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Quantification of Coronary Artery Stenosis with 16-Slice MSCT in Patients before CABG Surgery: Comparison to Standard Invasive Coronary Angiography

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ABSTRACT

Objective: Invasive, selective coronary angiography is the gold standard for evaluation of coronary artery disease (CAD) and degree of stenosis. The purpose of this study was to compare 3-dimensional (3D) reconstructed 16-slice multislice computed tomographic (MSCT) angiography and selective coronary angiography in patients before elective coronary artery bypass graft (CABG) procedure.

Methods: Sixteen-slice MSCT scans (Philips Mx8000 IDT) were performed in 50 patients (42 male/8 female; mean age, 64.44 ± 8.66 years) scheduled for elective CABG procedure. Scans were retrospectively electrocardiogram-gated 3D reconstructed. The images of the coronary arteries were evaluated for stenosis by 2 independent radiologists. The results were compared with the coronary angiography findings using the American Heart Association segmental classification for coronary arteries.

Results: Four patients (8%) were excluded for technical reasons. Thirty-eight patients (82.6%) had 3-vessel disease, 4 (8.7 %) had 2-vessel disease, and 4 (8.7%) had an isolated left anterior descending artery stenosis. In the proximal segments all stenoses >50% (56/56) were detected by MSCT; medial segment sensitivity was 97% (73/75), specificity 90.3%; distal segment sensitivity was 90.7% (59/65), specificity 77%.

Conclusion: Accurate quantification of coronary stenosis greater than 50% in the proximal and medial segments is possible with high sensitivity and specificity using the new generation of 16-slice MSCTs. There is still a tendency to overestimate stenosis in the distal segments. MSCT seems to be an excellent diagnostic tool for screening patients with possible CAD.

INTRODUCTION

Coronary artery disease has been the most common cause of hospitalization and mortality in industrialized countries for many years [Hill 1998, Windecker 1999]. Therapeutic decision making requires reliable diagnostic assessment of the coronary arteries. Selective coronary angiography has been the gold standard of coronary imaging during the last 5 decades [Sones 1959]. Since 1959 selective coronary angiography has allowed the precise definition of highly stenotic lesions and therefore remains the basis for catheter-based or surgical myocardial revascularization [Sones 1959, Pfeiler 2000]. On the other hand, it is an invasive and potentially harmful procedure with a small risk of serious events (arrhythmia, stroke, coronary artery dissection, death) [Bashore 2001]. Furthermore, the catheterization procedure involves hospital admission and discomfort for the patient. More than 50% of the invasive coronary angiography studies are not followed by interventional or surgical therapy [Windecker 1999]. From the background of growing numbers of purely diagnostic coronary angiographies, a noninvasive method could be a less risky and cheaper alternative. With the introduction of 4-slice multidetector scanners in 1998, computed tomography (CT) has entered the field of noninvasive imaging of the coronary arteries. Despite all promising advances, some limitations remained for multislice cardiac CT (MSCT) with 4-slice detectors. Stents or severely calcified arteries couldn't be adequately visualized [Achenbach 2000, Becker 2000]. For patients with higher heart rates a diagnostic outcome cannot be guaranteed, despite careful selection of separate reconstruction intervals for left and right coronary arteries [Kopp 2000, 2001, Flohr 2003]. The scan time of approximately 40 seconds is problematic in patients with limited ability to cooperate [Flohr 2003]. The development and introduction of the 16-slice CT scanner technology in 2001 allowed more robust and reliable detection of coronary artery disease [Heuschmid 2002, Nieman 2002].

The purpose of this study was to compare the gold standard invasive coronary angiography with 3-dimensional (3-D) reconstructed 16-slice MSCTs in patients planning to undergo elective CABG procedure.

PATIENTS AND METHODS

We studied 50 patients (42 male and 8 female) with diagnosed coronary artery disease (CAD) who were scheduled for elective CABG procedure. CAD was diagnosed by conventional coronary angiography, and decision making for CABG was determined before the CT examination was performed. Before surgery all of the patients underwent 3-D recon-

