Acute chest pain in the emergency department: Role of cardiac CTA

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The evaluation of acute chest pain in the Emergency Department (ED) remains an important problem. In the United States, more than 6 million patients present annually for this indication, which is second in frequency to presentation for abdominal pain. The pertinent focus of clinical evaluation is to distinguish those patients with acute coronary syndrome (ACS) (which includes transmural myocardial infarction, subendocardial infarction, and unstable angina) from those with chest pain due to myriad other causes. These etiologies may be life-threatening, such as pulmonary embolism or aortic dissection, or they may constitute a less serious threat, such as musculoskeletal pain or gastroesophageal reflux.[1]

In many ways, the conventional approach to the assessment of chest pain is unsatisfactory. Approximately 15% of patients in the ED have ACS. Yet, approximately 50% of patients, the majority of whom prove to have benign causes for their chest pain, are admitted to the hospital.[1] This abundance of caution on the part of ED physicians is due to concern of medicolegal exposure, for which missed myocardial infarction is the leading cause. Notwithstanding a conservative approach, 2% to 5% of patients—many of whom have atypical symptoms—who prove ultimately to have ACS are mistakenly discharged. A chest pain evaluation in the ED is time-consuming, often exceeding 12 hours. Clearly, methods to improve diagnostic precision and speed the chest pain work-up would be welcome. This article describes the conventional evaluation for chest pain and focuses on the potential for the use of multidetector computed tomography (MDCT) to affect the current diagnostic approach.

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Conventional assessment

In patients who present to the ED with chest pain, the standard assessment to exclude a myocardial assessment includes a history and physical examination, electrocardiogram (ECG), and cardiac bioenzymes. In many patients, this evaluation is sufficient to provide an adequate triage. There are several formal scoring systems that classify the risk level of the patient according to initial assessment. For example, the thrombolysis in myocardial infarct (TIMI) risk score for unstable angina and non-transmural myocardial infarction uses a 7-point scale based on historical information (such as age and coronary risk factors) and current presentation (such as ST wave changes on electrocardiography) to stratify the likelihood of an adverse outcome.[2]

In order to further assess risk and streamline evaluation among patients with acute chest pain, dedicated chest pain units (CPUs) have been developed. The major purposes of CPUs are: A) to identify patients who are at high risk and rapidly triage them, and B) to reduce inappropriate hospital admissions among patients who can be shown to be at low-to-intermediate risk.[3]

Thus, from the standpoint of noninvasive imaging, 3 discrete risk groups can be identified. The high-risk patients (corresponding to CPU Group A above) who have characteristic ECG findings and elevated biomarkers require immediate intervention, and there is no role for non-invasive evaluation. A second group can be classified as very low-low risk (eg, pleuritic or noncharacteristic chest pain), and these patients are usually treated outside the CPU setting. The third group is composed of low-to-intermediate risk patients who have atypical chest pain and/or ECG findings that cannot be easily disregarded. If cardiac disease is suspected, these patients may be admitted to a CPU (CPU Group B). These individuals commonly undergo further non-invasive testing, sometimes with exercise testing but often with a variety of imaging techniques. The latter include myocardial perfusion imaging and echocardiography. Other patients have chest pain that is suggestive of serious noncardiac etiologies (such as pulmonary emboli, aortic dissection, or pneumonia) and may undergo chest radiography or chest CT. More recently, cardiac CT has been proposed as an effective method to assess acute chest pain of suspected cardiac origin, either dedicated to the heart or as a comprehensive assessment of the heart and thorax (triple rule-out). The following sections review the various imaging options for assessing acute chest pain.

Chest radiography

The chest radiograph has served for decades as the initial imaging technique to evaluate acute chest pain in the ED. This technique is valuable for the diagnosis of many causes of noncardiac chest pain, such as pneumothorax, pneumonia, pulmonary neoplasm, and rib fractures.

Direct evidence of myocardial ischemia is uncommon on chest radiography, but indirect findings may be visible in the form of tram-track calcifications of the coronary arteries, which indicates atherosclerosis. The sensitivity for detection of coronary artery calcification on chest radiography is <50%. Coronary artery calcification is visualized in the "coronary triangle" overlying the mid-upper part of the left heart and involving the proximal parts of the left coronary arteries.[4] Radiographically evident coronary calcium has been linked with a higher prevalence of significant coronary artery stenosis.

