

Accuracy of MSCT Coronary Angiography with 64 Row CT Scanner—Facing the Facts

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Abstract: Improvements in multislice computed tomography (MSCT) angiography of the coronary vessels have enabled the minimally invasive detection of coronary artery stenoses, while quantitative coronary angiography (QCA) is the accepted reference standard for evaluation thereof. Sixteen-slice MSCT showed promising diagnostic accuracy in detecting coronary artery stenoses haemodynamically and the subsequent introduction of 64-slice scanners promised excellent and fast results for coronary artery studies. This prompted us to evaluate the diagnostic accuracy, sensitivity, specificity, and the negative and positive predictive value of 64-slice MSCT in the detection of haemodynamically significant coronary artery stenoses.

Thirty-seven consecutive subjects with suspected coronary artery disease were evaluated with MSCT angiography and the results compared with QCA. All vessels were considered for the assessment of significant coronary artery stenosis (diameter reduction $\geq 50\%$). Thirteen patients (35%) were identified as having significant coronary artery stenoses on QCA with 6.3% (35/555) affected segments. None of the coronary segments were excluded from analysis. Overall sensitivity for classifying stenoses of 64-slice MSCT was 69%, specificity was 92%, positive predictive value was 38% and negative predictive value was 98%. The interobserver variability for detection of significant lesions had a κ -value of 0.43.

Sixty-four-slice MSCT offers the diagnostic potential to detect coronary artery disease, to quantify haemodynamically significant coronary artery stenoses and to avoid unnecessary invasive coronary artery examinations.

Keywords: MSCT, multislice computed tomography, coronary angiography

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Introduction

Quantitative coronary angiography (QCA) is the accepted reference standard for evaluation of coronary artery stenoses. It offers unequalled temporal and spatial resolution and an opportunity for therapeutic interventions in the same setting. Nevertheless, as the procedure is invasive and entails some inconvenience and risks for the patient,¹ a non-invasive method has been sought. Current 16-slice computed tomography (MSCT) scanners are advantageous for the assessment of coronary artery disease (CAD), but because of motion artefacts or arteriosclerosis, distal segments are not clearly visible and so basically not assessable.^{2,3}

We aimed to assess the accuracy of 64-slice CT in depicting haemodynamically significant stenotic lesions of the coronary arteries in comparison with QCA as a standard of reference.

Materials and Methods

Subjects

Forty-four consecutive subjects (22 men, 22 women, mean age 64.3 ± 2.3 years, range 32–97) referred to our centre for suspected CAD between December 2004 and March 2005 were evaluated retrospectively. Exclusion criteria for the MSCT study were renal failure (creatinine $> 120 \mu\text{mol/L}$), heart rate > 85 beats/minute, intolerance to iodine-containing contrast agent, previous coronary bypass surgery and inability to hold breath on command. Four (0.09%) patients were excluded from the study because of previous coronary bypass surgery and 3 (0.06%) due to heart rate exceeding 85 beats per minute. Those patients were evaluated by electron beam computer tomography (EBCT) as part of our standard protocol for depicting coronary artery disease. The remaining 37 subjects underwent both MSCT coronary angiography and QCA and were included in the study. The mean interval time between CT angiography and QCA was 23.5 ± 14.4 days (range 6–60 days). Every patient was administered two squirts of Nitrolingual[®] prior to examination. None of the patients were receiving beta receptor blocking medication at the time of MSCT examination. All participating subjects gave written informed consent. Formal approval by our institutional review board was not necessary as we use EBCT routinely for non-invasive evaluation of coronary artery lesions in patients with suspected or known coronary artery disease.

