be beneficial when delivered rapidly (24). Portable chest radiography has been studied for limited use in this setting of suspected ACS (21), on the basis of the individual patient care environment, and found to be of low yield. Although no study should delay the “door-to-balloon” time, unless a potential contraindication, such as aortic dissection, is suspected (25), portable chest radiography may be appropriate because it can exclude a secondary pathology (e.g., pneumonia, pneumothorax, abnormal line placement) important to communicate with the catheterization staff.

Clinical Scenario 2: Initial History or Physical Examination and/or Chest Radiography Identifies a Likely Noncardiac Diagnosis

Diagnoses with high short-term mortality risk, such as ACS, PE, and AAS, may be ruled out at this stage on the basis of patient history, physician examination, and chest radiography. In this scenario, all imaging modalities under consideration are considered rarely appropriate.

SECTION 2: IMAGING OF PATIENTS WITH CP AND A LEADING DIAGNOSIS OF NON-ST-SEGMENT ELEVATION ACS

Clinical Rationale

CP and other conditions consistent with possible myocardial ischemia (or rule-out ACS) are among the most common ED presentations. CP represents a high-volume, potentially high-risk scenario in which the majority of patients are actually at low risk for ACS. Over the past 20 years, there has been substantial progress on improving methods that can accurately and rapidly identify the

relatively few high-risk ACS patients among the large presenting volume of low-risk patients.

Obtaining a history is of critical importance in the initial evaluation of ED CP patients. Although often not sufficient to exclude myocardial ischemia in a particular patient, a history allows risk stratification into high-, intermediate-, and low-risk groups in which additional diagnostic testing, such as cardiac marker analysis and imaging techniques, can be more appropriately targeted. The characteristics of the pain and the presence of associated symptoms are useful for risk stratification (17,20). Although risk factors for coronary disease are often assessed, they have limited value for identifying patients with MI because they are frequently outweighed by the CP characteristics, history of coronary disease, and findings on ECG (26).

A number of risk stratification models that combine clinical and electrocardiographic findings have been shown to predict short-term outcomes in patients with symptoms suggestive of myocardial ischemia (17,20,21). These algorithms have similar sensitivity but significantly higher specificity than physicians' evaluations, potentially identifying lower risk patients who could be evaluated in lower intensity settings or discharged home. Despite these potential advantages, few algorithms have been incorporated into standard practice. One risk stratification algorithm is the TIMI risk score, which is composed of seven variables of equal weight. Although the TIMI score was initially derived and validated in a clinical trial population with definite ACS, subsequent studies in lower risk ED patients have also shown that it can assist in risk stratification, although to a lesser degree (27). Recent studies have suggested that when contemporary troponin testing at 0 and 2 hours is combined with a TIMI risk score of 0 (adapted to include only the initial troponin value), occurring in approximately 10% of all ED CP patients, such a strategy may identify patients at very low risk (28,29).

ECG is the initial test in patients with CP or suspected ACS because it can be performed rapidly, is inexpensive, and can readily identify STEMI patients who will benefit from early reperfusion. The presence of ischemic changes, including ST-segment depression (21), identifies a high-risk patient group, while conversely, completely normal findings on ECG identify a group of patients at relatively lower risk for MI and ischemic complications, the majority of whom can be evaluated in lower intensity settings, such as observation units. The presence of normal electrocardiographic findings on initial presentation in those patients eventually ruling in for MI identifies a group at lower risk for mortality and unfavorable outcomes compared with those with ischemic changes, but the absolute event rates are not low enough to drive discharge triage decisions (17,30).

In all patients with suspected ACS, the early determination of biomarker (troponin) status is very important because many diagnostic and treatment decisions will be, in part, determined by troponin positivity or negativity. Although the previous description of the acquisition of information implies serial determination of history, physical examination, chest radiography, and biomarker analysis, in practice, many of these are done in parallel.