Complications of earlier episodes of myocardial ischemia may be evident on chest radiography. An enlarged cardiac silhouette may be due to a previous myocardial event. Curvilinear calcification of the left heart border is consistent with a prior myocardial infarction.[5] The putative mechanism is impaired wall motion followed by local thrombus formation and dystrophic calcification. Focal bulging of the left heart border may represent a postinfarction myocardial aneurysm or pseudoaneurysm. An additional indirect sign of ischemic chest pain is congestive heart failure. The radiographic findings correlate with the severity of congestive heart failure.

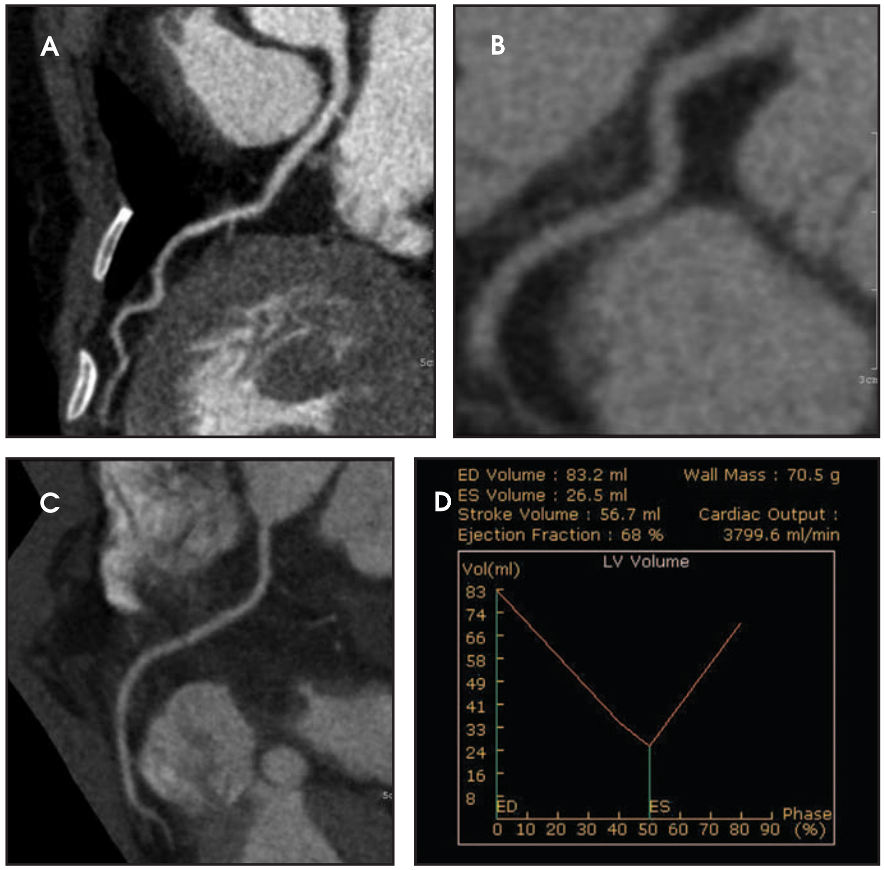

FIGURE 1. Electrocardiographic-gated cardiac CT angiographic images reveal a normal (A) left anterior descending artery, (B) left circumflex artery, and (C) right coronary artery. (D) The ejection fraction was also normal. ED = end diastole; ES = end systole; LV = left ventricular.

Stress testing

Single-photon–emission CT (SPECT) myocardial perfusion imaging has an established role in both high-risk and less critical evaluation of chest pain. In patients who present to the ED with chest pain and nonspecific ECG changes, myocardial perfusion SPECT provides incremental risk stratification value over clinical data for predicting unfavorable cardiac events.[6] After injection of technetium (Tc)-99m–based perfusion tracer during chest pain and imaging 45 to 60 minutes later, stress testing permits the assessment of myocardial blood flow at the time of injection. In a series of observational studies, the negative predictive value for ruling out ACS has approximated 99%. Thus, a normal myocardial perfusion study predicts a small risk of ACS in this setting.[7] Patients who exhibit abnormal regional perfusion have a higher risk of cardiac events during hospitalization and subsequently. However, myocardial perfusion imaging has several disadvantages. It is difficult to obtain during off-hours, requires movement of the patient out of the ED suite, is prone to false-positive results in some populations, and does not address potential noncardiac causes of chest pain.