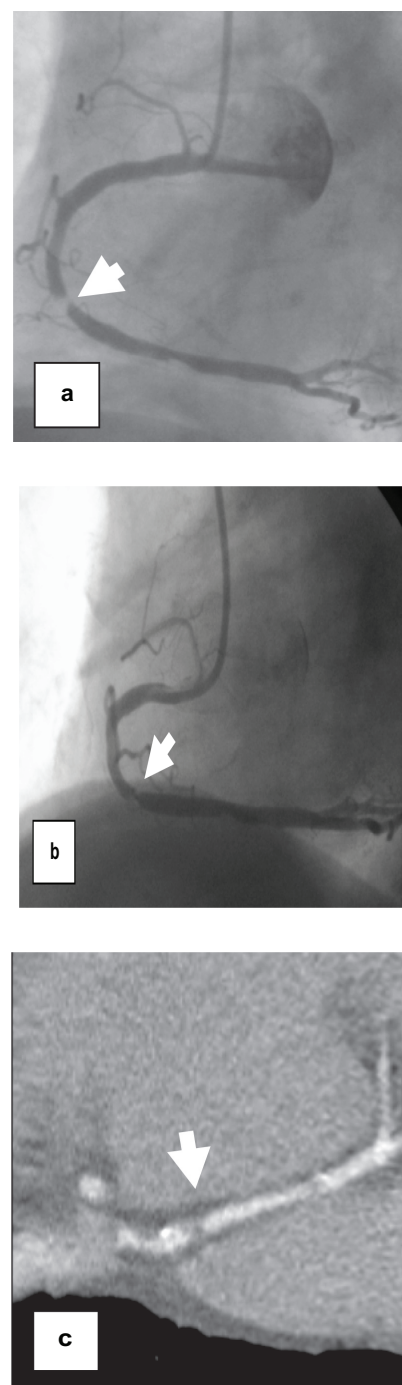


Figure 1. a–c) 64-row CT 0.7 mm thick multiplanar reconstruction and **b)** conventional angiogram demonstrating a high-grade stenosis in segment 2 (AHA classification) due to a soft plaque (white arrow).

Invasive coronary angiography

Invasive coronary angiography was performed according to standard techniques after MDCT. Coronary angiograms were evaluated by an independent cardiologist with quantitative coronary angiography (QCA) as standard of reference for detecting and grading coronary arterial stenotic lesions. Coronary arteries were

divided into segments according to the classification of the American Heart Association.⁴ All coronary segments visualized upon catheterisation were included in the study. The cardiologist was blinded to the results of the MDCT scan. Lesions with a diameter reduction of $\geq 50\%$ in relation to a reference segment were considered to represent significant stenoses.⁵

MSCT coronary angiography protocol

All CT scans were performed on a 64-row scanner with a rotation time of 0.37s (Somatom Sensation 64, Siemens, Forchheim, Germany). A bolus of 75 ml iodixanol (Visipaque[®] 320 mg/ml, Amersham Health, Buckinghamshire, UK) was injected in an antecubital vein with a flow rate of 4 ml/sec, followed by a 50 ml saline chasing bolus. A test bolus with 10 ml iodixanol followed by a 50 ml saline chasing bolus was administered to determine the optimal start delay by measuring the highest peak of concentration of contrast medium in the ascending aorta. Scanning was performed from the tracheal bifurcation to the diaphragm using an effective tube current of 750 mAs and an x-ray tube potential of 120 kV.

MSCT image reconstruction

A retrospective ECG-gated technique was used for image reconstruction. The data sets were reconstructed during the mid-to-end diastolic phase with a reconstruction window set at -300 ms to -450 ms before

the next R-wave (60%–70% of the R-R interval). When the heart rate was irregular, the ECG was edited manually to compensate for the temporal variability in the reconstruction phase. The reconstructed slice was 1 mm thick with an increment of 0.7 mm. All MSCT data were filtered with a “B30 f medium smooth” kernel.

CT data analysis

CT data from the coronary arteries were analysed according to the guidelines for QCA.⁵ Two experienced observers blinded to the patients' clinical histories evaluated each vessel segment independently for the presence of haemodynamically significant stenoses. Significant stenosis was defined as narrowing of the coronary lumen $\geq 50\%$. All vessels were included in the analysis; no diameter threshold was set. Upon reconstruction, the vessel diameter was oriented perpendicular to the vessel's course for measurement. Depending on coronary anatomy and image quality, different visualization techniques such as multi-planar reformation (MPR) were used. Each vessel was analysed on at least two planes. When the findings of the two observers disagreed, a final decision was obtained by consensus. The maximum attenuation in the ascending aorta was measured to document adequate vessel opacification expressed in Hounsfield Units (HU).

