

# Detection of Coronary Artery Stenoses by Contrast-Enhanced, Retrospectively Electrocardiographically-Gated, Multislice Spiral Computed Tomography

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**Background**—Multislice spiral computed tomography (MSCT) with retrospectively ECG-gated image reconstruction permits coronary artery visualization. We investigated the method's ability to identify high-grade coronary artery stenoses and occlusions.

**Methods and Results**—A total of 64 consecutive patients were studied by MSCT (4×1 mm cross-sections, 500-ms rotation, table feed 1.5 mm/rotation, intravenous contrast agent, retrospectively ECG-gated image reconstruction). All coronary arteries and side branches with a luminal diameter  $\geq 2.0$  mm were assessed concerning evaluability and the presence of high-grade stenoses ( $>70\%$  diameter stenosis) or occlusions. Results were compared with quantitative coronary angiography. Of 256 coronary arteries (left main, left anterior descending, left circumflex and right coronary artery, including their respective side branches), 174 could be evaluated (68%). In 19 patients (30%), all arteries were evaluable. Artifacts caused by coronary motion were the most frequent reason for unevaluable arteries. Overall, 32 of 58 high-grade stenoses and occlusions were detected by MSCT (58%). In evaluable arteries, 32 of 35 lesions were detected, and the absence of stenosis was correctly identified in 117 of 139 arteries (sensitivity, 91%; specificity, 84%). If analysis was extended to all stenoses with  $>50\%$  diameter reduction, sensitivity was 85% (40 of 47) and specificity was 76% (96 of 127).

**Conclusions**—MSCT with retrospective ECG gating permits the detection of coronary artery stenoses with high accuracy if image quality is sufficient, but its clinical use may presently be limited due to degraded image quality in a substantial number of cases, mainly due to rapid coronary motion. (*Circulation*. 2001;103:2535-2538.)

**Key Words:** imaging ■ coronary disease ■ tomography

The latest generation of multislice spiral computed tomography (MSCT) scanners permits image acquisition in 4 parallel slices with a rotation time of 500 ms. Using the simultaneously recorded ECG, images can be reconstructed with a data acquisition window of  $\leq 250$  ms.<sup>1,2</sup> This approach permits visualization of the coronary lumen after intravenous injection of contrast agent.<sup>3-7</sup> We conducted a comparison of MSCT with retrospectively ECG-gated image reconstruction and quantitative coronary angiography (QCA) in 64 patients to assess the accuracy of MSCT for the detection of coronary stenoses and occlusions in all segments of the epicardial coronary arteries, including side branches, with a diameter  $\geq 2.0$  mm.

## Methods

A total of 64 consecutive patients referred for invasive coronary angiography due to suspected coronary artery disease were investigated (48 men and 16 women; mean weight,  $79 \pm 14$  kg; mean age,

$63 \pm 10$  years). Only patients in sinus rhythm, without implanted pacemakers or valve prostheses, and without contraindications to the administration of iodinated contrast agent were included in the study. All patients gave written informed consent. The study protocol was approved by the institutional review board.

## Multislice Spiral CT

According to a previously published protocol,<sup>4</sup> MSCT data were acquired using a Siemens Volume Zoom CT scanner during intravenous injection of contrast agent (160 mL at 4 mL/s) in 4 parallel slices (1.0 mm collimation) with a gantry rotation time of 500 ms and a table feed of 1.5 mm/rotation. The tube current was 150 mA at 140 kV. Using the algorithm 180°MCI (Multislice Cardiac Interpolation),<sup>1</sup> cross-sectional images were reconstructed with a slice thickness of 1.2 to 1.4 mm in 1.0-mm intervals using retrospective ECG gating to obtain image acquisition windows of 125 to 250 ms (full-width tenth-maximum of phase contribution profile<sup>1</sup>), depending on the patient's heart rate.<sup>4</sup> For each patient, 10 data sets were created during different time instants of the cardiac cycle (0% to 90%

