Multimodality Imaging of Anatomy and Function in Coronary Artery Disease

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Chapter 4

Diagnostic Accuracy of 64-slice Multi-Slice Computed Tomography in the Non-Invasive Evaluation of Significant Coronary Artery Disease

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Abstract

Background

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 (CAD) 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 due to a heart rate above 90 beats per minute 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. 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.

Conclusion

The present study confirms that 64-slice MSCT enables accurate and non-invasive 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. While 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 [1]. In addition, results of numerous studies comparing MSCT to conventional coronary angiography suggested enhanced sensitivity of the technique as well, with no loss in specificity [2]. Currently, 64-slice MSCT systems are rapidly installed, offering further improved image quality while acquiring data in even shorter periods of time [3;4]. 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 [5]. Conventional catheter-based coronary angiography was performed prior or after MSCT and served as 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 64 x 0.5 mm and a rotation time of 0.4 s. The tube current was 300 mA, at 120 kV. In obese patients (BMI ≥ 30 kg/m^2), parameters were adjusted to 350 mA at 135 kV in order to improve image quality. Non-ionic contrast material was administered in the antecubital vein with an amount of 80-110 ml, depending on the total scan time, and a flow rate of 5.0 ml/sec (Iomeron 400 ®). 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 10s.

During the MSCT examination, ECG was recorded simultaneously for retrospective gating of the data. An initial data set was reconstructed at 75% of the R-R 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 artefacts, sharper reconstruction kernels were explored to improve image quality. Finally, images were transferred to a remote workstation (Vitrea2, Vital Images, Plymouth, Minn. USA) for post-processing 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 of scoring MSCT coronary angiograms. Image analysis was performed blinded to the results of coronary angiography. 3D volume rendered reconstructions were used to obtain general information of the status and course of the coronary arteries. Then, the original transaxial slices were inspected for the presence of significant (≥50% reduction of lumen diameter) narrowing, assisted by curved multiplanar reconstructions. Segmentation of the coronary arteries was performed based on the American Heart Association-American College of Cardiology guidelines [6]. 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 run-off of contrast distally.
Conventional angiograms were evaluated by an experienced observer without knowledge of the MSCT data who identified the available coronary segments based the American Heart Association-American College of Cardiology guidelines [6]. Each segment was then evaluated for the presence of ≥50% diameter stenosis, based on evaluation of 2 orthogonal views.

Statistical analysis

Obstructive CAD was defined as luminal narrowing of 50% or more. Accordingly, sensitivity, specificity, positive and negative predictive values (including 95% confidence intervals) for the detection of stenosis ≥50% on conventional angiography, were calculated on a patient, vessel and segmental basis. 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 as part of the left circumflex. All statistical analyses were performed using SPSS software (version 12.0, SPSS Inc, Chicago, Il, USA). A value of $P<0.05$ was considered statistically significant.

Results

Patient characteristics

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

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

	n (%)
Male/Female	46/14
Age (years)	60 ± 11
(range)	38-80
Heart Rate (beats per minute)	60 ± 11
(range)	44 - 83
Average calcium score (Agatston)	423 ± 868
(range)	0 - 6264
Beta-Blocking medication	43 (72%)
Diabetes Mellitus	6 (10%)
Hypertension [a]	26 (43%)
Hypercholesterolemia [b]	27 (45%)
Positive family history	22 (37%)
Current smoking	33 (55%)
Body Mass Index ≥ 30 kg/m^2	15 (25%)
History of CAD	
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%)
Number of coronary arteries narrowed as determined on angiography	
None	14 (23%)
1	26 (43%)
>1	20 (33%)

[a] defined as systolic blood pressure ≥140 mm Hg and/or diastolic blood pressure ≥90 mm Hg, and/or use of anti-hypertensive medication.
[b] defined as total serum cholesterol ≥230 mg/dl and/or serum triglycerides ≥200 mg/dl or use of a lipid-lowering agent.

