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LEARNING OBJECTIVES

Upon completion of this activity, participants should be able to:

- Review the algorithm for the management of patients with chest pain.
- Recognize the potential of 64-slice CT in assessment of chest pain in the ER.
- Compare the accuracy of 64-slice CT with stress echocardiography and radionuclide SPECT myocardial scintigraphy.
- Discuss the need for rapid and accurate triage of chest pain patients in the emergency department.

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Chest pain in the emergency room: evaluation and triage with coronary CT angiography

By Aamer Chughtai, M.D., and Ella A. Kazerooni, M.D.

An estimated 1.1 million people in the U.S. are expected to have a new or recurrent myocardial infarction annually, with an additional 150,000 cases of unstable angina diagnosed.¹ While the incidence of myocardial infarction increases with age and the number of atherosclerosis risk factors, it can occur at any age, with approximately half of all myocardial infarcts in the U.S. occurring in patients under the age of 65 years, and in people without risk factors.^{2,3} Public health campaigns over the last 25 years aimed at developing early recognition of such symptoms of myocardial infarction as chest pain, coupled with the development of emergency department chest pain centers, has increased public awareness of this too often fatal disease process.

Guidelines for management include targeted clinical examination and a 12-lead electrocar-

diogram (ECG) within 10 minutes of reaching the emergency department, and a door-to-needle time for patients with acute MI of less than 30 minutes in the cardiac catheterization suite, so that percutaneous revascularization can be completed with 90 minutes.²⁻⁴ The shorter the time from symptom onset to revascularization, the better the cardiac outcome.^{5,6} Initiatives to further reduce the time from symptom onset to opening of the culprit artery have been introduced and include prehospital ECG analysis.^{7,8}

Chest pain is a common complaint, one for which more than five million patients seek care in an emergency room setting each year in the U.S. at an estimated cost of \$10 billion. Chest pain centers have evolved that can see large numbers of chest pain patients, the minority of whom actually suffer from an acute coronary syndrome, such as ST elevation myocardial in-



FIGURE 1. 61-year old woman who presented to the emergency department with chest pain. Coronary CTA demonstrated normal coronary arteries. Normal left anterior descending coronary artery is shown in curved planar reformat (A), surface rendered (B), and straight vessel (C) views. Stress echocardiography was normal. The patient was discharged to home after only a few hours.

farction (STEMI), non-ST elevation MI, and unstable angina.² The majority of patients have either nonischemic or noncardiac causes of their symptoms. In a multicenter study by Coronado et al, 76% of patients triaged in the emergency department with chest pain did not suffer from an acute coronary syndrome. Of the 24% of patients confirmed to actually have an acute coronary syndrome, 35% had an acute MI and 65% suffered from unstable angina.⁹ A one-month audit of our own chest pain center revealed that only 12% of patients presenting with chest pain to our emergency room had a cardiac cause of pain.

These low- and moderate-risk chest pain patients consume extensive healthcare resources to decide whether or not their pain is related to significant atherosclerotic cardiac disease. While the initial triage tools of ECG and targeted clinical examination are sensitive for acute MI, they have limited sensitivity for the diagnosis of unstable angina.¹⁰ Echocardiography and myocardial perfusion SPECT add incremental value.¹¹⁻¹³ However, they are also insufficiently sensitive for unstable angina, and for practical reasons are frequently not performed until the morning after clinical presentation.

Despite current clinical algorithms, approximately 2% of patients with acute coronary syndrome are mistakenly sent home undiagnosed, which has both clinical and legal ramifications. The likelihood of mortality due to an acute MI increases with delays in diagnosis, with a mortality of 1.6% for patients treated within 70 minutes of event onset versus 6% for patients treated within six hours.¹⁴ Identifying which patients have significant coronary artery disease, after the approximately 5% to 10% of patients with a clear-cut acute coronary syndrome are initially recognized, is a daily clinical challenge. This problem has led to extended emergency room stays and hospitalizations for many patients who prove on further evaluation not to have significant cardiac disease and is estimated to be responsible for 1.6 million hospital days annually in the U.S. A one-month audit of our emergency room indicates the average length of stay from chest pain patients there is 20.5 ± 6.5 hours, with a range of 5.6 to 34.6 hours.