Stress echocardiography is also a versatile and powerful imaging modality in evaluation and risk stratification of patients presenting to the ED with chest pain.[8] The prognostic information provided is comparable to that obtained with nuclear stress testing. It is portable and also has the advantage of providing incremental information of value by evaluating baseline ventricular function,

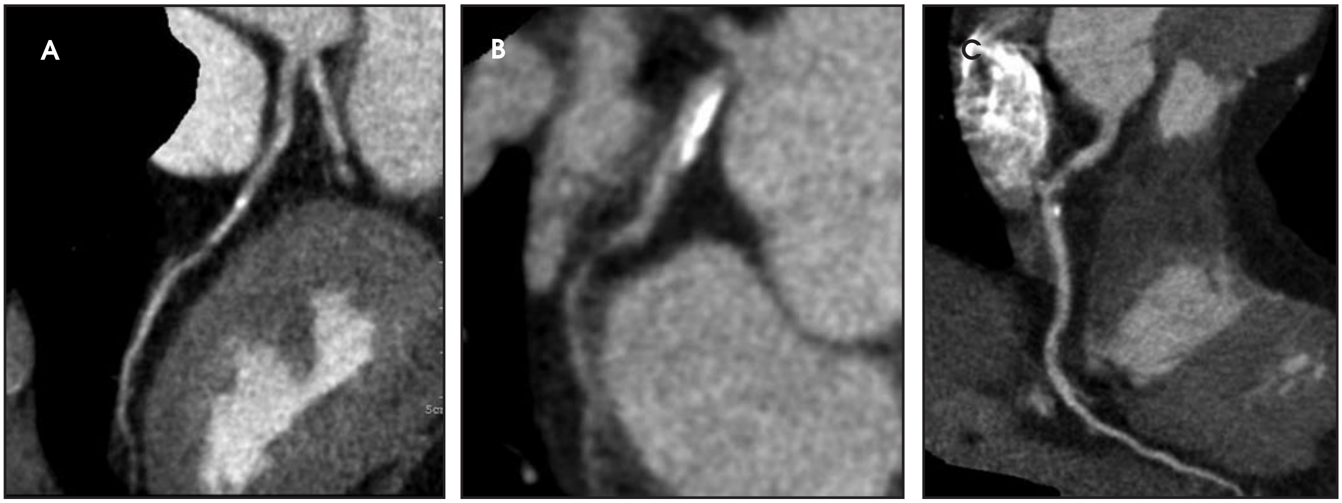

FIGURE 2. *These electrocardiographic-gated cardiac CT angiographic images obtained with a triple rule-out protocol reveal 3-vessel coronary artery disease: (A) left anterior descending artery, (B) left circumflex artery, and (C) right coronary artery.*

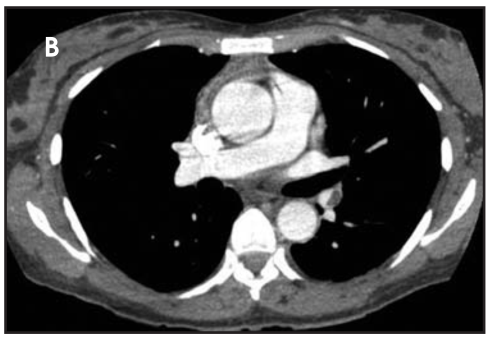

FIGURE 3. *This electrocardiographic-gated cardiac CT angiography study was obtained with a triple rule-out protocol. The coronary arteries were normal. (A) The left anterior descending artery [LAD] is shown. (B) A left lower lobe pulmonary embolus was the cause of chest pain.*

valvular function, aortic root morphology, and pericardial anatomy. A negative stress echocardiography study predicts very low cardiac event rates and thus can be the basis for discharge of the patient from the ED. Disadvantages include inferior sensitivity and specificity as compared with radionuclide perfusion imaging (particularly in patients with nontransmural MI or resolved wall motion abnormalities), difficulty in obtaining the study during off-hours, and inability to visualize causes of chest pain outside the heart.