MSCT coronary angiography

In 854 segments evaluated on conventional coronary angiography, a total of 74 significant stenoses was identified. MSCT image quality was insufficient in 12 (1.4%) segments to allow further evaluation. Reasons for uninterpretability were low contrast-to-noise due to a high BMI (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 RCA (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 a significant lesion on MSCT. A total of 14 lesions that were non-significant on conventional coronary angiograpy were overestimated on MSCT, while 11 lesions were falsely deemed to be insignificant. Accordingly, resulting sensitivity and specificity for the detection of significant lesions were 85% and 98% 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 patent stented segments.

Figure 1. Example of a patient with significant coronary artery disease.

In Panel A, a 3D volume rendered reconstruction is shown, providing an overview of the left anterior descending (LAD) and left circumflex (LCx). An enlargement of the section indicated by the black arrowhead (Panel B) demonstrates a significant narrowing in the LAD (black arrowhead) and, more distally, a small coronary calcification (white arrowhead) that can also be observed on the curved multiplanar reconstruction (Panel D). Cross-sectional images (Panel E) confirm the presence of a significant non-calcified lesion. In Panel F, a curved multiplanar reconstruction of the LCx without significant lesions is provided. In the right coronary artery (Panel G, 3D volume rendered reconstruction and Panel H, curved multiplanar reconstruction), no significant narrowings were observed as well. Findings were confirmed by conventional coronary angiography (Panels C and I).

Vessel analysis

Due to extensive calcifications, 1 left circumflex was deemed uninterpretable. In the remaining 239 coronary arteries, 46 of 53 coronary arteries were correctly identified as having one or more significant lesions whereas the absence of any stenosis was correctly identified in 179 of 186 vessels, resulting in a sensitivity and specificity of 87% and 96%, respectively.

Patient analysis

Conventional coronary angiography identified 31 patients with one or more significant lesions. On MSCT, 29 (94%) of these patients were correctly identified. In one 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. MSCT correctly ruled out the presence of any significant lesion in 28 of 29 (97%) patients. Only 3 patients were incorrectly diagnosed by MSCT. In one patient, a significant lesion in origin of the second diagonal was missed due to the small size of the coronary side-branch. In the other patient with false negative MSCT results, a significantly diseased left anterior descending and left circumflex were incorrectly classified as having non-obstructive disease. Finally, in one patient who was incorrectly classified positive, a lesion of approximately 40% located in the left anterior descending was overestimated by MSCT.
Results of all analyses including positive and negative predictive values with 95% confidence intervals are summarized in Table 2.

Table 2. Diagnostic accuracy of Multi-Slice Computed Tomography (n=60).

	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. Importantly, only 12 (1%) segments could not be evaluated for the presence or absence of significant lesions due to 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 segmental basis are preferred, since 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 [4;7], 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 [3;4;8]. Similar sensitivity and specificity of 86% and 95% on segmental basis were reported by Raff et al, who performed 64-slice MSCT in 70 patients [7]. More recently, results in 52 patients presenting with a wide range of clinical conditions were reported by Mollet and colleagues [4]. As a result of the highly symptomatic population included, a higher sensitivity (100%) with somewhat lower specificity (92%) was obtained.

Since the purpose of the present study was to compare the diagnostic accuracy of MSCT to 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 favourably to most of the other available data on MSCT coronary angiography, it stipulates the current lack of data in lower CAD prevalence populations. Considering that non-invasive coronary angiography is most likely to be used in these particular populations to allow definite exclusion of significant CAD, data on the performance of MSCT in these populations are needed.

Despite rapid technological advancements, several limitations inherent to MSCT remain. First, a stable and preferably low heart rate remains essential for high-quality MSCT images and administration of beta-blockers prior to the examination is often needed. Secondly, 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 and colleagues, the ability to visually quantify the grade of luminal obstruction on MSCT remains limited, even with 64-slice technology [3]. Indeed, also in the present study, the degree of stenosis was incorrectly estimated as either more or less than 50% diameter narrowing in 2 patients, resulting in false diagnosis although in fact the presence of lesions was correctly identified. Accordingly, quantification of MSCT coronary angiography is likely to provide enhanced diagnostic accuracy while also improving 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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