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## Imaging of coronary atherosclerosis with multi-slice computed tomography

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**Diagnostic Accuracy of 64-Slice Multislice  
Computed Tomography in the Noninvasive  
Evaluation of Significant  
Coronary Artery Disease**

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## Abstract

**Aims:** The purpose of the present study was to determine the diagnostic accuracy of current 64-slice multi-slice computed tomography (MSCT) in the detection of significant coronary artery disease, using conventional coronary angiography as the gold standard.

**Methods:** In 61 patients scheduled for conventional coronary angiography, 64-slice MSCT was performed and evaluated for the presence of significant (>50% luminal narrowing) stenoses.

**Results:** One patient had to be excluded because of a heart rate >90 beats/min during data acquisition. In the remaining 60 patients (46 men, 14 women; average age 60±11 years), 854 segments were available for evaluation. Of these segments 842 (99%) were of sufficient image quality. Conventional coronary angiography identified 73 lesions, of which 62 were detected by MSCT. The corresponding sensitivity and specificity were 85% and 97%, respectively. On a patient-per-patient analysis, sensitivity, specificity, and positive and negative predictive values were 94%, 97%, 97%, and 93%, respectively.

**Conclusions:** The present study confirms that 64-slice MSCT enables the accurate and noninvasive evaluation of significant coronary artery stenoses.

## Introduction

In a short period of time, spiral multi-slice computed tomography (MSCT) has rapidly matured into a technique that is on the verge of being used as an alternative modality in the clinical evaluation of patients suspected of having coronary artery stenoses. Although thorough assessment of the entire coronary tree was still problematic with the original 4-slice systems, substantial improvement was obtained with the introduction of 16-slice scanners.<sup>1</sup> In addition, the results of numerous studies comparing MSCT with conventional coronary angiography suggested enhanced sensitivity of the technique as well, with no loss in specificity.<sup>2</sup> Currently, 64-slice MSCT systems are rapidly installed, offering further improved image quality while acquiring data in even shorter periods of time.<sup>3,4</sup> Accordingly, the purpose of the present study was to determine the diagnostic accuracy of current 64-slice MSCT in the detection of significant coronary artery disease (CAD), using conventional coronary angiography as the gold standard.

## Methods

### Patients and study protocol

The study group consisted of 61 patients who were scheduled for conventional coronary angiography. In addition, MSCT coronary angiography was performed. Patients with contraindications to MSCT were excluded.<sup>5</sup> Conventional catheter-based coronary angiography was performed before or after MSCT and served as the reference standard. All patients gave written informed consent to the study protocol, which was approved by the local ethics committee.

### Data acquisition

MSCT was performed using a Toshiba Multi-Slice Aquilion 64 system (Toshiba Medical Systems, Tokyo, Japan), with a collimation of 64x0.5 mm and a rotation time of 0.4 seconds. The tube current was 300 mA, at 120 kV. In obese patients (body mass index  $\geq 30$  kg/m<sup>2</sup>), parameters were adjusted to 350 mA at 135 kV to improve image quality. Nonionic contrast material was administered in the antecubital vein, with an amount of 80 to 110 ml, depending on the total scan time, and a flow rate of 5.0 ml/s (Iomeron 400, Bracco, Altana, Pharma, Konstanz, Germany). Automated peak enhancement detection in the descending aorta was used for timing of the bolus using a threshold of +100 Hounsfield units. Data acquisition was performed during an inspiratory breath hold of approximately 8 to 10 seconds.

During the MSCT examination, electrocardiography was performed simultaneously for retrospective gating of the data. An initial data set was reconstructed at 75% of the RR interval, with a slice thickness of 0.5 mm and a reconstruction interval of 0.3 mm. In 17 patients, additional reconstructions were explored to obtain more optimal reconstruction phases. Similarly, in case of high-density artifacts, sharper reconstruction kernels were explored to improve image quality. Finally, images were transferred to a remote workstation (Vitrea2, Vital Images, Plymouth, Minnesota) for postprocessing and evaluation. Conventional diagnostic coronary angiography was performed according to standard techniques.

## Data analysis

MSCT angiograms were evaluated by an invasive cardiologist with several years of experience in scoring MSCT coronary angiograms. Image analysis was performed blinded to the results of coronary angiography. Three-dimensional volume-rendered reconstructions were used to obtain general information on the status and courses of the coronary arteries. Then the original transaxial slices were inspected for the presence of significant ( $\geq 50\%$  reduction of luminal diameter) narrowing, assisted by curved multiplanar reconstructions. Segmentation of the coronary arteries was performed on the basis of the American Heart Association/American College of Cardiology guidelines.<sup>6</sup> Segments containing coronary stents were included in the analysis; the presence of restenosis in a stented segment was identified by reduced or complete absence of contrast within the stent as well as reduced or absent runoff of contrast distally. Conventional angiograms were evaluated by an experienced observer without knowledge of the MSCT data who identified the available coronary segments on the basis of the American Heart Association/American College of Cardiology guidelines.<sup>6</sup> Each segment was then evaluated for the presence of  $\geq 50\%$  diameter stenosis, on the basis of the evaluation of 2 orthogonal views.

