Detection of Coronary Artery Stenoses With Thin-Slice Multi-Detector Row Spiral Computed Tomography and Multiplanar Reconstruction

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***Background*—**We analyzed the accuracy of multi-detector row spiral computed tomography (MDCT) using a 16-slice CT scanner with improved spatial and temporal resolution, as well as routine premedication with β-blockers for detection of coronary stenoses.

***Methods and Results*—**Seventy-seven patients with suspected coronary disease were studied by MDCT (12×0.75-mm cross-sections, 420 ms rotation, 100 mL contrast agent IV at 5 mL/s). Patients with a heart rate above 60/min received 50 mg atenolol before the scan. In axial MDCT images and multiplanar reconstructions, all coronary arteries and side branches with a diameter of 1.5 mm or more were assessed for the presence of stenoses exceeding 50% diameter reduction. In comparison to invasive coronary angiography, MDCT correctly classified 35 of 41 patients (85%) as having at least 1 coronary stenosis and correctly detected 57 of 78 coronary lesions (73%). After excluding 38 of 308 coronary arteries (left main, left anterior descending, left circumflex, and right coronary artery in 77 patients) classified as unevaluable by MDCT (12%), 57 of 62 lesions were detected, and absence of stenosis was correctly identified in 194 of 208 arteries (sensitivity: 92%; specificity: 93%; accuracy: 93%; positive and negative predictive values: 79% and 97%).

***Conclusions*—**MDCT coronary angiography with improved spatial resolution and premedication with oral β-blockade permits detection of coronary artery stenoses with high accuracy and a low rate of unevaluable arteries. **(*Circulation*. 2003;107:664-666.)**

Key Words: imaging ■ coronary disease ■ tomography

Contrast-enhanced multi-detector row spiral computed tomography (MDCT) has recently been introduced as a method for noninvasive visualization of coronary artery stenoses.[1–6] However, image quality has been insufficient for reliable detection of coronary stenoses in a substantial number of cases. Calcifications often rendered severely diseased coronary segments unevaluable and coronary arteries were frequently affected by motion artifacts.[1–5] MDCT scanners with higher spatial and temporal resolution, especially through decreased slice thickness and faster rotation, have recently been introduced and should reduce partial volume effects and motion artifacts.[6,7,8] Also, it has been observed that the patient's heart rate during the scan critically influences image quality.[9,10] A heart rate of 60 beats per minute or less has been identified as a threshold that is desirable to minimize motion artifacts, but it is unclear whether this can be achieved in the majority of patients in a clinical setting. We therefore investigated the applicability and accuracy of a protocol that incorporates MDCT scanning with 0.75 mm slice thickness and routine administration of an oral β-blocker before the scan for the noninvasive detection of coronary artery stenoses.

Methods

Seventy-seven patients were investigated (50 male, 27 female; mean weight: 82±14 kg; mean body mass index: 28.1±4.5; mean age: 58±14 years). They were consecutively recruited from inpatients scheduled for invasive coronary angiography because of suspected coronary artery disease (Canadian Cardiovascular Society class I to III). Patients with unstable angina, contraindications to the administration of contrast agent, or cardiac arrhythmias, or those in an unstable hemodynamic situation were excluded. The study protocol was approved by the institutional review board.

Premedication

All patients received 50 mg atenolol (Tenormin, AstraZeneca) orally 1 hour before the scan if the heart rate was more than 60 bpm. No

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subject with severe obstructive pulmonary disease was present in the patient group we studied. We administered 2.5 mg of isosorbide dinitrate to all patients sublingually immediately before the MDCT scan.

MDCT Scan Protocol

Using a 16-slice MDCT scanner (Siemens Sensation 16), a volume data set was acquired (12×0.75-mm collimation, gantry rotation time 420 ms, table feed 2.8 mm per rotation, tube voltage of 120 kV), covering the distance from the carina to the diaphragmal face of the heart. Tube current was modulated according to the ECG, with a maximum current of 500 mA during a time period of 330 ms centered around 55% of the cardiac cycle and reduction by 80% during the remaining cardiac cycle, leading to an estimated average effective radiation dose of 4.3 mSv.[11] We continuously injected 100 mL of contrast agent at a rate of 5 mL/s.

Cross-sectional images were reconstructed with a slice thickness of 1.0 mm in 0.5 mm intervals with the use of an ECG-gated half-scan reconstruction algorithm[8] to obtain an image acquisition window of 210 ms. Initially, one data set was reconstructed with the reconstruction window starting at 55% of the cardiac cycle. If motion artifacts were present in any of the coronary arteries, image reconstruction was repeated with the reconstruction window offset 10% toward the beginning and end of the cardiac cycle until images without motion artifacts were obtained or until 10 data sets had been created, in which case the data set with the fewest motion artifacts was used for further evaluation for each coronary artery separately. The data sets were analyzed by one cardiologist experienced in tomographic coronary imaging using the original axial images and multiplanar reconstructions. By visual estimation, coronary arteries were classified as evaluable or unevaluable, and in evaluable arteries, the presence of significant stenosis (exceeding 50% diameter reduction) was assessed. Side branches were included in the analysis of the respective main coronary artery.