The presence of clear ischemic changes on initial ECG, either ST-segment elevation or depression, identifies an ACS patient in whom admission and rapid management are mandatory; in this case, the initial triage and treatment strategy is guideline driven (24). However, diagnostic initial electrocardiographic findings are present in only a minority of patients. The remaining clinically stable patients have possible myocardial ischemia and suspected NSTEMI ACS. It is this group in which subsequent risk stratification evaluation and potential use of additional diagnostic tools such as imaging modalities are needed.

Because of the limitations of historical, physical examination, and electrocardiographic data, many of these patients are admitted or placed into observation units, though most are later determined to have nonischemic causes of their symptoms. Despite this low threshold for admission, some patients with AMI are inadvertently discharged (31), with subsequent morbidity and mortality 2 to 3 times that of those AMI patients who are admitted, on the basis of older studies (32). Although some of these inadvertently discharged patients may have infarctions, it is likely that some have unstable angina that may subsequently evolve into MI, underscoring the importance of identifying these patients. The findings that 2% of patients with AMI are inadvertently discharged from EDs are based on studies that used less sensitive troponin assays. In current practice, with more sensitive troponin assays, this number is likely to be smaller. In addition, patients with unstable angina who were troponin negative with old assays might be identified by elevated troponin using contemporary assays.

Thus, if the history, initial electrocardiographic results, and troponin biomarkers with or without the use of risk scores are diagnostic for ACS, a triage decision to admit and treat should be made and an evidence-based treatment strategy initiated (21). If the initial data are sufficient to confirm a diagnosis that is not ACS (such as pericarditis, a diagnosis not considered in this document), direct early discharge from the ED with appropriate follow-up may be warranted. However, after this initial information, uncertainty often continues to exist regarding an ACS diagnosis. It is in this population—patients with suspected NSTEMI or ACS—that further workup and risk stratification are warranted. In this document, we consider two pathways of further workup: an early assessment pathway and an observational pathway.

Early Assessment Pathway and Observational Pathway

For the purpose of this document, to frame the appropriate use of cardiovascular imaging techniques within the clinical context of their use in this setting, we adopt two pathways for the evaluation of ED patients with suspected ACS. The first evaluation pathway is referred to as the early assessment pathway. With this strategy, imaging may be used early in the evaluation process, with the goal of ruling in or ruling out ACS or MI through the identification of wall motion abnormalities, perfusion defects, or obstructive CAD without the need to wait for serial biomarker analysis. Imaging tests in this pathway do not require stress physiology but rather image anatomy (CCTA), function (echocardiography, CMR), or perfusion (resting SPECT, CMR) at rest. Stress examinations were not considered by the rating panel in the early assessment pathway. Patients in the ED with CP syndromes and history of MI or revascularization (i.e., known CAD) may have evidence of resting wall motion or resting perfusion abnormalities, as well as abnormal coronary anatomy by definition, which would confound the evaluation of a new symptom complex suspicious for ACS by these testing modalities. Clinical scenarios 3 to 7 considered in the early assessment pathway appear in [Table 2.1](#).

The second pathway is referred to as the observational pathway, and it involves serial analysis of cardiac biomarkers to rule in or out myocardial necrosis and MI. Testing in this pathway may involve stress physiologic testing, and thus stress examinations were considered by the rating panel in clinical scenarios 8 to 10. Assessments at rest are generally less appropriate for patients managed in the observational pathway. Patients in the ED with CP syndromes and history of MI or revascularization (i.e., known CAD) may have evidence of resting and/or stress wall motion or perfusion abnormalities, as well as abnormal coronary anatomy, which, as noted previously, would complicate the evaluation of a new symptom complex suspicious for ACS, although stress testing would identify currently existing ischemia. Ratings for the observational pathway appear in [Table 2.2](#).

Description of Clinical Scenarios in the Early Assessment Pathway

The early assessment pathway uses tests to inform the ED physician regarding ACS for purposes of triage decision making. Some tests provide information that may be generally useful for management purposes (e.g., assessment of ejection fraction), but these are not directly useful for the diagnostic purpose of identifying a patient with an ACS. Patients considered in this pathway may or may not have ongoing symptoms. Some physiologic testing, such as analysis of wall motion abnormalities, is, importantly, influenced by whether ischemia is ongoing, whereas other modalities, such as coronary CT angiographic assessment of coronary anatomy, are not. Studies have suggested that perfusion imaging test results may remain positive for a resting perfusion abnormality several hours after symptom resolution (33).

