Calcium Scoring and Cardiac Computed Tomography

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KEYWORDS

• Atherosclerosis • Angiography • Risk stratification • Outcomes • Cardiac computed tomography • Calcium score

KEY POINTS

- Computed tomography (CT) angiography is now the most accurate noninvasive assessment tool for heart disease, with the highest concordance to invasive angiography.
- The use of CT angiography in the emergency department will undoubtedly become the dominant strategy, with emphasis on diagnosis, cost, and prognosis.
- Coronary artery calcium can be accurately depicted on nongated studies, such as those performed for lung cancer screening, and can help doctors identify patients at high risk for future cardiovascular disease.

INTRODUCTION

Accurate and efficient evaluation of acute chest pain remains clinically challenging because traditional diagnostic modalities have many limitations. Recent advances in noninvasive imaging technologies have potentially improved both diagnostic efficiency and clinical outcomes of patients with acute chest pain while reducing unnecessary hospitalizations. However, controversy remains regarding much of the evidence for these technologies. This article primarily reviews the role of coronary computed tomography (CT) angiography (CTA) in the assessment of an individual's coronary risk, and its usefulness in the emergency department (ED) in facilitating appropriate disposition decisions. Also discussed is coronary artery calcification (CAC) incidentally found on CT scans when done for indications such as evaluation of pulmonary embolism or lung cancer. The evidence base and clinical applications for both techniques are described, together with cost-effectiveness and radiation exposure considerations.

BACKGROUND

In the United States more than 6 million patients with chest pain present to the ED each year.[1] The limited predictive value of clinical history and physical examination complicates accurate risk stratification, particularly in patients with normal cardiac biomarkers and nondiagnostic electrocardiograms (ECG).[2] Consequently, more than 60% of patients admitted to the hospital for evaluation of acute coronary syndrome (ACS) are discharged with a noncardiac diagnosis.[3] Conversely, the rate of missed diagnosis of ACS in the ED remains unacceptably high, ranging from 2% to 8%, with missed diagnoses associated with a 2-fold increase in mortality.[4,5]

Effectively ruling out an acute myocardial infarction is difficult. The standard 12-lead ECG has inadequate sensitivity and negative predictive value (NPV) in ruling out any form of ACS.[6] Troponin measurement has a low sensitivity in excluding myocardial ischemia or early manifestations of ACS.[7] Rest echocardiography has limited

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sensitivity in detecting ACS, and is generally not relied on in this setting.[8] Exercise treadmill echocardiography is limited by moderate predictive accuracy in detecting coronary artery disease (CAD) and the frequent presence of baseline ECG abnormalities (eg, left bundle branch block) that preclude accurate interpretation.[9] Single-photon emission CT myocardial perfusion imaging (MPI) remains a cornerstone of evolving clinical care, with emerging and novel applications that will continue to improve the care of patients with cardiovascular disease in the future.[10] Multidetector CT now provides noninvasive coronary imaging, and patients with a low or intermediate probability of CAD can be imaged with radiation levels significantly lower than those of catheterization and nuclear imaging.[11]

CORONARY COMPUTED TOMOGRAPHIC ANGIOGRAPHY

In recent years, cardiac CT angiography (CCTA) has evolved significantly, with a reduction in radiation dose and improvement in diagnostic accuracy. Prospective electrocardiographic gating is becoming more frequently used, as it results in high-quality images at the lowest possible radiation dose, but requires adequate patient preparation and heart-rate control to avoid misregistration (misalignment) artifacts.[12] When appropriately applied, the doses for a CCT angiogram average 2 mSv, markedly lower than for invasive coronary angiography or nuclear imaging.

Diagnostic Accuracy of CT Angiography

The accuracy of CCTA for assessing the presence and severity of coronary stenosis (**Fig. 1**), relative to that of invasive angiography, has been extensively reported.[13] One of the first studies assessing this issue, reported by Sato and colleagues,[14] used 4- and 16-detector scanners, and found sensitivity of 95.5% and specificity of 88.9% for the detection of ACS. Gallagher and colleagues[15] compared CCTA with stress nuclear imaging for the diagnosis of ACS in 85 patients, and found that CCTA accuracy was at least comparable with that of nuclear imaging. A meta-analysis including 9 studies totaling 566 patients using scanners with 64 or fewer detectors revealed a per-patient pooled sensitivity of 95% (95% confidence interval [CI] 90%–98%) and specificity of 90% (95% CI 87%–93%) in detecting ACS in comparison with invasive coronary angiography.[16] A second meta-analysis including 16 studies, totaling 1119 patients, found sensitivity and specificity of 96% (95% CI 93%–98%) and 92% (95% CI 89%–94%), respectively.[17] Both studies

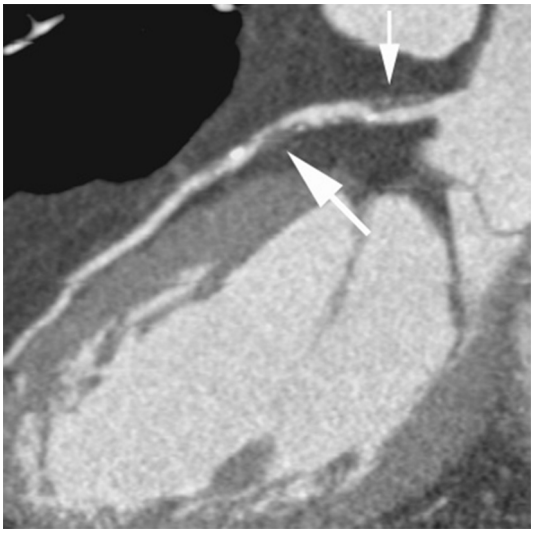

Fig. 1. Example of computed tomography angiogram demonstrating stenosis and atherosclerotic plaque in the left anterior descending artery (*white arrows*).

demonstrate higher diagnostic accuracy for ACS with CCTA than with other previously studied modalities, including exercise treadmill, stress magnetic resonance imaging, stress nuclear imaging, and stress echocardiography.

The ROMICAT trial,[18] which was an observational cohort study of patients with acute chest pain and normal initial ECG and troponins, found sensitivity and NPV of 100% for the absence of plaques on CCTA to detect ACS, and sensitivity and NPV for nonsignificant CAD of 77% and 98%, respectively.

Recently, Chow and colleagues[19] reported sensitivity of 98% (95% CI 87%–100%), specificity of 100% (95% CI 85%–100%), a positive predictive value of 100% (95% CI 90%–100%), and an NPV of 97% (95% CI 80%–100%) for 64-slice CCTA in comparison with invasive coronary angiography in 107 patients with acute chest pain.

Rubinshtein and colleagues[20] reported higher predictive values of CCTA in diagnosing ACS in comparison with standard diagnostic criteria. In a preliminary study, Hoffmann and colleagues[21] evaluated 40 patients with acute chest pain, normal cardiac biomarkers, and a nondiagnostic ECG who underwent CCTA in addition to the standard of care (SOC) diagnostic evaluation before hospital admission. The investigators found at least 1 significant coronary stenosis on CCTA in all patients with final diagnosis of ACS, whereas significant CAD was excluded in 26 of the 35 patients without a final diagnosis of ACS. In another study the same group, low-risk patients randomized to CCTA or SOC diagnostic evaluation were found to have similar accuracy and safety for

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