Quantitative Coronary Angiography

Invasive coronary angiograms were obtained 1 day after MDCT after intracoronary injection of 0.2 mg of isosorbide dinitrate. Angiograms were evaluated by a blinded independent observer with the use of quantitative coronary angiography (QCA) (QuantCor.QCA, Pie Medical Imaging) and used as gold standard for stenosis detection. Lesions with a diameter reduction of 50% or more were considered to represent significant stenoses. All lesions with a reference diameter (vessel diameter in non-diseased artery immediately proximal to the lesion) of 1.5 mm or more were included in the comparison to MDCT.

Results

Heart Rate

The mean heart rate one hour before the scan was 69±10 bpm (range: 51 to 96 bpm). Fifty patients were on long-term β-blocker medication. All 65 patients with a heart rate above 60 bpm received 50 mg atenolol. At the time of the MDCT investigation, the mean heart rate was 62±10 bpm (range: 43 to 97 bpm), and 36 patients had a heart rate below 60 bpm. In those 65 patients who received atenolol, the mean reduction in heart rate was 8 bpm (70 bpm to 62 bpm; $P<0.0001$, Wilcoxon matched-pairs signed-ranks test).

Detection of Coronary Stenoses

MDCT was performed without complications in all patients. The mean scan duration was 21±2 seconds (18 to 27 seconds). A median of 5 data sets per patient were reconstructed at different time instants in the cardiac cycle to minimize motion artifacts. On the basis of invasive coronary angiography, 41 patients had significant coronary artery disease (1-vessel disease: 20 patients; 2-vessel disease: 6; 3-vessel disease: 15), and 35 of these were correctly detected by MDCT (sensitivity: 85%; specificity: 78%; negative and positive predictive value: 82% and 81%). In 57 of 77 patients (74%), all arteries were evaluable. In these patients, 28 of 30 were correctly classified by MDCT as having at least 1 stenosis (sensitivity: 93%; specificity: 81%; negative and positive predictive value: 92% and 85%).

Overall, 16 occlusions and 62 stenoses exceeding 50% diameter reduction were present, and 57 of these 78 lesions were correctly detected by MDCT (sensitivity: 73%). Thirty-eight coronary arteries were classified as unevaluable by MDCT (left main [LM]: 3; left anterior descending coronary artery [LAD]: 8; left circumflex [LCX]: 12; right coronary artery [RCA]: 15) because of motion artifacts in 26 cases and severe calcifications in 12 cases. In evaluable arteries, 57 of 62 stenoses were correctly identified by MDCT (LM: 4/4; LAD: 21/24; diagonal branches: 3/3; LCX: 9/10; obtuse marginal branches: 3/3; RCA: 17/18; sensitivity: 92%, specificity 93%, accuracy 93%; Figures 1 and 2). The mean diameter reduction of false-negative lesions in QCA was 69% (54% to 88%). MDCT overestimated 14 lesions (LM: 0; LAD: 6, diagonal branches: 0; LCX: 3, obtuse marginal branches: 0; RCA: 5) which were therefore classified as "false-positive." In QCA, the mean diameter reduction of these lesions was 37% (range: 23% to 46%).

In those 36 patients with a heart rate below 60 bpm, 138 of 144 coronary arteries were evaluable (96%), and 34 out of 42 stenoses were detected (overall sensitivity 81%). For evaluable coronary arteries, a sensitivity of 92% (34 of 37) and specificity of 90% (91 of 101) was found in this patient group.

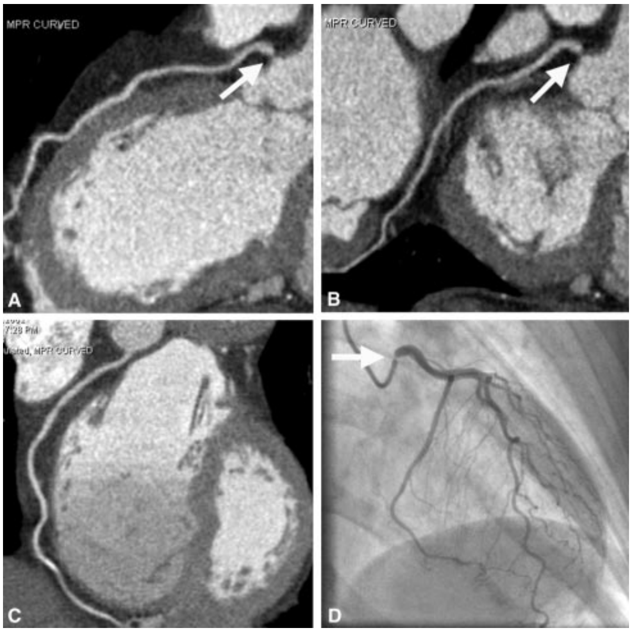

Figure 1. Patient with an ostial stenosis of the left main coronary artery. A, Curved multiplanar reconstruction of the left main and left anterior descending coronary artery showing the ostial stenosis (arrow). B, Curved multiplanar reconstruction of the left main and circumflex coronary artery, again with the left main stenosis (arrow). C, Curved multiplanar reconstruction of the right coronary artery. In accordance with results shown by invasive coronary angiography (not shown), no stenoses are present. D, Invasive angiogram showing severe left main ostial stenosis (92% diameter reduction; arrow).