Clinical Scenario 3: Initial ECG and/or Biomarker Analysis Unequivocally Positive for Ischemia

CCath is beneficial in patients in whom initial ECG and/or biomarker analysis is unequivocally positive for ischemia, as revascularization may be associated with more favorable outcomes (21,34-36). Thus, CCath is considered appropriate, whereas all other rest imaging modalities are considered rarely appropriate.

Clinical Scenario 4: Equivocal Initial Troponin or Single Troponin Elevation Without Additional Evidence of ACS

In such patients, the diagnosis of ACS remains uncertain. Both rest SPECT and CCTA are appropriate and have been evaluated in randomized trials (19,37,38). Rest echocardiography and rest CMR may be appropriate, and CCath is rarely appropriate.

Clinical Scenario 5: Ischemic Symptoms Resolved Hours Before Testing

Assessment for wall motion abnormalities by echocardiography or other testing is dependent on the presence of ongoing ischemia. Thus, if symptoms have resolved many

TABLE 2.2 Suspected Non-ST-Segment Elevation ACS: Observational Pathway—After Assessment of Serial Cardiac Troponin

Indication	Exercise ECG	Echocardiography		CMR		SPECT/PET		CCTA	CCath
		Rest	Stress/Rest	Rest	Stress/Rest	Rest	Stress/Rest		
8. Diagnosis unequivocally positive for NSTEMI/ACS	M*	M*	M*	M*	M*	M*	M*	M*	A
Serial troponins or ECG not positive for NSTEMI/ACS									
9. Serial ECG and troponins negative for NSTEMI/ACS	A	R	A	R	A	R	A	A	R
10. Serial ECG or troponins borderline for NSTEMI/ACS	M*	M*	A	R	A	R	A	A	M*

Appropriate use key: A = appropriate; M* = may be appropriate as determined by lack of consensus by rating panel; R = rarely appropriate.

ACS, acute coronary syndrome; CCath, catheter-based coronary angiography; CCTA, coronary CT angiography; CMR, cardiovascular MR; ECG, electrocardiography; NSTEMI, non-ST-segment elevation myocardial infarction; SPECT, single-photon emission computed tomography.

hours before assessment, such tests will be insensitive for the diagnosis of ACS. Resting perfusion abnormalities may persist for several hours after ischemia resolves, although it is unknown at what time point sensitivity decreases (33). Clinical trials using rest perfusion imaging to distinguish ACS versus non-ACS CP and improve triage have allowed enrollment of patients up to 3 hours after symptom resolution (37,39). In this setting, CCTA is considered appropriate, whereas rest CMR and rest SPECT may be appropriate. Rest echocardiography and CCath are rarely appropriate.

Clinical Scenario 6: TIMI Risk Score = 0, Early hsTrop Negative

As noted under “Testing Considerations,” although high-sensitivity troponins (13) are, at the time of rating, not approved for use in the United States, they are increasingly used outside the United States. Moreover, an emerging body of literature suggests that incorporating these biomarkers can identify a group of patients already at very low clinical risk whose ACS prevalence and event rate are very low. Conceptually, in such a setting, no further testing may be considered, as the yield would likely be low. The rating panel has considered CCTA appropriate in this setting, as some of the extant trials of CCTA versus standard-of-care evaluation have generally included relatively low-risk populations. In one study, there were no cardiac deaths, and only 1% of patients had MIs within 30 days (38). In this population, CCTA was rated as appropriate, and all other imaging modalities were rated as rarely appropriate.

Clinical Scenario 7: Normal or Nonischemic Initial ECG, Normal Initial Troponin

This scenario refers to patients in whom the initial electrocardiogram is not diagnostic for ischemic changes and the initial troponin result (not high-sensitivity assay) is also not diagnostic for NSTEMI or ACS. This scenario represents a large proportion of patients seen in this setting, in whom there generally remains uncertainty about the diagnosis after initial ECG and biomarker analysis. Such patients have been considered at low to intermediate risk for ACS. CCTA is appropriate, and rest SPECT may be appropriate, with data based on randomized trials (19,37,38). Rest echocardiography, rest CMR, and CCath are rarely appropriate.