Since many of these patients may have noncardiac and/or nonemergent etiologies for chest pain, a diagnostic test with a high negative predictive value for coronary artery disease that can also exclude other life-threatening cases of chest pain, such as pulmonary embolism and aortic

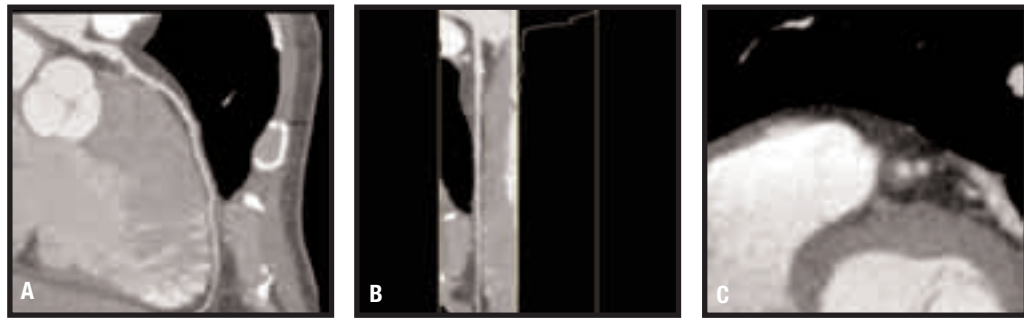


FIGURE 2. 52-year old man who presented to the emergency department with exertional dyspnea and chest pain. Coronary CTA revealed atherosclerotic plaques with calcified and large noncalcified components in the proximal LAD, as shown on curved planar reformat view (A), straight vessel view (B), and in cross section (C). Note excellent demonstration of the noncalcified plaque.

dissection, could result in more efficient and cost-effective triage and diagnosis for the large number of patients presenting to emergency rooms annually. In addition, the opportunity costs of having these patients discharged from valuable emergency room beds more quickly can potentially make even a relatively “expensive” diagnostic test cost-effective.¹⁵⁻¹⁷ An alternative diagnostic testing strategy that reduces resource use and improves diagnostic accuracy is needed. There is growing evidence that 64-slice ECG-gated multislice coronary CT angiography (CTA) may be that test.

64-SLICE CORONARY CTA

Rapid advances in CT technology, particularly the advent of 64-slice CT scanners, mean that it's now possible to acquire coronary CT angiographic studies in as little as five seconds. The published data for 64-slice scanners indicate they have surpassed 16-slice scanners in accuracy, with the technique appearing to be more robust and reproducible in clinical practice.¹⁸⁻²⁰

Generally, scanners with more detector rows show greater temporal and spatial resolution. Ferencik et al demonstrated improved resolution using 64-slice coronary CT angiography, which can be attributed to greater detector coverage and fewer motion-related artifacts because of the faster gantry rotation time.²¹ Leschka et al demonstrated a sensitivity and specificity for classifying stenoses with 64-slice CT of 94% and 97% respectively, with a negative predictive value of 99%.¹⁹ Raff et al demonstrated specificity, sensitivity, and positive predictive value and negative predictive value for the presence of significant stenoses of 86%, 95%, 66%, and 98%, respectively when measured by segment; 91%, 92%, 80%, and 97%, respectively, when measured by artery, and 95%, 90%, 93%, and 93%, respectively, when measured by patient.²⁰ Similarly, Mollet et al evaluated the demonstrated sensitivity, specificity, PPV, and NPV of 99%, 95%,

76%, and 99% respectively for 64-slice coronary CTA.²² While one meta-analysis concluded that contrast-enhanced CT with four or 16 slices was not sufficiently sensitive to rule out coronary artery disease,²³ another indicates that 64-slice coronary CTA has a sensitivity of 95.9% and specificity of 88.6% for stenoses $\geq 50\%$ diameter at the patient level, even when accounting for the impact of missing patient data due to such technical limitations as nonvisible coronary segments secondary to motion or calcification.²⁴

CORONARY CTA IN THE EMERGENCY DEPARTMENT

Before the development of MSCT, perfusion imaging with radionuclide SPECT was one of the triage methods used in the emergency department for patients with chest pain.²⁵ Technetium-99m sestamibi SPECT has been shown to have a high NPV (99%) for excluding acute cardiac events.²⁶ For this scan, however, patients have to be moved from the emergency department to the nuclear medicine department, which may be some distance away, often the morning following presentation, as the service is usually not available all day, every day.²⁷ Stress echocardiography can also be used and is believed to be equivalent to nuclear perfusion testing.¹³ With the high NPV of coronary CT angiography, and more and more MSCT scanners being physically positioned in or near emergency departments, there is great clinical interest in using coronary CTA for the triage of patients with chest pain.