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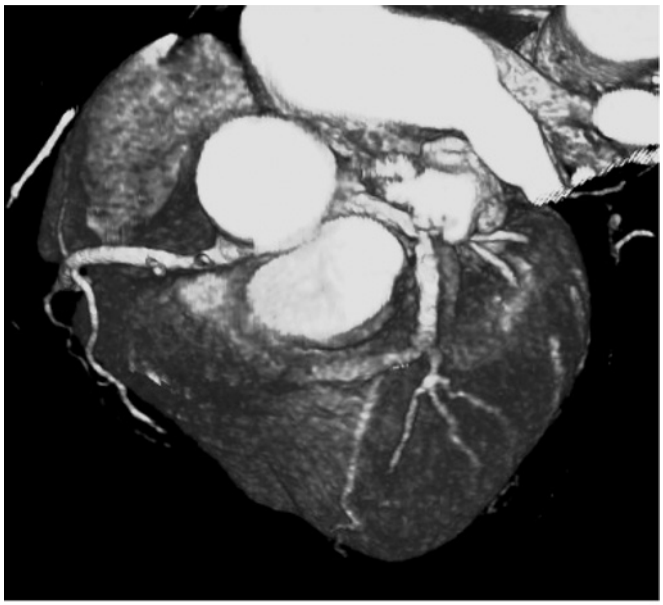

Figure 1. Volume rendering of the left main coronary artery and the proximal right coronary artery.

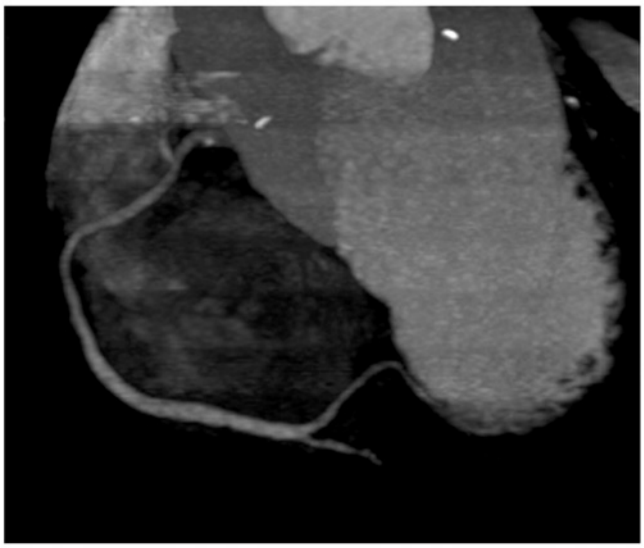

Figure 2. Multiplanar reformation of the right coronary artery.

structed electrocardiogram (ECG)-gated MSCT of the heart. Informed consent was obtained prior to the examination. Patient demographic data were recorded.

All of the patients were examined with a 16-detector row MSCT scanner (Phillips Mx8000 IDT; Phillips Medical Systems, Nederland BV, Netherlands) during a single breathhold of 20 to 25 seconds duration. The standardized examination protocol included a 16 × 0.75–mm collimation, pitch of 0.24, and tube rotation time of 0.42 seconds. Each scan was obtained at 140 kV and 400 mA. Ionic contrast material (Imeron 400; Byk Gulden, Konstanz, Germany) was administered via an 18-G access in the cubital vein. The scan delay was determined by injection of a 30-mL test bolus with a flow rate of 3 mL/s and repeated scanning every second at the level of the ascending aorta. The time to peak enhancement plus 6 seconds was chosen as delay time. For vessel and ventricle enhancement 100 mL of contrast material was injected at a flow rate of 5 mL/s followed directly by a 50 mL saline chaser bolus injected with a flow rate of 4 mL/s.

Image reconstruction was performed with 0.75 mm effective section thickness, 0.4 mm increment, and B30f kernel. Reconstruction was performed by using retrospective ECG gating. Depending on the heart rate, 2-, 3-, or 4-segmental reconstruction was performed. Each data set was reconstructed 10 times before the next R-peak.

All data sets were displayed by using several visualization techniques: transverse scanning, 3-D reformation (Figure 1), and multiplanar reformation (MPR) (Figure 2). Three-dimensional reformation was performed by using a volume-rendering technique. MPR allows the investigator to place and maneuver cross-sectional image planes through a 3-D volume.

Evaluation of the coronary arteries was performed according to the classification of the American Heart Association, which divides the coronary arteries into 15 segments [Windecker 1999] (Figure 3). Each dataset was examined by 2 experienced radiologists who reached a final consensus decision and were unaware of the conventional angiographic results. In each coronary arterial segment the extent of atherosclerosis had to be determined, despite poor visibility as well as blooming artifacts or blending with overlying vessels, by grading the stenosis as hemodynamically relevant (stenosis >50%) or not (stenosis <50%).