Image quality was defined for each segment as being excellent (no artefacts), good (minor artefacts), adequate

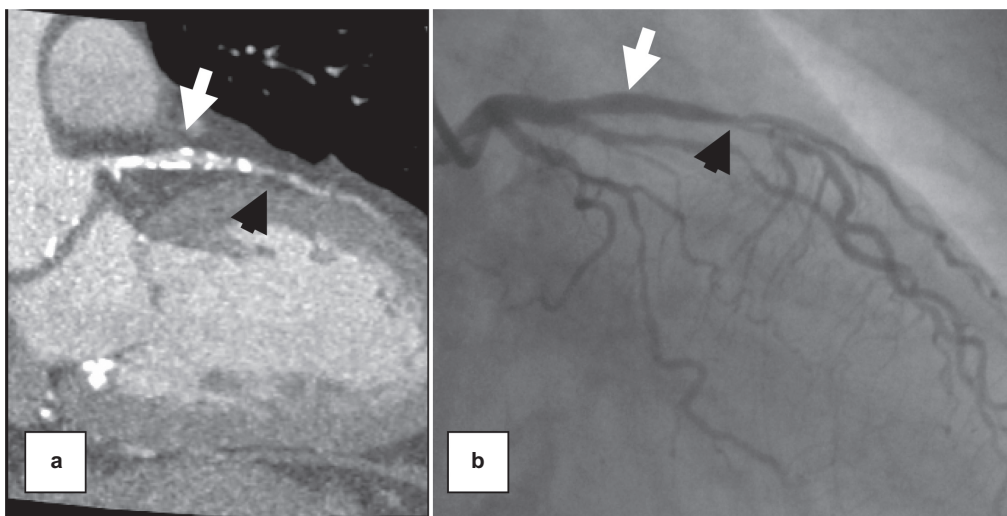


Figure 2. a) 64-row CT 0.75 mm thick multiplanar reconstruction and b) conventional angiogram: A non significant calcified lesions in the left anterior descending coronary artery (Segment 6, AHA classification, white arrow), that was overestimated as a haemodynamically stenotic lesion by MSCT and a significant lesion due to a soft plaque (Segment 7, AHA classification; black arrow) are visible on right anterior oblique view (RAO).



(moderate artefacts) and poor (severe artefacts). When image quality was not excellent, the reasons for impaired visualization were classified according to the following causes: calcium deposits, motion artefacts, opacified adjacent structures (such as contrast enhanced ventricle or cardiac vein), low vessel opacification. Motion artefacts were defined as any impairment in image quality caused by vessel movement resulting in blurred or doubled vessel contours. Arteriosclerosis was rated as either moderate (minor sclerosis of the vascular wall) or severe (extensive sclerosis with artefacts impairing vessel lumen visualization).

Statistical analysis

All statistical analysis was done with commercially available statistical software (SPSS 11.5 for Windows, SPSS Incorporation, Chicago, IL, USA). Quantitative variables are expressed as mean and standard deviation. Sensitivity, specificity, positive predictive value and negative predictive value for 64-slice CT coronary angiography for detecting significant stenoses are calculated from chi square tests of contingency; 95% confidence intervals are calculated from binominal expression. QCA is the standard of reference.

Results

A total of 35 haemodynamically significant stenoses of 555 coronary artery segments were identified in 35% (13/37) of the patients; there were no complete occlusions. One-vessel disease was identified in 16% (6/37), two-vessel disease in 10% (4/37) and three-vessel disease in 16% (6/37) of the patients. There was no significant coronary artery stenosis in 56% (21/37) of the patients. None of the patients took beta—blocking medication. The mean heart rate was 73.4 ± 1.7 (range 45–85); the median blood pressure was 133 ± 1.5 mmHg systolic and 77.5 ± 1.3 mmHg diastolic.

Results for coronary artery stenoses, image quality and reasons for impaired visualization are listed in Table 1.

Maximum attenuation of contrast medium in the ascending aorta was $340 \text{ HU} \pm 46$.

From a total of 35 haemodynamically significant stenoses detected with QCA, 24 were correctly identified with MSCT coronary angiography (Fig. 1). The overall sensitivity was 69% (95% CI: 53.6–80.7), the specificity 92% (95% CI: 91.3–93.1), the positive predictive value 38% (95% CI: 23.3–44.1) and the negative predictive

value 98% (95% CI: 96.7–98.8). The interobserver variability for detection of significant lesions had a κ -value of 0.43. Seven stenoses were missed in the LAD (4 in the proximal, 2 in the middle and 1 in the distal segment), one in the distal RCA and one in the distal LCX. The stenoses in the LAD were missed due to severe arteriosclerosis, those in the RCA and in the LCX were overlooked due to motion artefacts.

