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Prognostic Value of Coronary CT Angiography and Calcium Score for Major Adverse Cardiac Events in Outpatients

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OBJECTIVES This study sought to evaluate the prognostic value of coronary artery calcium score (CACS) and coronary computed tomography angiography (CTA) for major adverse cardiac events (MACE).

BACKGROUND The prognostic value of CACS has been well described. Few studies use the rich information of coronary CTA to predict future clinical outcomes and compare CACS with coronary CTA.

METHODS We followed up 5,007 outpatients who were suspected of having coronary artery disease (CAD) and who underwent cardiac CTA. Cardiac CT was assessed for CACS and the extent, the location, the stenosis severity, and the composition of the plaque in coronary CTA. The endpoint was MACE, defined as composite cardiac death, nonfatal myocardial infarction, or coronary revascularization.

RESULTS Follow-up was completed in 4,425 patients (88.4%), with a median follow-up period of 1,081 days. At the end of the follow-up period, 363 (8.2%) patients had experienced MACE. Cumulative probability of 3-year MACE increased across CT strata for CACS (CACS 0, 2.1%; CACS 1 to 100, 12.9%; CACS 101 to 400, 16.3%; and CACS >400, 33.8%; log-rank $p < 0.001$); for coronary CTA (no plaque 0.8%, nonobstructive disease 3.7%, 1-vessel disease 27.6%, 2-vessel disease 35.5%, and 3-vessel disease 57.7%; log-rank $p < 0.001$); and for characteristics of the plaques (5.5% for calcified plaque, 22.7% for noncalcified plaque, and 37.7% for mixed plaque; log-rank $p < 0.001$). The area under the receiver-operating characteristic curves showed the incremental value of CACS and coronary CTA for predicting MACE: 0.71 for clinical risk factors, which improved to 0.82 by adding CACS and further improved to 0.93 by adding coronary CTA (both $p < 0.001$).

CONCLUSIONS The CACS and coronary CTA findings have prognostic value and have incremental value over routine risk factors for MACE, and coronary CTA is superior to CACS. Cardiac CT seems to be a promising noninvasive modality with significant prognostic value. (J Am Coll Cardiol Img 2012;5: 990–9) © 2012 by the American College of Cardiology Foundation

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The multivariable statistical models of traditional coronary heart disease risk factors, such as Framingham risk score, are widely recommended for coronary risk stratification among individual patients (1,2). But the models have limitations in their ability to discriminate persons who will or will not experience coronary artery disease (CAD) (3). Since the first report of the use of contrast-enhanced computed tomography (CT)

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to obtain noninvasive coronary angiograms in 1995 (4), cardiac CT has evolved to become a highly accurate method in the diagnosis of CAD, comparable to conventional invasive coronary angiography (5). Given the uncertainty of current risk factors predictive models, a recommended approach to improve risk prediction over the traditional risk factors is coronary artery calcium score (CACS), and the prognostic value of CACS has been well described (6,7). The CONFIRM (Coronary CT Angiography Evaluation for Clinical Outcomes: An International Multicenter Registry) study showed that nonobstructive and obstructive CAD by coronary computed tomography angiography (CTA) are associated with higher rates of mortality, whereas absence of CAD is associated with a very favorable prognosis (8). Although coronary CTA can give us rich information regarding plaque burden, few studies have evaluated that information to predict future clinical outcomes and compare with the prognostic power of CACS.

METHODS

Patient selection. We evaluated 6,477 consecutive patients between January 2007 and August 2008 in Fu Wai Hospital who underwent cardiac CT using a 64-slice multidetector CT scanner. All of these patients were referred for cardiac CT studies by their cardiologists. The coronary CTA was performed because of symptoms of chest pain, to exclude coronary disease in patients carrying 1 or more risk factors or electrocardiographic abnormalities, or to evaluate prior revascularization. For the present study, we excluded subjects with a history of coronary revascularization (percutaneous coronary intervention [PCI], n = 991), coronary artery bypass graft surgery (CABG) (n = 263), history of acute myocardial infarction (MI) (n = 54), inadequate image quality because of motion artifacts or inadequate contrast concentration (n = 49), or having other heart diseases (cardiomyopathy n = 55, valvular heart disease n = 15, congenital heart disease n = 43). In total, 5,007 patients were enrolled (Fig. 1).

Data acquisition. Scans were performed using a 64-row spiral CT scanner (Light Speed VCT, GE Healthcare, Milwaukee, Wisconsin). Patients with a pre-scan heart rate of 70 beats/min or higher were given 25 mg to 50 mg of metoprolol (Selokeen, AstraZeneca, Zoetermeer, the Netherlands) orally 1 h before scanning. First, patients underwent nonenhanced prospective electrocardiography (ECG)-gated sequential scan to measure CACS. Thereafter, coronary CTA was performed using retrospective ECG gating with ECG-based tube current modulation. A double-head power injector (Stellant, Medrad, Pittsburgh, Pennsylvania) was used to inject contrast media through a 20G trocar in an antecubital vein. A test bolus (10 ml contrast agent followed by a 20-ml saline flush) with injection rate of 5 ml was used to determine the timing of scan delay and image acquisition time. Depending on patient weight, iohexol 350 mgI/ml (Omnipaque 350, GE Healthcare) or iopromide 370 mgI/ml (Ultravist 370, Bayer-Schering Pharma, Berlin, Germany) was injected at a speed of 4 to 5.5 ml/s. The main scanning parameters were as follows: 64 detectors; 0.625 mm individual detector width; 350 ms gantry rotation time; 120 kV tube voltage; ECG-modulated tube current ranged from 200 to 550 mA (the tube current was 550 mA during 40% to 80% RR interval when diagnostic image quality was required, and remained at 200 mA during the other phases of the RR interval); 0.16 to 0.22 pitch; 400 mm table feed/rotation; 200 to 250 mm field of view.

Image analysis. All the scans were retrospectively analyzed on the workstation (Deep Blue, ADW4.3, GE Healthcare). Calcium was defined as the presence of at least 3 contiguous pixels with a density >130 HU. The total calcium burden in the coronary arteries was quantified by the scoring algorithm proposed by Agatston et al. (9), and predefined calcium score categories (0, 1 to 100, 101 to 400, and >400) were used (10). The coronary artery tree was segmented according to the modified American Heart Association classification, and these segments were subsequently investigated for the presence and characteristics of coronary plaques. The degree of stenosis was classified as significant

ABBREVIATIONS AND ACRONYMS

CABG = coronary artery bypass graft surgery
CACS = coronary artery calcium score
CAD = coronary artery disease
CI = confidence interval
CT = computed tomography
CTA = computed tomography angiography
ECG = electrocardiography
HR = hazard ratio
LM = left main
MACE = major adverse cardiac events
MI = myocardial infarction
PCI = percutaneous coronary intervention
ROC = receiver-operating characteristic