CT scanning

The use of CT scanning to evaluate chest pain in the ED for noncardiac causes extends back at least 2 decades. The advent of spiral CT in the early 1990s led to more frequent placement of scanners in or near the ED. Emergency physicians have become increasingly reliant on CT scanning to diagnose a variety of conditions related to trauma, headache, and abdominal pain. In the chest, CT scanning has been applied widely in patients with suspected pulmonary embolism, aortic dissection, and pneumonia.

Cardiac CT scanning was first developed in the late 1980s using electron-beam CT (EBCT). The EBCT scanner has no moving parts, enabling an excellent temporal resolution that is critical for assessment of the coronary arteries, which are small and subject to both cardiac and respiratory motion. The major application of EBCT was to evaluate the quantity of coronary calcium, as an adjunct to traditional risk factor measurement. The presence of coronary calcium is indicative of coronary artery disease.

Electron-beam CT has been studied in ED patients with atypical acute chest pain in the low-to-intermediate risk category. Three separate ED studies showed a high sensitivity for detected coronary calcium, indicative of coronary disease (98% to 100%). The authors found a high negative predictive value, which led them to suggest that a negative EBCT study might permit early discharge from the ED.[9-11]

The development of multidetector CT (MDCT) in the late 1990s extended the application of conventional CT to coronary artery assessment. Because of rapid technologic advancements and overall versatility, MDCT has now supplanted EBCT as the technique of choice to assess the coronary arteries. Current standard MDCT scanners produce 64 slices, a spatial resolution of 0.5 to 0.6 mm, and temporal resolution of 50 to 150 msec, depending on whether a single- or double-tube configuration is used.[12] Recently, MDCT scanners with more slices and better z-axis coverage, including a scanner with 16 cm of longitudinal coverage capable of 320 slices, have become commercially available.

With MDCT, it is possible to determine the extent of coronary calcification and to acquire coronary CT angiography (CTA) and ventricular function and perfusion. Coronary CTA is increasingly

Table 1. University of Maryland 64-slice CT scan acquisition and contrast administration protocols*

Parameter	Coronary CTA only	Triple rule-out
Premedication	ß-blocker (if HR >65), NTG	ß-blocker (if HR >65), NTG
kV/mAs	120/500	120/600
Field of view (FOV)	250 (10 cardiac phases)	400/250 (Full FOV,10 cardiac phases)
Reconstruction (mm)	0.675	0.9/0.675
Longitudinal coverage	Carina, below inferior cardiac margin	Entire chest
Direction	Cranial-caudal	Caudal-cranial
Time (sec)	8	15
Contrast administration		
Test injection	20 mL @ 6 mL/sec	20 mL @ 6 mL/sec
Injection protocol	80 mL (100%) @ 6 mL/sec	100 mL (100%) @ 6 mL/sec
	40 mL (50/50) @ 5 mL/sec	50 mL (saline) @ 5 mL/sec
	50 mL (saline) @ 5 mL/sec	
	Bolus tracking	Bolus tracking

* These protocols are based on the department's use of Brilliance CT (Philips Medical Systems, Bothell, WA).
CTA = CT angiography; HR = heart rate; NTG = nitroglycerin.

used for outpatient evaluation of chest pain, with sensitivity and specificity >85% in coronary arteries larger than 2 mm and a negative predictive value >90%.[13]

As more 64-slice CT scanners are placed in or near the ED and as ED physicians have become increasingly comfortable with their use, 2 competing protocols have developed. A dedicated cardiac CTA identical to an outpatient protocol optimizes visualization of the heart and coronary arteries (Figure 1). The alternative protocol is usually called the triple rule-out, referring to the assessment of coronary artery disease, pulmonary embolism, and aortic dissection. It represents a comprehensive evaluation of the heart and noncardiac structures in the chest (Figures 2 and 3). The triple rule-out protocol is similar to a pulmonary embolism protocol in that it uses a wide field of view and covers the length of the thorax but also employs cardiac gating. The major advantage of the triple rule-out protocol is to detect pulmonary emboli that are outside the view of a dedicated coronary CTA (Figure 3). Disadvantages of this comprehensive approach are the potential for less optimal visualization of the coronary arteries and a higher radiation dose because of the greater longitudinal coverage (Table 1). The decision of whether to use a triple rule-out rather than a dedicated cardiac CT protocol in patients with acute chest pain and suspected coronary artery disease should be predicated largely on the pretest likelihood of pulmonary embolism, based on clinical likelihood (eg, Well's criteria) or serum markers.[14]