The rating was excellent for 61.3% (340/555) of all coronary artery segments, good for 25.2% (140/555), adequate for 4% (26/555) and poor for 8% (49/555). There were small isolated sclerotic plaques in 25.2% (140/555) of all coronary artery segments and 2.5% (14/555) showed extensive arteriosclerosis. The main reason for impaired vessel visualization was calcium deposits; 23.8% (132/555) of all segments had impaired visualization because of minor or major arteriosclerosis (Fig. 2). The proximal, middle and distal LAD was most affected by sclerosis, followed by the RCA and the LCX. In 10.2% (57/555) of the coronary artery segments, opacified adjacent structures impaired vessel visualization; 6.8% (38/555) had decreased image quality because of motion artefacts. In all cases, vessels could still be evaluated; nevertheless, image quality suffered moderately, whatever the reason for impaired visualization.

Discussion

Improvements in MSCT angiography of the coronary vessels have enabled the minimally invasive detection of coronary artery stenoses, with reportedly high sensitivity and specificity. With four-row MSCT, a sensitivity of up to 86% for the detection of coronary artery stenoses has been reported.^{6–8} Sixteen-slice CT angiography of the coronary vessels has a reported sensitivity of 73%–95% for all segments, depending mainly on the modality of analysis, the diameter of the vessel and patient selection criteria.^{2,3,9,10}

Our 64-slice CT data show that MSCT has the potential to detect haemodynamically significant coronary artery stenoses; nevertheless, this new generation of MSCT scanners also has technical limitations that must be confronted. Recent studies have reported two major limitations in assessing coronary artery disease with MSCT: severe arteriosclerosis and motion artefacts.^{2,3} Severe arteriosclerosis is still a major limitation for detecting significant coronary artery stenoses with this new technique. According to a recent study, motion

Table 1. Diagnostic accuracy of 64-slice CT coronary angiography for detecting significant stenosis in coronary arteries.

	Total (%)	LM (%)	LAD ^a (%)	Prox LAD (%)	Mid LAD (%)	Dist LAD (%)	LCX ^a (%)	Prox LCX (%)	Dist LCX (%)	LPDA (%)
Coronary stenosis >50%	6 (35/555)	–	15 (17/111)	30 (11/37)	14 (5/37)	3 (1/37)	5 (4/74)	5 (2/37)	5 (2/37)	3 (1/37)
Calcium deposits										
No detectable calcium	72 (401/555)	78 (29/37)	55 (61/111)	35 (13/37)	59 (22/37)	70 (26/37)	72 (53/74)	51 (19/37)	92 (34/37)	89 (33/37)
Moderate calcification	25 (140/555)	19 (7/37)	42 (47/111)	62 (23/37)	38 (14/37)	27 (10/37)	27 (20/74)	46 (17/37)	8 (3/37)	11 (4/37)
Massive calcification	3 (14/555)	3 (1/37)	3 (3/111)	3 (1/37)	3 (1/37)	3 (1/37)	1 (1/74)	3 (1/37)	–	–
Quality of vessel visualization										
Excellent	59 (328/555)	78 (29/37)	56 (62/111)	57 (21/37)	54 (20/37)	57 (21/37)	61 (45/74)	65 (24/37)	57 (21/37)	57 (21/37)
Good	27 (152/555)	19 (7/37)	33 (37/111)	41 (15/37)	35 (13/37)	24 (9/37)	26 (19/74)	27 (10/37)	24 (9/37)	24 (9/37)
Adequate	5 (26/555)	–	5 (5/111)	–	5 (2/37)	8 (3/37)	5 (4/74)	3 (1/37)	8 (3/37)	5 (2/37)
Poor	9 (49/555)	3 (1/37)	6 (7/111)	3 (1/37)	5 (2/37)	11 (4/37)	8 (6/74)	5 (2/37)	11 (4/37)	14 (5/37)
Reasons for decreased image quality^b										
Low opacification	0 (1/227)	–	2 (1/49)	–	6 (1/17)	–	–	–	–	–
Motion artefacts	58 (132/227)	88 (7/8)	71 (35/49)	94 (15/16)	65 (11/17)	56 (9/16)	55 (16/29)	77 (10/13)	38 (6/16)	31 (5/16)
Calcium deposits	25 (56/227)	–	14 (7/49)	–	18 (3/17)	25 (4/16)	28 (8/29)	15 (2/13)	38 (6/16)	44 (7/16)
Adjacent structures^c	17 (38/227)	13 (1/8)	12 (6/49)	6 (1/16)	12 (2/17)	19 (3/16)	17 (5/29)	8 (1/13)	25 (4/16)	25 (4/16)
Diagnostic accuracy										
Sensitivity	69 (24/35)	NA	59 (10/17)	64 (7/11)	60 (3/5)	0 (0/1)	100 (4/4)	100 (2/2)	100 (2/2)	0 (0/1)
Specificity	92 (480/520)	97 (36/37)	85 (80/94)	85 (22/26)	81 (26/32)	89 (32/36)	93 (65/70)	89 (31/53)	97 (34/35)	100 (36/36)