Many studies are currently under way to test the feasibility and accuracy of 64-row multislice coronary angiography in chest pain centers for the triage of patients with chest pain. Multicenter studies are largely in the development stage, demonstrating the intense interest in this subject. The so-called “triple rule out” CT, to rule out coronary disease, aortic disease, and pulmonary embolism, is a protocol variant

of coronary CTA, allowing diagnosis or exclusion of many causes of chest pain. It requires longer acquisition time and more intravenous contrast, coverage, and radiation exposure than a dedicated coronary CTA, with modification of the contrast protocol to optimize visualization of both right and left sides of the cardiac circulation.

Raptopoulos et al looked at different eight- and 16-slice CT protocols to optimize opacification of the pulmonary arteries, the coronary arteries, and the thoracic aorta for the triple rule out CT. This was possible using retrospective gating with 150 mL of intravenous contrast material followed by a saline chaser bolus, and scanning in the caudal to cranial direction. With 64-slice MSCT, the coronary arteries can be scanned using 0.5- to 0.625-mm collimation with retrospective ECG gating, followed by a scan of the thorax at 1- to 2-mm collimation without ECG gating in 20 to 25 seconds, using an intravenous contrast volume of 120 to 150 mL.²⁸

Published data on the specific subject of chest pain CT in the emergency setting is limited. Sato et al¹⁷ reported on the use of four-slice coronary CTA in 31 patients admitted to the emergency department with chest pain of at least 30 minutes duration and with nondiagnostic ECG changes and normal serum enzymes. Of these, 22 patients (71%) had an acute coronary syndrome diagnosed clinically. They defined an acute coronary syndrome on CT as having coronary artery stenosis of 75% with low-attenuation plaques and/or a myocardial perfusion defect. The reference standard was coronary stenosis of 75%, confirmed by catheter coronary angiography, and/or subsequent troponin I elevation. CT detected stenoses with low-attenuation plaques in 21 patients, and a nontransmural myocardial perfusion defect in three patients, yielding a sensitivity and specificity of 95.5% and 88.9%, respectively, for CT to identify ACS. One false-positive and one false-negative result were detected. The authors concluded that coronary CTA “provides diagnostic operating characteristics suitable for triage of patients with ACS in the ED.”

White et al studied whether 16-slice ECG-gated MSCT can provide a comprehensive assessment of cardiac and noncardiac causes of chest pain. They looked at 69 patients presenting to the emergency department with chest pain but without definitive findings of acute myocar-

dial infarction by history, physical examination, ECG, and cardiac enzymes.¹⁵ Seventy-five percent of subjects had no significant CT findings and a final diagnosis of clinically insignificant chest pain. Nineteen percent had significant CT findings to explain chest pain, 10 with a cardiac etiology and three with a non-cardiac etiology that was concordant with the final clinical diagnosis. CT missed clinically significant coronary artery stenoses in two patients (3%), and overdiagnosed two coronary

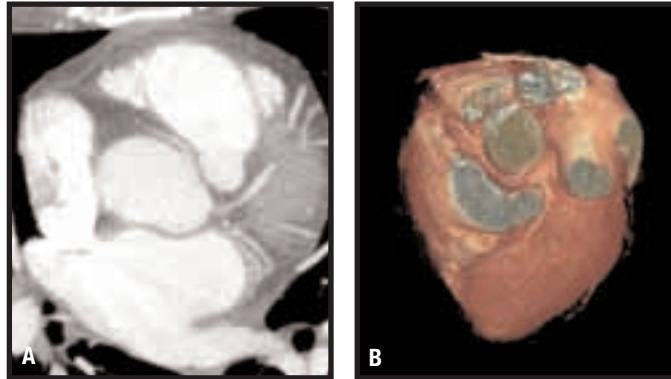


FIGURE 3. 52-year old woman who presented to the emergency department with sudden-onset chest pain. Coronary CTA revealed a malignant anomalous right coronary artery, arising in the ascending aorta posterior to the pulmonary outflow tract, and coursing between the pulmonary outflow tract and ascending aorta, as shown on maximum-intensity projection (A) and surface rendered view (B).

stenoses. Sensitivity and specificity for establishing a cardiac cause of chest pain were 83% and 96%, respectively, and 87% and 96%, respectively, for both cardiac and noncardiac causes of chest pain.