The utility of MDCT in the assessment of ED chest pain has been studied in several single-center clinical trials, initially with 16-slice and more recently with 64-slice CT scanners. Both dedicated cardiac CT and triple rule-out protocols have been used.[15-23] In most of these studies, findings on MDCT were evaluated based on the presence of ACS as a standard of reference, using several criteria. Nearly all studies have shown high accuracy and negative predictive value, suggesting that it may be safe to discharge patients whose studies are negative. In studies that used a triple rule-out protocol, a small prevalence of noncardiac disease, particularly pulmonary embolism, was identified as the cause of acute chest pain.

Two recent randomized single-center trials have compared a conventional diagnostic protocol with coronary CTA as the first-line approach to assessment of low-to-intermediate–risk acute chest pain in the ED.[19,23] One study of 197 patients—98 of whom were evaluated with a standard of care protocol and 99 of whom underwent a coronary CTA protocol—used the absence of coronary disease over a 6-month period of follow-up or a negative invasive coronary angiography as a primary endpoint.[19] Both groups showed high accuracy (95% in the coronary CTA arm, 91% for conventional care) but the time to establish a diagnosis (3.4 hours versus 15 hours) and the cost ($1586 versus $1872) was significantly better for the CTA patients. In addition, patients who had been triaged to the coronary CTA group had fewer follow-up evaluations for chest pain. In the second study, the authors showed that no patient who underwent CTA and was discharged returned with a cardiac event and that admitted patients in the CTA group had a shorter length of hospital stay.[23] These studies suggest that coronary CTA compares favorably with conventional approaches in the evaluation of ED patients with acute chest pain. The first multicenter investigation, the Coronary Computed Tomography for Systematic Triage of Acute Chest Pain Patients to Treatment trial (CT-STAT), will add to existing data.

While these early investigations suggest a promising role for cardiac CTA, several important considerations remain prior to widespread implementation of this technique. One concern is that CTA evaluation of the coronary arteries in the ED setting will be used inappropriately, leading to overutilization, as many radiologists believe is the case for CT pulmonary angiography.

One approach to limit excessive CTA use is to work closely with a designated ED physician to develop appropriate guidelines. The guidelines used for admission to a CPU may be an appropriate starting point. The high negative predictive value of ED cardiac CTA investigations suggests that patients at low-to-intermediate risk for ACS should be targeted. For patients with substantial coronary disease or those in whom it cannot be excluded, further testing may be necessary.

Another critical issue is the challenge of providing ED cardiac CTA coverage on an around-the-clock basis. For academic and larger community practices, the use of internal radiologists or residents may be sufficient. Portals or thin-client systems are becoming available that allow some of this work to be done remotely. Another option is to engage a nighthawk service to provide a preliminary reading during off-hours.

A final important consideration common to all CT scanning is ionizing radiation.[24] Retrospectively ECG-gated 64-slice coronary CTA produces a patient exposure ≥15 mSv (3.6 mSv is the annual background dose). With the triple rule-out protocol, the dose may exceed 20 mSv. However, alternative cardiac testing, such as radionuclide imaging and coronary angiography, can also give large doses (≥25 mSv for a stress thallium study).[25] Current available strategies to reduce exposure are ECG-triggered dose modulation, in which current is decreased during systole when optimal visualization is not usually needed, and a decrease in kVp in thin patients. A larger dose reduction may be achieved in patients with heart rates <70 with prospective axial gating, in which the radiation beam is switched on only during the key part of the cardiac cycle, typically diastole. Prospective gating, which has not been widely used in the ED setting, may reduce radiation dose by as much as 80%.[26]

Conclusion

The available research and clinical experience to date suggest a likely role for cardiac CTA in the assessment of acute chest pain. Much work remains to be done to determine its appropriate use and the best way to implement a protocol that makes the most efficient use of time-pressured radiologists and avoids overutilization.

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Products used

- Brilliance 64-slice CT scanner (Philips Medical Systems, Bothell, WA)
- MX View workstation (Philips Medical Systems)
- Omnipaque and Visipaque intravenous contrast agents (GE Healthcare, Princeton, NJ)