Description of Imaging Modalities

Resting SPECT Myocardial Perfusion Imaging

A number of studies have examined the use of resting myocardial perfusion imaging in the setting of suspected ACS (37,39-43). Several reports have concluded that the use of resting SPECT in the ED in such patients is

associated with shorter length of stay and lower costs and can reduce unnecessary hospital admissions (37,39,43,44). A large body of observational literature established a high NPV for a normal resting perfusion image to rule out an MI or short-term cardiac events (45). Two randomized trials have been reported. In a smaller trial, in which management after imaging was protocol directed, a strategy incorporating resting SPECT was associated with shorter length of stay and lower cost, with similar safety (44). In a much larger trial, in which management after imaging was left to the discretion of the ED physician (“effectiveness,” i.e., how a test performs in real life to influence decisions), the incorporation of resting SPECT resulted in fewer unnecessary admissions, with an unnecessary admission defined as those patients admitted from the ED whose final diagnoses were not ACS (37). There was, however, no outcome difference 30 days after ED presentation compared with those who underwent standard ED care. In this latter trial, patients were enrolled if they were within 3 hours of symptom resolution. Resting SPECT is limited in distinguishing chronic from acute ischemia.

Echocardiography

Resting 2-D echocardiography is rapid and noninvasive. Two-dimensional echocardiography provides information about myocardial ischemia by evaluating segmental wall motion and ejection fraction (9,46), but the positive predictive value (PPV) is not high (9,47). It may detect other possible pathologies that may be associated with CP, such as valvular disease, pericarditis, and cardiomyopathy. Like resting SPECT, 2-D echocardiography is limited in distinguishing chronic from acute ischemia. In addition, resting echocardiography cannot determine the presence of an underlying high-grade coronary stenosis in the absence of impaired myocardial perfusion at rest that results in wall motion abnormalities. Thus, most studies have shown that resting echocardiography to detect acute ischemia is useful only if there are ongoing symptoms at the time of imaging.

When contrast agents are used to assess myocardial perfusion, echocardiography is reported to achieve higher sensitivity than wall motion analysis alone with both rest and stress (48-52). Although not currently used in routine practice, these methods have moved from research-only tools to clinical availability in some centers of expertise.

CCTA

Coronary calcium scoring was not considered by the rating panel because there are few data on coronary calcium scoring using multidetector CT hardware in patients who present to the ED in whom ACS is the leading differential diagnosis. Moreover, in patients at intermediate to high

risk for CAD, a calcium score of 0 is often associated with myocardial ischemia on provocative testing (53). For patients with coronary calcium detected by CT, the examination would require additional imaging, such as CCTA, that interrogates the coronary lumen.

For patients with CP in the ED, using stenosis detection as a surrogate for ACS and ACS events, CCTA has reported high sensitivity (86%-100%) and NPV (93%-100%), although the PPV using invasive coronary angiography as the reference standard is still limited (50%-90%) (54-58). CCTA has been used to evaluate not only the severity of stenosis but also plaque characteristics associated with vulnerability and risk for events (18). However, CCTA is limited in patients with extensive coronary calcium, which generally increases with the risk for ACS as well as with age. Initial reports suggested that a CT-based strategy decreases time to diagnosis (compared with SPECT), length of hospital stay, unnecessary admissions, total costs, and repeat evaluations for recurrent CP, while allowing safe discharge after a negative evaluation (18,56,59,60). Two large randomized strategy-controlled trials have evaluated the early use of CCTA (i.e., before the completion of serial troponin assessments) in patients with low to intermediate likelihood for ACS in the ED setting. Litt et al (38) compared a CCTA pathway with traditional care for safety, defined as absence of MI or cardiac death within 30 days of presentation. Both pathways were found to have a <1% rate of major adverse cardiovascular events (MACEs). Secondary end point analysis demonstrated earlier and more direct ED discharges in the patient group randomized to undergo CCTA as part of their evaluation strategy. Hoffmann et al (19) conducted a randomized controlled trial of 1,000 patients seen at nine U.S. centers, with patients randomized to an early CCTA pathway or standard evaluation. They found as the primary end point that length of stay was shorter among patients randomized to a strategy incorporating early CCTA compared with a standard evaluation strategy. There were no undetected cases of ACS and no significant differences in MACEs. Secondary end points, including time to diagnosis and direct ED discharges, were also favorably affected by CCTA. In a subgroup of patients with full cost information, ED costs were lower in the CCTA strategy group, though overall costs at 30 days were similar. Radiation exposure was higher in the CCTA group, and there was more downstream testing in the CCTA group. Also, patients in the CCTA arm underwent more revascularization procedures, some of which may have occurred in the absence of a stress test to judge ischemic burden of a lesion. In both of these trials, MACE rates for the CCTA arm and standard of care were less than 1%. The results of the studies of the use of CCTA in the ED have undergone meta-analysis (61) confirming the reduction in length of stay and cost but with slightly