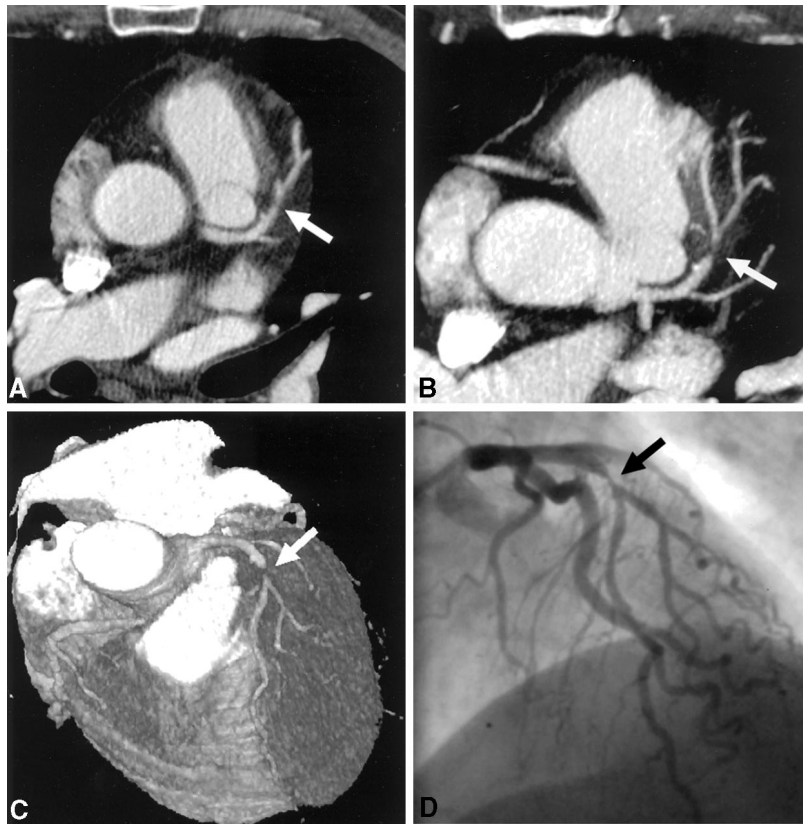
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**Figure 1.** MSCT and coronary angiography in a patient with a stenosis of the LAD. A, Cross-sectional image in axial orientation obtained by MSCT. The proximal LAD shows narrowing of the lumen (arrow). B, Sliding thin-slab maximum-intensity projection (slab thickness, 10 mm) of the left main coronary artery and LAD (arrow indicates stenosis). C, 3D reconstruction of the heart and contrast-enhanced coronary arteries shows the LAD stenosis (arrow). D, Invasive coronary angiography confirms the presence of the stenosis (arrow; 84% diameter reduction; reference diameter, 3.5 mm.).

of the R wave-to-R wave interval). For each individual artery, the data set containing the fewest motion artifacts was used for further evaluation.

On the basis of the cross-sectional images, sliding thin-slab maximum-intensity projections,<sup>8</sup> and 3D reconstructions rendered on an off-line workstation (NetraMD, ScImage), the coronary arteries were classified as evaluable or unevaluable. In the evaluable arteries, the presence of high-grade stenoses and occlusions was assessed using visual estimation (Figure 1). Results were documented separately for the 4 major epicardial arteries (left main, left anterior descending [LAD], left circumflex, and right coronary artery). Side branches were included in the analysis of the respective coronary artery (eg, a stenosis detected in a diagonal branch would be documented as an LAD stenosis).

### Quantitative Coronary Angiography

Invasive coronary angiograms were obtained in all patients 1 to 3 days after MSCT using 6-French catheters. The angiograms were evaluated by QCA with automated vessel contour detection after catheter-based image calibration (QuantCor QCA, Pie Medical Imaging). Lesions with a mean diameter reduction  $\geq 70\%$  in 2 planes were considered high-grade stenoses. In addition, the reference diameter of every lesion (vessel diameter in nondiseased artery immediately proximal to the lesion) was documented because only lesions in vessel segments with a lumen diameter  $\geq 2.0$  mm were included in the analysis.