(Continued)



Table 1. (Continued)

	Total (%)	LM (%)	LAD ^a (%)	Prox LAD (%)	Mid LAD (%)	Dist LAD (%)	LCX ^a (%)	Prox LCX (%)	Dist LCX (%)	LPDA (%)
Positive predictive value	38 (24/64)	0 (0/1)	42 (10/24)	64 (7/11)	33 (3/9)	0 (0/4)	44 (4/9)	33 (2/6)	67 (2/3)	NA
Negative predictive value	98 (480/491)	100 (36/36)	92 (80/87)	85 (22/26)	93 (26/28)	97 (32/33)	100 (65/65)	100 (31/31)	100 (34/34)	97 (36/37)
Coronary stenosis >50%		RCA^a (%)	Prox RCA (%)	Mid RCA (%)	Dist RCA (%)	DIA 1 (%)	DIA 2 (%)	OM (%)	PLA (%)	RPDA (%)
	7 (8/111)	8 (3/37)	3 (1/37)	11 (4/37)	3 (1/37)	3 (1/37)	—	5 (2/37)	3 (1/37)	3 (1/37)
Calcium deposits										
No detectable calcium	58 (64/111)	54 (20/37)	65 (24/37)	54 (20/37)	92 (34/37)	92 (34/37)	92 (34/37)	78 (29/37)	92 (34/37)	81 (30/37)
Moderate calcification	37 (41/111)	41 (15/37)	30 (11/37)	41 (15/37)	5 (2/37)	5 (2/37)	8 (3/37)	19 (7/37)	8 (3/37)	16 (6/37)
Massive calcification	5 (6/111)	5 (2/37)	5 (2/37)	5 (2/37)	3 (1/37)	3 (1/37)	—	3 (1/37)	—	3 (1/37)
Quality of vessel visualization										
Excellent	59 (66/111)	62 (23/37)	62 (23/37)	62 (23/37)	54 (20/37)	54 (20/37)	57 (21/37)	62 (23/37)	57 (21/37)	54 (20/37)
Good	28 (31/111)	30 (11/37)	24 (9/37)	30 (11/37)	27 (10/37)	27 (10/37)	24 (9/37)	30 (11/37)	24 (9/37)	27 (10/37)
Adequate	6 (7/111)	5 (2/37)	5 (2/37)	8 (3/37)	5 (2/37)	5 (2/37)	5 (2/37)	3 (1/37)	5 (2/37)	3 (1/37)
Poor	6 (7/111)	3 (1/37)	8 (3/37)	8 (3/37)	14 (5/37)	14 (5/37)	14 (5/37)	5 (2/37)	14 (5/37)	16 (6/37)
Reasons for decreased image quality^b										
Low opacification	—	—	—	—	—	—	—	—	—	—
Motion artefacts	71 (32/45)	86 (12/14)	64 (9/14)	65 (11/17)	47 (8/17)	47 (8/17)	44 (7/16)	64 (9/14)	31 (5/16)	47 (8/17)
Calcium deposits	18 (8/45)	14 (2/14)	21 (3/14)	18 (3/17)	29 (5/17)	29 (5/17)	31 (5/16)	21 (3/14)	44 (7/16)	35 (6/17)
Adjacent structures ^c	11 (5/45)	—	14 (2/14)	18 (3/17)	24 (4/17)	24 (4/17)	25 (4/16)	14 (2/14)	25 (4/16)	18 (3/17)



Diagnostic accuracy	88 (7/8)	100 (3/3)	100 (1/1)	75 (3/4)	100 (1/1)	NA	100 (2/2)	0 (0/1)	0 (0/1)
Sensitivity									
Specificity	87 (90/103)	82 (28/34)	83 (30/36)	97 (32/33)	94 (34/36)	100 (37/37)	94 (33/35)	100 (36/36)	92 (33/36)
Positive predictive value	35 (7/20)	33 (3/9)	14 (1/7)	75 (3/4)	33 (1/3)	NA	50 (2/4)	NA	0 (0/3)
Negative predictive value	99 (90/91)	100 (28/28)	100 (30/30)	97 (32/33)	100 (34/34)	100 (37/37)	100 (33/33)	97 (36/37)	97 (33/34)

^aResults for LAD, LCX and RCA represents summarized measurements of dependent segments (LAD: proximal, mid and distal LAD; LCX: proximal and distal LCX; RCA: proximal, mid and distal RCA).

