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Coronary artery bypass grafts: assessment of graft patency and native coronary artery lesions using 16-slice MDCT

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Abstract The objective of this study was to evaluate the accuracy of electrocardiography (ECG)-gated 16-slice multidetector-row computed tomography (MDCT) in detection of stenosis of bypass grafts and native coronary arteries in patients who have undergone coronary artery bypass grafting (CABG). ECG-gated contrast-enhanced MDCT using 12×0.75-mm collimation was performed in 20 patients with recurrent angina 4.75 years after undergoing CABG. A total of 50 grafts, 16 arterial and 34 venous, were examined. All graft and coronary segments were evaluated for stenosis in comparison with conventional coronary angiography (CCA). Among the 80 arterial graft segments, 62 could be assessed (77.5%). Sensitivity, specificity, and positive and negative predictive values for stenosis were 96.2%, 97.2%, 96.2%, and 97.2%, respectively. In a total of 180 venous graft segments, 167 could be assessed. Sensitivity, specificity, and positive and negative predictive values for stenosis were 98.5%, 93.9%, 91.8%, and 98.9%, respectively. MDCT could assess 179 of 260 native coronary artery segments (68.8%).Sensitivity, specificity, and positive and negative predictive values for stenosis were 92.1%, 76.9%, 87.5%, and 84.7%, respectively. Sixteen-slice MDCT provides excellent image quality and diagnostic accuracy in detection of graft and coronary artery lesions in patients with suspected graft dysfunction.

Keywords Bypass graft · Cardiovascular disease · CT coronary arteriography

Introduction

In patients with coronary artery disease (CAD), surgical myocardial revascularization is performed to treat diseased vessels. Treatment is either by arterial conduits, such as internal mammary artery (IMA), radialis, gastroepiploic, etc., or homologous venous coronary artery bypass grafts (CABG). Generally speaking, patients have a reduction of clinical symptoms and an increase in quality of life after revascularization [1]. However, thoracic discomfort can persist in a subgroup of patients after surgical therapy. These symptoms are often difficult to distinguish from angina pectoris, and the question of bypass occlusion or bypass stenosis may be raised. Previous studies revealed an incidence of bypass occlusion during the first year of up to 5% for IMA grafts and up to 20% for venous grafts [2, 3]. Ten years post CABG, 15% of arterial grafts [3] and approximately 40–50% of venous grafts [4] are occluded. In addition, native coronary artery disease progresses in about 5% of patients annually [5]. At present, the diagnostic method of choice in this situation is invasive catheter angiography (ICA) to investigate coronary artery and bypass status. However, it is an invasive procedure, with 0.1% mortality and risk of minor or even major complications [6]. Noninvasive techniques such as magnetic resonance imaging (MRI) [7–10], computed tomography (CT) [10–15], and, since 1999, multidetector-row computed tomography (MDCT) [10, 16–19], can demonstrate graft patency. However, a clinically useful imaging technique should be able to evaluate progression of CAD in addition to graft disease.

Since 2002, the second-generation MDCT scanner with faster gantry rotation speed and more detector rows has been available. First publications suggest vastly improved image quality and reliable detection of obstructive CAD [20–23]. The aim of our study was to evaluate feasibility, image quality, and clinical accuracy of a 16-slice MDCT scanner in detecting graft and coronary artery stenosis using conventional coronary angiography (CCA) as the standard of reference.

Materials and methods

Patient study

Twenty patients with recurrent angina after undergoing CABG who were referred to our institution for conventional coronary angiography (CCA) were included. A total of 50 grafts, 16 arterial and 34 venous, with a total of 65 distal anastomoses were examined. Six patients had only venous grafts, three had only arterial grafts, and 11 had both venous and arterial grafts. Of the 34 venous grafts, 24 were solitary, nine sequential, and one an Y-graft with three anastomoses. Of the 16 arterial grafts, 15 were solitary, 14 to the left anterior descending (LAD) and one to the right coronary artery (RCA), and one a radialis artery T-graft with three distal anastomoses.

Exclusion criteria were known irregular heart rate (HR), known allergy to iodinated contrast media, renal failure (serum creatinine level >1.5 mg/dl), or substantial cardiac failure. The interval between the surgical procedure and CT evaluation was 4.75 (range 1–12) years. All patients underwent MDCT angiography 1 day before CCA. An oral premedication with β-blocker was attempted in all patients. Contraindications for β-blocker medication was atrioventricular block ≥II°, intrinsic HR <50 beats/min (bpm), asthma bronchiale, and cardiac failure; 18 of 20 (90%) patients received 50–100 mg metoprolol tartrate depending on cardiac frequency 45 min before the CT scan (Lopresor Mite, Novartis Pharma GmbH, Nueremberg, Germany). No additional β-blocker was administered in case of insufficient HR reduction.

The study was approved by the ethics committee, and patients were enrolled after giving written informed consent.