## Statistical analysis

Obstructive CAD was defined as luminal narrowing of  $\geq 50\%$ . Accordingly, sensitivity, specificity, and positive and negative predictive values (including 95% confidence intervals) for the detection of stenoses  $\geq 50\%$  on conventional angiography were calculated on patient, vessel, and segmental bases. A patient or vessel was classified as correct positive if the presence of any stenosis was identified correctly. In the per vessel analysis, the intermediate branch was considered part of the left circumflex. All statistical analyses were performed using SPSS software version 12.0 (SPSS, Inc., Chicago, Illinois). A value of  $p < 0.05$  was considered statistically significant.

# Results

## Patient characteristics

In total, 61 consecutive patients (46 men, 15 women; average age  $60\pm 11$  years) were included. The average interval between MSCT and conventional angiography was  $49\pm 61$  days. In 1 patient, the heart rate increased to  $>90$  beats/min during MSCT, rendering the complete data set uninterpretable. The characteristics of the remaining 60 patients are listed in Table 1. In total, CAD was suspected in 25 patients (42%), whereas it was known in 35 patients (58%). A total of 44 stented segments were included in the analysis.

**Table 1.** Clinical characteristics of the study population (n=60)

Characteristic	Value
Men/women	46/14
Age (yrs) (range)	$60\pm 11$ (38–80)
Heart rate (beats/min) (range)	$60\pm 11$ (44–83)
Average calcium score (Agatston) (range)	$423\pm 868$ (0–6,264)
$\beta$ -blocking medication	43 (72%)
Diabetes mellitus	6 (10%)
Hypertension*	26 (43%)
Hypercholesterolemia†	27 (45%)
Positive family history	22 (37%)
Current smoking	33 (55%)
Body mass index $\geq 30$ kg/m <sup>2</sup>	15 (25%)
No history	25 (42%)
Previous coronary angioplasty	33 (55%)
Previous coronary bypass grafting	0
Previous myocardial infarction	33 (55%)
Anterior wall	26 (79%)
Inferior wall	7 (21%)
No. of coronary arteries narrowed on angiography	
None	14 (23%)
1	26 (43%)
$\geq 1$	20 (33%)

\* Defined as systolic blood pressure  $\geq 140$  mm Hg and/or diastolic blood pressure  $\geq 90$  mm Hg and/or the use of antihypertensive medication.

† Defined as total serum cholesterol  $\geq 230$  mg/dl and/or serum triglycerides  $\geq 200$  mg/dl or the use of a lipid-lowering agent.

## MSCT coronary angiography

In 854 segments evaluated with conventional coronary angiography, a total of 74 significant stenoses was identified. MSCT image quality was insufficient in 12 segments (1.4%) to allow further evaluation. Reasons for uninterpretability were a small contrast-to-noise ratio due to a large body mass index (n=2), extensive calcifications (n=5), and small vessel size (n=5). A total of 6 uninterpretable segments were located in the left circumflex coronary artery (segment 10, n=3; segment 12, n=1; and segment 17, n=2), whereas 4 uninterpretable segments were located in the distal right coronary artery (segment 4, n=2, and segment 16, n=2) and 1 in the first diagonal branch. In the remaining 842 segments, the presence of stenosis was correctly ruled out by MSCT in 755 of 769 segments, while 62 of 73 segments were correctly identified as having significant lesions on MSCT. A total of 14 lesions that were nonsignificant on conventional coronary angiography were overestimated on MSCT, while 11 lesions were falsely deemed to be insignificant. Accordingly, the resulting sensitivity and specificity for the detection of significant lesions were 85% and 98%, respectively, on a segmental level. In the 44 stented segments, 3 of 3 segments with significant in-stent restenosis were correctly detected, whereas the absence of significant lesions was correctly identified in 41 stented segments.

## Vessel analysis

Because of extensive calcifications, 1 left circumflex artery was deemed uninterpretable. In the remaining 239 coronary arteries, 46 of 53 coronary arteries were correctly identified as having  $\geq 1$  significant lesions, whereas the absence of any stenosis was correctly identified in 179 of 186 vessels, resulting in sensitivity and specificity of 87% and 96%, respectively.

## Patient analysis

Conventional coronary angiography identified 31 patients with  $\geq 1$  significant lesions. On MSCT, 29 of these patients (94%) were correctly identified. In 1 of these patients, however, a lesion in the left anterior descending coronary artery was misjudged to be significant on MSCT, whereas in fact a lesion in the right coronary artery proved to be significant during conventional coronary angiography. In the remaining patients, the correct lesion was identified on MSCT. An example of a patient with a significant stenosis is provided in Figure 1.