This important work describes both the success and failures of 16-slice ECG-gated MSCT for chest pain patients without an obvious acute coronary syndrome. The authors demonstrate feasibility and suggest the promise that CT holds as a comprehensive method for evaluating cardiac and noncardiac chest pain in stable emergency department patients. Their closing comment was that “further hardware and software improvements will be necessary for adoption of this paradigm in clinical practice.” That conclusion reminds us to proceed carefully in adopting this technique until there is sufficient data to evaluate it against existing guidelines for the evaluation of chest pain patients, and until the impact on patient outcome, such as cardiac event rates, is investigated. As the quest for a perfect noninvasive diagnostic test continues, there has been no question as to the cost-effectiveness of MSCT and its role in making timely decisions in the ED.

Perhaps the best available data on the use of coronary CTA for chest pain patients presenting to the emergency department comes from the presentation by

Raff et al at the American College of Cardiology meeting this last spring. They presented their experience with 200 low-risk, stable emergency department chest pain patients with normal ECGs and cardiac enzymes. Patients were randomized to either the usual guideline-based standard of care with SPECT, or to coronary CTA.²⁹ Exclusion criteria included patients with a prior history of coronary artery disease, cardiomyopathy, arrhythmia, body mass index greater than 38, and serum creatinine greater than 1.5. Patients in the CT group had a shorter length of stay (median 6.2 hours versus 14.1 hours, $p < 0.0001$), a shorter time to cardiac diagnosis (median 3.3 hours versus 12 hours, $p < 0.0001$), and a lower cost of care (median \$1595 versus \$1784, $p = 0.053$) than patients in the standard care group. Interestingly, more patients in the CTA group underwent invasive coronary angiography (11 versus three, $p = 0.028$). While there was no significant difference in major adverse cardiac events between the groups, given the infrequency of these events, the sample size of 200 patients does not allow evaluation of this outcome. The authors concluded that coronary CTA can “rapidly and definitively exclude CAD as the cause of acute chest pain,” and that “immediate CTA reduces length of stay and cost of care without increasing risk.” Further investigation with a larger number of subjects is needed to determine the impact of 64-slice coronary CTA on the rate of such cardiac events as subsequent myocardial infarction and cardiac mortality.

NONCARDIAC FINDINGS

By the very nature of cross-sectional imaging with MSCT, noncardiac causes of chest pain, including aortic dissection and pulmonary embolism, can be diagnosed. In one study, a new noncardiac finding was noted in 58% of patients presenting with chest pain, of whom 22% had clinically significant findings including malignancy.³⁰

Similarly, Patel et al reported that 66% of patients undergoing coronary CTA had a noncardiac CT finding, of which 40% were significant or potentially significant, requiring either therapeutic intervention or additional diagnostic testing. It is worth noting that 2% of patients had pulmonary embolism; 8% had a thoracic aortic aneurysm, pseudoaneurysm, or dissection; and 16% had lung nodules, two of which so far have proven to be lung cancers.³¹

Aortic aneurysm, dissection, and acute intramural hematoma are potentially life-threatening causes of chest pain, for which the clinical presentation can be nonspecific and mimic that of ischemic coronary disease. The inadvertent administration of anticoagulants for the treatment of acute coronary syndrome or pulmonary embolism could be fatal in patients eventually diagnosed with thoracic aortic dissection.³² Similarly, the signs and symptoms of pulmonary embolism mimic those of other acute cardiothoracic disease processes.

Using four- and 16-slice scanners, Hayter et al showed a very high NPV of 99.7% and PPV of 100% and specificity

of 100% and sensitivity of 99% for the diagnosis of acute aortic disorders, including dissections, intramural hematomas, and acute penetrating ulcers.³³ Another study reported accuracy and specificity of 100% with MSCT for diagnosis of acute aortic dissection, aortic arch anomalies, and intramural hematoma. The entire length of the aorta can be scanned in less than a minute, providing all the necessary information for surgery. This saves valuable time before a potentially emergent surgery.³⁴ Recently the Prospective Investigation of Pulmonary Embolism Diagnosis (PIOPED) II study reported a sensitivity and specificity of MSCT pulmonary an-

giography for PE of 90% and 95%, respectively.³⁵

SUMMARY

Given the high accuracy of CT for the diagnosis of significant coronary artery disease, acute aortic disease and pulmonary embolism, coupled with the 99% NPV of coronary CTA, ECG-gated CT in the emergency department setting should prove to be a safe, efficient, and cost-effective test for the evaluation of chest pain patients presenting to the emergency department. Excitement about this use of MSCT is tremendous, with many efforts to validate its use now under way.

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