### Results

MSCT was performed without complications in all patients. Out of 256 coronary arteries, 82 were judged to be unevaluable due to reduced image quality (32%). The most frequent reasons for impaired evaluability were motion artifacts (39 arteries) and severe vessel calcification (27 arteries). The right coronary artery was most frequently affected by degraded image quality (33 patients). In 19 patients (30%), all arteries were evaluable by MSCT.

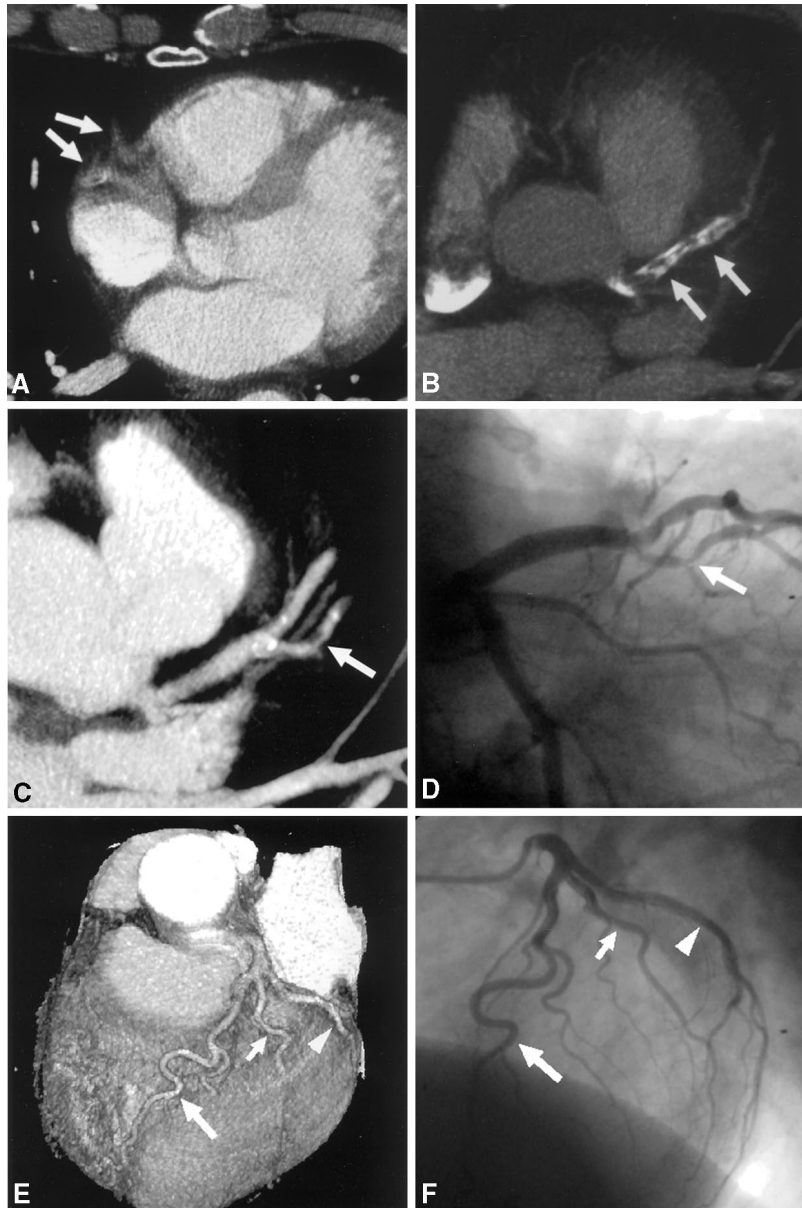
In the 174 evaluable arteries, all 6 occlusions and 26 of 29 high-grade stenoses ( $\geq 70\%$  diameter reduction) in vessel segments with a diameter  $\geq 2.0$  mm were correctly detected by MSCT (Figures 1 and 2). One of one lesion in the left main coronary artery, 19 of 22 in the LAD and diagonal branch, 5 of 5 in the left circumflex and marginal branches, and 7 of 7 lesions in the right coronary artery were correctly identified. All 3 false-negative stenoses were located in diagonal branches with a mean reference diameter of  $2.6 \pm 0.4$  mm. In 117 of 139 coronary arteries, the absence of high-grade stenoses and occlusions was correctly detected, and in 22 cases, the presence of a high-grade lesion was incorrectly suspected based on MSCT. By QCA, the mean diameter reduction of these false-positive lesions was  $28 \pm 20\%$ ; in 5 lesions, the diameter reduction was between 50% and 70%.