increased resulting use of invasive angiography and revascularization downstream.

CMR

Rest CMR can image regional and global ventricular function and myocardial perfusion and identify scar. When it has been used in ED patients, generally in observational studies with modest numbers of patients, contrast-enhanced perfusion, delayed enhancement, and cine evaluation of wall motion have been shown to have sensitivity of 70% to 85% to detect ischemic conditions (62-64). Normal results on CMR have been associated with a low-risk prognosis. Imaging coronary anatomy has not been done routinely in these studies and is not widely performed; most of the information in the literature involves analysis of perfusion, scar, and function.

CCath

Although catheter angiography remains the clinical standard for the diagnosis of CAD, it has been found to be more limited in value for the initial evaluation of patients at less than high risk for ACS (21). It can be used to confirm ACS in patients with positive screening results and interventions in the case of perfusion or wall motion abnormalities suggestive of hemodynamically significant stenosis or occlusion or in patients for whom noninvasive testing cannot provide a definitive diagnosis.

Description of Clinical Scenarios in the Observational Pathway

Although the evolution of imaging modalities has enabled the potential use of imaging tests early in the evaluation process, the majority of patients currently seen for assessment of ED CP syndromes—and who do not have initially diagnostic electrocardiographic or biomarker evidence of NSTEMI or ACS—are evaluated in the observational pathway. By definition, patients in this pathway have undergone initial ECG and biomarker testing that has not led to a clear diagnosis of ACS, but ACS is still a consideration. Thus, serial ECG and troponin biomarker analysis are used to rule out NSTEMI or ACS (or rule it in), and if ruled out, stress testing with or without imaging may be performed to assess for the potential of induction of ischemia. Anatomic testing for CAD with CCTA may also be appropriate in this pathway. The protocol of serial biomarkers followed by more definitive testing in the observational pathway has been evaluated in non-randomized studies (65) as well as in randomized clinical trials (66,67).

The rating group considered two different groups of patients. The first group comprised patients for whom the diagnosis was unequivocally positive for NSTEMI or ACS from the analysis of serial biomarkers and ECG. The second group of patients comprised those for whom serial troponin and ECG were not positive for NSTEMI or ACS.

By definition of being in the observation pathway and having undergone serial ECG and biomarker assessments, these patients would be at least 9 to 24 hours out from ED presentation. They may still be in the ED, but by the nature of the observational pathway and practices at different hospitals, they also may have been moved to CP evaluation units or telemetry floors.

The intention for this indication was that such patients are clinically stable, having likely received initial guideline-directed medical therapy for possible ACS or NSTEMI. These patients are considered similar to those enrolled in ACS clinical trials examining strategies of routine invasive versus selective invasive (“ischemia-guided”) strategies, such as TACTICS-TIMI 18 (Treat Angina With Aggrastat and Determine the Cost of Therapy With an Invasive or Conservative Strategy-TIMI 18) or ICTUS (Invasive Versus Conservative Treatment in Unstable Coronary Syndromes). Regarding the specifics of the stress testing choices, a wide range of stress testing modalities and timing of stress testing has been reported among numerous randomized trials (68-73). Thus, we have used the word *stress* generically so as not to create numerous additional categories of exercise (maximal or submaximal) or pharmacologic stress for each modality, and we could not specify optimal timing of testing. It should be assumed that the type of stress used and the timing of testing would not be clinically contraindicated in the specific situation.