^bRate of reasons for decreased image quality were calculated from all vessel segments scored other than excellent.

^cContrast-enhanced ventricle or cardiac vein.

Abbreviations: Dist, distal; LM, left main artery; LPDA, left posterior descending artery segment; NA, not applicable; OM, obtuse marginal branch; Prox, proximal; RPDA, right posterior descending artery segment.

artefacts could be minimized by reducing the gantry rotation time; nevertheless, that study involved coronary arteries with a diameter of less than 1.5 mm.¹¹

We excluded no vessels from examination and there was no threshold for vessel diameter. Our overall sensitivity of 69% and overall specificity of 92% are comparable to a recent study by Leber et al¹² with an overall sensitivity of 73% and an overall specificity of 97% for quantifying obstructive and non-obstructive coronary lesions with 64-slice CT without setting a threshold for vessel diameter. A high negative predictive value of 98% in this study suggests an important future role of the 64-row scanner for diagnosing CAD and for reliably excluding CAD in patients with symptoms of coronary heart disease who may presently undergo QCA. In comparison to a recent study dealing with the diagnostic accuracy of non-invasive 64-slice CT coronary angiography,¹³ however, we note a lower overall sensitivity of 68.6% in our cohort. This might be explained by the fact that our chosen protocol differed in some points from the protocol of Pugliese et al,¹³ but is still comparable. In an attempt to avoid irradiation of small vessels due to an excessive concentration of contrast medium, we chose a concentration of 270 mg/ml. Secondly, we tried to administer a minimal volume of contrast medium; 75 ml of contrast medium and a chasing bolus of 50 ml were deemed acceptable for detecting haemodynamically significant coronary stenoses on the basis of a recent study dealing with administration of different volumes of contrast media.¹⁴ Measurements of the maximum attenuation in the ascending aorta showed values of 340 HU ± 46. We differ from the protocol of Pugliese et al¹³ in one important item: we did not administer any additional medication such as beta-blockers. Despite a threshold of 85 beats per minutes, we noticed only a moderate degradation of image quality due to motion artefacts, although this did cause us to miss two significant stenoses in the distal RCA and distal LCX.

Further, only MCST makes it possible to view the vessel and the vessel wall; that is the outstanding advantage compared to QCA. QCA only shows the vessel lumen, but not the vessel wall, which indicates whether a patient has CAD.

Advantages of this new scanner generation are better image quality thanks to improved spatial and temporal resolution. The shorter scanning time decreases breath hold time and requires fewer enhancements of adjacent structures due to better exploitation of contrast media.



Limitations of the study

The κ -value is quite low, probably due to the small number of patients and a very low prevalence of CAD of 6.3% in comparison to 18% in another recent study;¹⁵ together, these are the major limitations of this study. The retrospective study design can also be seen as a limitation. Further, the radiation exposure inherent to this technique might be a limitation in evaluating subjects with suspected CAD. Prospective ECG tube current modulation is the most effective way to reduce radiation.¹⁶ It has one major disadvantage: possible image quality impairment in the early diastole, which can make it difficult to evaluate the RCA. Finally, QCA and MSCT were not performed simultaneously. However, the mean delay of 23.5 days is acceptable with regard to the natural progression of CAD.¹⁷

In conclusion, our initial data suggest that the 64-slice CT generation has potential for non-invasive assessment of haemodynamically significant coronary artery disease and identification of patients suffering from CAD, but we must be aware of its limitations such as motion artefacts and especially severe arteriosclerosis that still impairs consistent vessel analysis. Further prospective studies are necessary to determine optimal heart rate and vessel size for optimal image quality.

Disclosures

This manuscript has been read and approved by all authors. This paper is unique and is not under consideration by any other publication and has not been published elsewhere. The authors report no conflicts of interest.

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