Findings were compared with the corresponding coronary angiograms, which were examined in the same way (Figure 4). Results obtained from the invasive coronary angiogram served as the reference standard.

The sensitivities and specificities of the MSCT scans in the detection of hemodynamically relevant stenosis >50% were calculated in correlation to the number of lesions detected in the coronary angiography. Calculation was performed for those segments that built the proximal (segments 1, 5, 6, 11), medial (segments 2, 7, 9, 12), and distal (segments 3, 4, 8, 10, 13, 14, 15) parts of the coronary artery tree.

RESULTS

During the MSCT investigations, no severe complications occurred. No patient developed an allergic reaction. Average investigation time, including preparation and scanning, was less than 15 minutes. Reconstruction of the images and preparation of the 3-D volumes took approximately 1 to 1 1/2 hours.

Fifty patients (42 male/8 female) scheduled for elective CABG procedure underwent 16-slice MSCT scanning preoperatively. Four patients had to be excluded for technical reasons. The mean age of the patients was 64.4 ± 8.66 years (range, 42-85 years). All patients had sinus rhythm. Thirty-eight (82.6%) of the 46 included patients had 3-vessel disease, 4 (8.75%) had 2-vessel disease, and 4 (8.7%) had 1-vessel disease. Overall 690 coronary segments were examined, and coronary artery disease was diagnosed using MSCT in 46 patients.

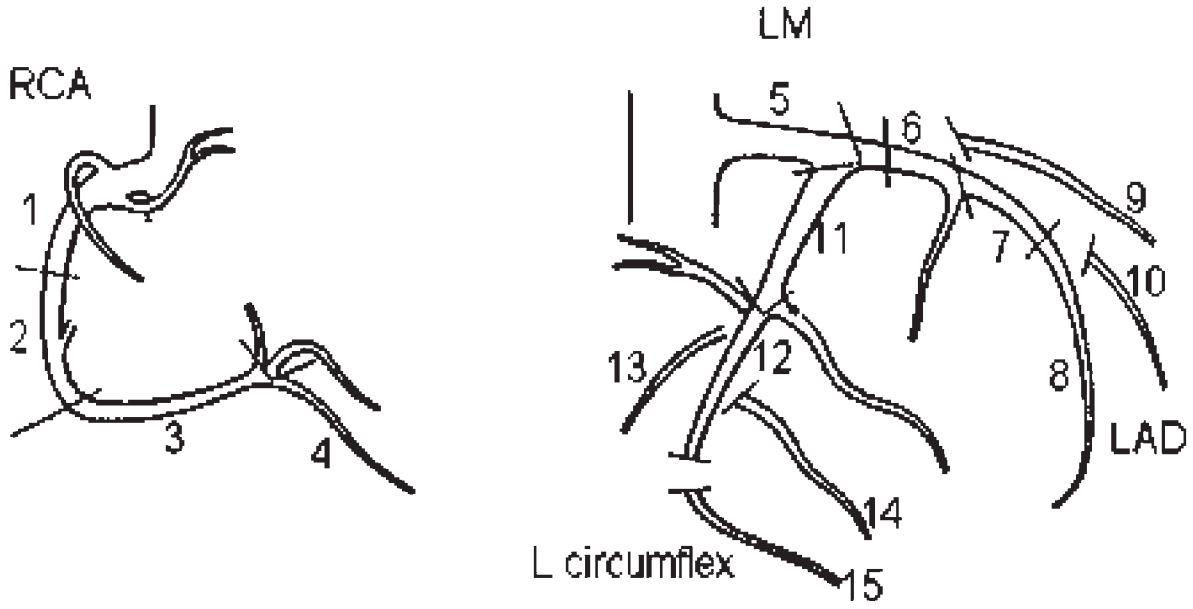

Figure 3. American Heart Association classification of coronary arteries. RCA indicates right coronary artery; LM, left medial artery; LAD, left anterior descending artery.

Table 1 shows stenosis >50% diagnosed using standard invasive angiography compared to results of the MSCT scans related to the coronary artery segments. All stenoses >50% in the proximal segments were correctly diagnosed by MSCT compared to the reference standard angiography (56 of 56). In the medial segments 84 hemodynamically relevant stenoses were seen in the CT scans compared to 75 in the angiograms. In the distal segments 118 were seen in the CT scans compared to 65 in the angiograms (Table 1).