Clinical Scenario 8: Any Electrocardiogram and/or Serial Troponins Unequivocally Positive for NSTEMI or ACS

If serial troponins demonstrate positive evidence of myocardial necrosis in the setting of ischemic symptoms or electrocardiographic changes, the diagnosis of NSTEMI or ACS is made, and management can follow existing guidelines (21). Often this will involve a strategy incorporating catheter angiography and potential revascularization, as numerous randomized trials have shown that patients with biomarker-positive NSTEMI or ACS generally have more favorable outcomes when managed with an “invasive strategy” consisting of invasive angiography followed by revascularization. Thus, CCath is considered appropriate in this scenario. However, for NSTEMI patients in the presence of certain comorbidities, particularly abnormal renal function, the outcome benefit of a direct invasive angiography and revascularization strategy compared with a “conservative” strategy narrows (74). In clinical trials of patients with ACS that have randomized patients to either an “invasive” or a “conservative” initial strategy (now also referred to in guidelines as an “ischemia-guided” strategy), the conservative strategy usually consists of stress testing with imaging, often stress SPECT, to assess the presence and extent of ischemia (68,69). Although many, but not all, such trials showed an

outcome advantage for the routine invasive strategy, it is also recognized that in real life, many patients covered by this indication may have comorbidities that might have excluded them from the randomized control trials, such as renal dysfunction mentioned previously, or may be elderly or frail, or simply would prefer a potentially less aggressive management direction. In these situations, clinical consideration could be given to an ischemia-guided strategy, using stress testing with or without imaging, to identify those patients with very extensive ischemia who might have a larger benefit from revascularization, while others could be treated medically. Because these scenarios generally fall outside of the clinical trials, the rating panel did not come to consensus on the alternative strategies besides invasive catheterization, and thus all are rated as “may be appropriate.”

Clinical Scenario 9: Serial ECG and Troponins Negative for NSTEMI or ACS

Patients in this scenario have no evidence of myocardial necrosis. The diagnosis of NSTEMI is ruled out, and the remaining diagnostic considerations include the possibility of troponin-negative unstable angina and CP not due to an ACS. It is in this situation that stress testing to assess for the induction of inducible ischemia is useful (all rest and stress studies are appropriate), as is imaging for anatomic CAD (CCTA is appropriate). Exercise electrocardiographic testing is also appropriate if it is anticipated that the patient can attain an adequate level of exercise stress and if the electrocardiogram is interpretable for stress-induced ischemia. As these tend to be low-risk patients, particularly in the setting of low pretest probability of ACS (75,76), outpatient testing can be considered.

Clinical Scenario 10: Serial ECG or Troponins Borderline for NSTEMI or ACS

Because the assays for troponin have varying precision, at times, results are reported that are detectable but not clearly elevated in a manner consistent with NSTEMI (77). In such a scenario, NSTEMI has neither been completely ruled in nor ruled out, and further testing is indicated. In this situation, stress testing for inducible ischemia or anatomic testing for the presence of CAD are appropriate, with all rest and stress studies as well as CCTA being considered appropriate.

Description of Diagnostic Studies

Exercise ECG Without Imaging

For low-risk patients with interpretable electrocardiograms, stress ECG without imaging has been reported to be associated with a decrease in unnecessary admissions (21,76,78,79). The excellent NPV of 98% to 99% has been confirmed, although the PPV is limited for obstructive

CAD (80-87). The lower PPV may be due to the lower risk population being studied. Use of the Duke treadmill score reduces the false-positive rate of exercise electrocardiographic testing rather than relying on ST-segment changes alone (88-91). Patients with normal stress test results at a high level of exertion have an excellent prognosis and can be safely discharged (92). Thus, for patients with normal results on ECG and the ability to exercise adequately, stress tests without imaging can be useful (17). For patients with potentially uninterpretable stress electrocardiograms (left ventricular hypertrophy with secondary ST-T changes, paced rhythms, left bundle branch block) or those who do not achieve an adequate stress heart rate, stress ECG will not be useful.