**Figure 1.** Example of a patient with significant coronary artery disease. (A) Three-dimensional volume-rendered reconstruction providing an overview of the left anterior descending (LAD) and left circumflex (LCx) coronary arteries. An enlargement of the section indicated by the *black arrowhead* (B) demonstrates a significant narrowing in the LAD coronary artery (*black arrowhead*) and, more distally, a small coronary calcification (*white arrowhead*) that can also be observed on the curved multiplanar reconstruction (D). Cross-sectional images (E) confirm the presence of a significant noncalcified lesion. (F) Curved multiplanar reconstruction of the LCx coronary artery without significant lesions. In the right coronary artery (G, 3-dimensional volume-rendered reconstruction; H, curved multiplanar reconstruction), no significant narrowing was observed as well. The findings were confirmed by conventional coronary angiography (C, I).



MSCT correctly ruled out the presence of any significant lesion in 28 of 29 patients (97%). Only 3 patients were incorrectly diagnosed by MSCT. In 1 patient, a significant lesion in the origin of the second diagonal was missed because of the small size of the coronary side branch. In the other patient with false negative MSCT results, significantly diseased left anterior descending and left circumflex arteries were incorrectly classified as having nonobstructive disease.

Finally, in 1 patient who was incorrectly classified as positive, a lesion of approximately 40% located in the left anterior descending artery was overestimated by MSCT. The results of all analyses, including positive and negative predictive values with 95% confidence intervals, are listed in Table 2.

**Table 2.** Diagnostic accuracy of multi-slice computed tomography (n=60)

Variable	Segmental Analysis	Vessel Analysis	Patient Analysis
Excluded	12/854, 1.4%	1/240, 0.4%	0%
Sensitivity	62/73 (85%, 77–93%)	46/53 (87%, 78–96%)	29/31 (94%, 86–100%)
Specificity	755/769 (98%, 97–99%)	179/186 (96%, 93–99%)	28/29 (97%, 91–100%)
Positive predictive value	62/76 (82%, 73–91%)	46/53 (87%, 78–96%)	29/30 (97%, 91–100%)
Negative predictive value	755/766 (99%, 98–100%)	179/186 (96%, 93–99%)	28/30 (93%, 84–100%)
Diagnostic accuracy	817/842 (97%, 96–98%)	225/239 (94%, 91–97%)	57/60 (95%, 89–100%)

## Discussion

On a segmental level, a diagnostic accuracy of 97% was observed. It is important that only 12 segments (1%) could not be evaluated for the presence or absence of significant lesions because of insufficient image quality. In addition, an excellent specificity of 98% was observed, with a somewhat lower sensitivity of 85%, on a segmental basis. Nonetheless, from a clinical point of view, data regarding the performance on a patient rather than a segmental basis are preferred, because the selection of patients needing further invasive evaluation or intervention will be based on these findings. In the present study, a sensitivity of 94% was noted, with a corresponding specificity of 97%, in the detection of patients with obstructive CAD. Thus, in contrast to several previous studies,<sup>4,7</sup> no loss in specificity was observed when shifting from a segmental to a patient analysis. The current observations are in line with the few initial investigations with 64-slice MSCT that have been published thus far.<sup>3,4,8</sup> Similar sensitivity and specificity of 86% and 95%, respectively, on a segmental basis were reported by Raff et al,<sup>7</sup> who performed 64-slice MSCT in 70 patients. More recently, results in 52 patients presenting with a wide range of clinical conditions were

reported by Mollet et al.<sup>4</sup> As a result of the highly symptomatic population included, a greater sensitivity (100%) with somewhat lower specificity(92%) was obtained.

Because the purpose of the present study was to compare the diagnostic accuracy of MSCT with that of invasive coronary angiography, only patients with a relatively high likelihood of having significant stenoses were included. As a result, only 42% of included patients presented without known CAD. Although this percentage still compares favorably with most of the other available data on MSCT coronary angiography, it stipulates the current lack of data in populations with lower CAD prevalence. Considering that noninvasive coronary angiography is most likely to be used in these particular populations to allow the definite exclusion of significant CAD, data on the performance of MSCT in these populations are needed.

Despite rapid technologic advancements, several limitations inherent to MSCT remain. First, a stable and preferably low heart rate remains essential for high-quality MSCT images, and the administration of  $\beta$  blockers before the examination is often needed. Second, the current lack of validated quantification algorithms for MSCT represents another important issue. Although visual evaluation will be sufficient in most segments, more precise assessment of the degree of luminal narrowing will be needed in a considerable number of examinations. However, as shown by Leber et al,<sup>3</sup> the ability to visually quantify the grade of luminal obstruction on MSCT remains limited, even with 64-slice technology. Indeed, also in the present study, the degree of stenosis was incorrectly estimated as either more or <50% diameter narrowing in 2 patients, resulting in false diagnoses, although in fact the presence of lesions was correctly identified. Accordingly, the quantification of MSCT coronary angiography is likely to provide enhanced diagnostic accuracy while improving the reproducibility of the technique, and further investments in the development of such algorithms are needed. Finally, the radiation burden of MSCT remains of concern.

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