Of 56 significant stenosis (>50%), 56 of 56 (100%) in the proximal segments, 73 of 75 (97%) in the medial segments, and 59 of 65 (91%) in the distal segments were correctly detected using MSCT (Table 2).

Blooming artifacts, as well as poor visibility, led to 11 false-positive interpretations of 109 medial segments and 59 false-positive results of 257 distal segments (Table 2).

Combined interpretation of all reconstruction techniques led to a sensitivity and specificity of 100% in the proximal segments. For medial segments, sensitivity was 97% and specificity 91%.

In the distal segments, sensitivity of 91% was reached for hemodynamically relevant stenosis (>50%), specificity was 77% (Table 3).

Figure 4. Coronary angiogram (left) and corresponding 3-dimensionally reconstructed multislice computed tomographic image of a significant left anterior descending artery stenosis (right).

Table 1. Segmental Allocation of Stenosis <50% Detected by Invasive Coronary Angiography (CA) Compared to Multislice Computed Tomographic Angiography (MSCT)

	Segment	No. CA-Detected Stenoses	No. MSCT-Detected Stenoses
Proximal	1	13	13
	5	6	6
	6	22	22
	11	15	15
		Total 56	Total 56
Medial	2	27	29
	7	23	24
	9	7	12
	12	18	19
		Total 75	Total 84
Distal	3	12	21
	4	9	17
	8	9	11
	10	7	12
	13	10	15
	14	8	23
	15	10	19
		Total 65	Total 118

DISCUSSION

Several previous reports have demonstrated the usefulness of MSCT. Assessment of significant coronary stenosis has been reported with a sensitivity of 58% to 86%. In most of the studies the evaluation was limited to branches more than 2 mm in diameter and a rate of nonevaluable arteries of up to 32% [Kopp 2000, 2001, Nieman 2002]. The presence of severe calcifications can impair evaluability of some of the coronary segments, and it is well known that atrial contraction in end-diastole can influence the movement of the right and circumflex arteries because of their anatomical position in the atrioventricular groove.

In our study each coronary segment had to be evaluated, despite poor visibility as well as blooming artifacts or blending with overlying vessels, by selecting different phases of reconstruction and use of different methods of reconstruction to compensate for the difference in motion of the major coronary arteries.

We found that significant stenosis (>50% reduction in diameter) in the proximal and middle segments could be detected with high sensitivity and specificity by noninvasive 16-slice MSCT angiography. The presence of extensive calcifications (blooming artifacts), motion artifacts, and poor visibility may result in misinterpretation and may lead to lower sensitivity and specificity in the distal segments. Nevertheless, severe calcification of coronary arteries is related to CAD, and its detection will contribute to clinical decision making.

Table 2. Numbers of Missed Stenosis and False Positive Results by Multislice Computed Tomographic Angiography

	Stenosis >50% Not Detected	False-Positive Results
Proximal segments	0 of 56	0 of 128
Medial segments	2 of 75 (3%)	11 of 109 (10%)
Distal segments	6 of 65 (9%)	59 of 257 (23%)

Table 3. Sensitivity and Specificity of Multislice Computed Tomographic Scans

	Sensitivity	Specificity
Proximal segments	100%	100%
Medial segments	97%	90%
Distal segments	91%	77%

One of the major limitations of CT angiography compared to invasive coronary angiography is the difference in the method of evaluation of the coronary stenosis. In our study, as in others, the coronary arteries were divided into segments, a procedure that cannot be done as precisely for MSCT as for conventional coronary angiography. Also the evaluation of coronary artery stenosis was based on visual estimation, which is a very observer-dependent method [Detre 1975]. Nevertheless MSCT technology is just at the beginning of its technical development. Advances in scanner technology and contrast media in the next few years will lead to more MSCT applications. Several CT manufacturers have announced the next generation of MSCT scanners, which will be equipped with an expanded number of thinner detector rows and shorter rotation time.

In various clinical situations, noninvasive angiography provides additional information or may substitute for conventional diagnostics in specific situations.

From the current perspective, noninvasive angiography will be useful for excluding patients with a relatively low likelihood obstructive coronary artery disease rather than for staging patients with a high likelihood of obstructive coronary artery disease. MSCT would be an attractive alternative to repeated catheterizations for follow-up on progression of disease and response to therapy. At its current stage of development CT angiography is well suited for use as a gatekeeper for invasive catheterization and may change the field of cardiovascular medicine.

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