Stress Echocardiography

Stress echocardiography may involve exercise or pharmacologic (dobutamine or atropine) stress, and it increases myocardial oxygen consumption such that the presence of a flow-limiting lesion will impair perfusion and create segmental systolic and diastolic dysfunction in the underperfused region. The presence and extent of an induced wall motion abnormality are more sensitive and specific than stress-induced electrocardiographic abnormalities alone (81,82,86) and have higher NPV for excluding obstructive CAD (93-97). Achievement of an adequate heart rate/demand response from exercise or from dobutamine stress is important to optimize sensitivity to detect underlying CAD. Thus, if exercise or tachycardic stress is felt to be clinically contraindicated, pharmacologic vasodilator stress with myocardial perfusion imaging by SPECT or CMR would be preferable. Visualization of endocardial borders for all myocardial segments is a prerequisite for optimal test accuracy. Stress echocardiography also detects the presence of prior infarction and provides information about cardiac hemodynamics, structure, and function.

Stress SPECT and PET

Stress myocardial perfusion imaging, with exercise or pharmacologic stress, may be used to detect the presence and extent of inducible perfusion abnormalities suggestive of ischemia, as well as the presence of prior infarction. Perfusion may be assessed with the use of widely available SPECT tracers and cameras or may be performed using PET imaging if tracers, equipment, and expertise are available. PET imaging may be useful in patients with larger body mass indexes because of its inherently better spatial resolution. Electrocardiographically gated SPECT or PET acquisition allows simultaneous evaluation of regional and global left ventricular function for this population (98,99). NPV is also

high (96%-100%). The annualized event rate after normal results on stress SPECT is low over follow-up (40,87,98-100).

Stress CMR

A small randomized trial assessed outcomes and costs in patients with suspected ACS and intermediate likelihood of CAD randomized to an observation unit strategy of serial biomarkers followed by adenosine stress CMR compared with an inpatient evaluation strategy (101). There were no differences in missed ACS from the index visit and no differences in outcome events between the two strategies over one year (102). Costs associated with the index visit, as well as costs out to one year of follow-up were lower with the observation unit/stress CMR strategy. These investigators reported, however, that among low-risk patients, a mandated CMR strategy incurred higher costs than a “provider-directed” imaging strategy, in which clinicians most often chose stress echocardiography (103).

SECTION 3: IMAGING OF PATIENTS WITH SUSPECTED PE

Clinical Rationale

Venous thromboembolic disease includes both PE and deep venous thrombosis (DVT). PE accounts for 100,000 to 180,000 deaths annually in the United States and afflicts millions of individuals worldwide. The 15% case fatality rate for PE exceeds the mortality rate for AMI (104,105). PE survivors may have impaired quality of life due to chronic thromboembolic pulmonary hypertension.

PE affects patients of widely varying ages, from teenagers to the elderly. Its onset is usually unpredictable, but associated risk factors may include prolonged immobility, trauma, recent surgery, cancer, oral contraceptive use, pregnancy, and postmenopausal hormone replacement.

Clinicians must remain vigilant to detect PE because of the diverse presenting signs and symptoms. For example, PE can present like other illnesses, such as pneumonia and congestive heart failure.

ECG is insensitive for PE but may raise suspicion or help confirm the diagnosis in patients with electrocardiographic manifestations of right-heart strain. Right-heart strain, however, may not be present, is not specific, and may be observed in patients with asthma, idiopathic pulmonary hypertension, or other etiologies of cor pulmonale. Patients with massive PE may have sinus tachycardia, slight ST- and T-wave abnormalities, or even entirely normal findings on ECG (106). Other abnormalities include incomplete or complete right bundle branch block and an S1Q3T3 complex. T-wave inversion in leads V₁ to V₄ has the greatest accuracy for identifying right ventricular dysfunction in patients with acute PE.

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