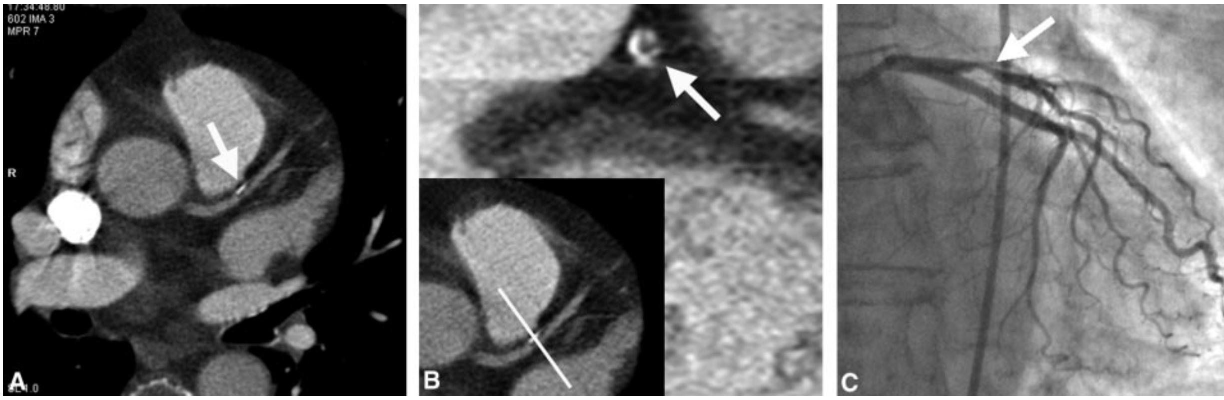

Figure 2. Patient with a stenosis of the left anterior descending coronary artery (LAD). A, Axial MDCT image showing the proximal LAD with a partly calcified lumen reduction (arrow). B, Multiplanar reconstruction orthogonal to the LAD yields a tomographic view of the lesion (arrow) and shows the excentric, partly calcified plaque and residual lumen filled with contrast agent. C, Invasive angiogram that shows an excentric stenosis of the LAD (arrow; 74% diameter reduction).

Discussion

MDCT with retrospective ECG gating and intravenous injection of contrast agent permits visualization of the coronary artery lumen and detection of stenoses. However, investigations with previous MDCT scanner generations revealed 2 major limitations: Coronary artery motion could frequently not be sufficiently suppressed and stenosis assessment was often impaired in the presence of coronary calcification, with an overall rate of unevaluable arteries of up to 32%.[1–5] We therefore evaluated an MDCT protocol that incorporated several improvements over previous techniques. Firstly, routine administration of oral β-blockers to all patients with a heart rate of more than 60 bpm lowered the mean heart rate during MDCT to 62 bpm. This is important because it has been observed that a low heart rate substantially reduces the occurrence of motion artifacts in MDCT.[9,10] Furthermore, simultaneous acquisition of 12 $\times$0.75-mm cross-sections yielded higher spatial resolution, and at the same time, the overall scan time (mean: 21 seconds) was substantially shorter than with previous scanners. Improved spatial resolution, through reduction of partial volume effects, improves diagnostic accuracy and potentially reduces the problems caused by calcification, whereas a shorter scan time may improve scan quality through the shorter breathhold duration and, in addition, requires less contrast agent. Finally, the faster rotation (420 ms) compared with previous scanners provided higher temporal resolution.

Using this protocol, coronary stenoses with a reference diameter down to 1.5 mm were analyzed, thus covering all lesions that may be potential targets for revascularization. Both motion and calcification rendered fewer arteries (12%) unevaluable than in most previous studies,[1–5] and a high sensitivity (92%) and specificity (93%) for the detection of coronary stenoses was achieved, confirming results previously obtained with this technology.[6]

Study Limitations

Limitations of our investigation include the relatively small number of patients and the fact that analysis was performed on a per-vessel instead of a per-segment basis. This approach was chosen because although coronary artery segments as defined by the American Heart Association[12] are commonly used in invasive angiography, their transfer to MDCT has not been validated, and because proximal stenoses or occlusions may deteriorate image quality in downstream segments, thus confounding results. MDCT findings were obtained using visual estimation, and coronary calcifications were not quantified in separate non-enhanced scans to limit radiation exposure. Finally, intravascular ultrasound would have constituted a better reference method than QCA. In summary, however, our results highlight the potential of thin-slice MDCT for coronary artery visualization and detection of coronary artery stenoses.

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