These values correspond to a sensitivity of 91%, specificity of 84%, positive predictive value of 59%, and negative predictive value of 98% for the detection of high-grade coronary artery stenoses by MSCT. When coronary arteries judged unevaluable by MSCT were included in the analysis, the overall sensitivity was 58% (32 of 55 stenoses detected).

If the threshold for the definition of stenosis in MSCT and QCA was lowered to 50% diameter reduction, sensitivity and specificity were 85% (40 of 47) and 76% (99 of 130), respectively, in evaluable arteries, and overall sensitivity was 55% (40 of 73 stenoses detected).

### Discussion

Our study demonstrates that MSCT with retrospective ECG gating permits the detection of high-grade coronary artery stenoses and occlusions with high sensitivity (91%) and



**Figure 2.** A, Cross-sectional image showing a motion artifact of the right coronary artery (arrows) that renders the artery unevaluable. B, Severe calcifications of the LAD (arrows) render the artery unevaluable concerning the presence of stenoses. C, Sliding thin-slab maximum-intensity projection (slab thickness, 10 mm) shows a high-grade stenosis of a large diagonal branch (arrow). D, Corresponding coronary angiogram (arrow shows stenosis of diagonal branch with 76% diameter reduction and reference diameter of 2.5 mm). E, 3D reconstruction of the heart and coronary arteries in a patient without coronary artery stenoses. F, Corresponding coronary angiogram. In E and F, large arrow indicates LAD; small arrow, diagonal branch; and arrowhead, left circumflex coronary artery.

specificity (84%) if an image quality sufficient for evaluation is obtained. These values are similar to the results of contrast-enhanced electron beam tomography.<sup>8-12</sup> However, probably because of the longer image acquisition time, the number of interpretable vessel seems to be lower with MSCT than with electron beam tomography. Only 68% of the coronary arteries could be evaluated in our study; a similar value was observed by Nieman et al.<sup>7</sup>

As opposed to previous studies, we verified our MSCT results by QCA and included all vessel segments, including side branches, in the analysis if the vessel diameter measured  $\geq 2.0$  mm. This approach was chosen because to be clinically useful, a noninvasive method must be able to reliably rule out coronary artery stenoses in all arteries that would be potential targets of revascularization therapy. Stenoses in vessels with a diameter  $< 2.0$  mm rarely constitute targets for revascularization.<sup>13,14</sup>

Although the image quality that can be obtained by MSCT is impressive, measures need to be taken to reduce the

number of unevaluable segments. Improvements may be achieved through the use of further refined image reconstruction algorithms, more suitable kernels, or by increasing the tube current (at the cost of higher radiation exposure). However, because most of the unevaluable segments were affected by coronary motion, further shortening the image acquisition window seems mandatory.

General drawbacks of MSCT for coronary visualization include the fact that the patient must be able to perform the necessary breathhold and the method requires the injection of iodinated contrast agent and exposes the patient to radiation. Therefore, the method may be considered not completely noninvasive. These drawbacks are similar to those of electron beam tomography; however, electron beam tomography has a markedly lower radiation dose. The effective dose for electron beam tomography coronary angiography was estimated at 1.7 mSv,<sup>15</sup> but the estimated dose for our MSCT protocol is 3.9 to 5.8 mSv.<sup>4</sup> The MSCT radiation dose can be even

higher when a higher tube current is used, and it can exceed the dose of invasive coronary angiography.<sup>15</sup> Only MRI can visualize the coronary arteries without contrast and radiation, but thus far, MRI has not achieved clinically satisfactory results for stenosis detection.<sup>16</sup>

The encouraging results obtained in this investigation justify further research to improve the accuracy of MSCCT for the detection of coronary stenoses, to evaluate its applicability and clinical usefulness in defined patient subsets, and to compare it to other methods for noninvasive coronary angiography, such as MRI and electron beam tomography.

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