Multidetector-row computed tomography

MDCT data sets were acquired 1 day before CCA using a 16-slice MDCT scanner (Sensation 16, Siemens Medical Systems, Forchheim, Germany) with 12 slices read out simultaneously in cardiac mode. Patients were examined whilst in a supine position by using the breath-hold technique. The breath-hold period was on average 20 s. Scanning range included the entire course of the venous grafts, but not the most proximal part of all IMA grafts, in order to maintain a manageable breath-hold period. To evaluate circulation time, 20 ml of contrast media (20 ml at 4 ml/s, 400 mg iodine/ml; Imeron 400, Altana Pharma, Konstanz, Germany) and a chaser bolus of 20 ml saline was administrated in an antecubital vein. Correct scanning delay was established by measuring CT attenuation values in the ascending aorta using the first slice after maximum contrast as circulation time. By using a dual-head and power injector (CT2, Medtron Saarbrücken, Germany), a total volume of 100 ml intravenous contrast agent plus 20 ml chaser bolus was injected (50 ml at 4 ml/s, then 50 ml at 2.5 ml/s). A contrast-enhanced scan was acquired using the following protocol: 12×0.75 mm collimation, ECG-triggered scan modulation, table feed 3.8 mm/rotation, and tube current 400 eff. mAs at 120 kV.

For image reconstruction, the standard built-in reconstruction algorithm was used. The reconstruction window was set to start at 60% RR interval for all native images as well as for the contrast-enhanced scan to determine the reconstruction interval with the least motion artifacts. If necessary, a test series reconstructing slices ranging from 35% to 75% relative to RR interval was performed in 5% steps. The time point with least motion artifacts was chosen to reconstruct the entire stack of images of the CTA scan. Total scan and reconstruction time was on average 35 min.

MDCT image interpretation

Two investigators who were aware of the initial CABG procedure but blinded to results of quantitative coronary angiography (QCA) evaluated the MDCT scans in a consensus reading. Depending on the individual case, axial slices and advanced postprocessing tools, such as multiplanar reconstruction (MPR) and maximum intensity projection (MIP), were used. Image quality was ranked on a five-point scale: excellent=1, good=2, diagnostic=3, “severe calcified” (vessel lumen obscured by calcification) or “blurred” (only contrast visualization inside the vessel possible, no luminal assessment regarding significant stenosis possible)=4, and not visible=5. Results were documented separately for all bypass graft and coronary segments. Bypass grafts were divided into four segments: 1=proximal anastomosis, 2=middle part, 3=distal anastomosis, and 4=recipient coronary artery segment. Consecutive graft anastomoses were regarded as separate segments.

Coronary segments were evaluated using a modified American Heart Association (AHA) classification [RCA: 1=proximal, 2=middle, 3=distal, 4=combined posterior descending and posterolateral branches, 5=left main stream; LAD: 6=proximal, 7=middle, 8=distal, 9=first diagonal, 10=second diagonal; left circumflex (CX): 11=proximal, 12=distal, 13=first marginal branch] [24]. Each bypass or coronary segment was classified in interpretable (image quality rank 1–3) or not interpretable (image quality rank 4–5). Segments were screened for the presence of relevant stenotic lesions (luminal narrowing of 50–100%) by visual estimation. Results of each patient and segment were compared with the findings of QCA.

Quantitative coronary angiography

In all patients, CCA were obtained using four French catheters the day following the MDCT exam. The CCA procedure itself was done under normal routine conditions, and any clinical consequence and treatment decisions drawn were solely based on the results of CCA. Two investigators blinded to the results of CT evaluated all angiograms by quantitative coronary and bypass analysis with automated vessel contour detection and manual correction. The catheter was used for calibration (Quantitative Coronary Analysis, Philips Medical Systems, Eindhoven, The Netherlands). Lesions with a lumen narrowing ≥50% were considered to be significant stenotic lesions.

Statistical analysis

The descriptive statistics were stratified for coronary artery segments and venous and arterial graft segments. QCA was regarded as the standard of reference. If a coronary vessel or bypass graft segment contained more than one lesion, the most severe lesion within the segment determined diagnostic accuracy of the assessment. Continuous data were summarized with the mean and standard deviation (SD). Diagnostic results in the detection of lesions were expressed as sensitivity, specificity, positive predictive value, and negative predictive value. Precision of the estimates was reported by providing 95% confidence intervals (CIs). In addition, the overall or so-called "worst-case" sensitivity, which regards lesions in noninterpretable segments as false negative assessments, was also calculated. Results between coronary arteries and venous and arterial grafts were compared by using the Fisher-Freeman-Halton test and Fisher's exact test. The two-tailed Fisher's exact test was further employed to compare diagnostic performance of MDCT in depicting obstructive disease between patients with low (<65 bpm) and high (≥65 bpm) heart rate during data acquisition [17].

Results

Image quality

MDCT was performed without complications in all patients. Out of all 520 graft and coronary segments scanned, 206 (147 graft segments) were found to be of excellent image quality, 72 (31 graft segments) of good image quality and 72 (47 graft segments) of diagnostic image quality. Major contributors to the noninterpretability of 16- detector row CT images were severe calcifications (Fig. 1). Eighty-six segments (14 graft segments) were severely affected by calcifications to such an extent that assessment of lumen was not possible, and 26 segments (two graft segments) were of blurred image quality so that no luminal assessment was possible. Out of all 32 non-visible segments, 15 were not covered in the scan volume and 17 were occluded in QCA. A total of 78.5% (408/520) segments (88.1% graft segments) showed fully diagnostic image quality. Coronary arteries could be fully assessed in only two of 20 (10%) patients due to one or more non-evaluable segments. In comparison, bypass graft segments could be fully assessed in ten of 20 patients (50%).

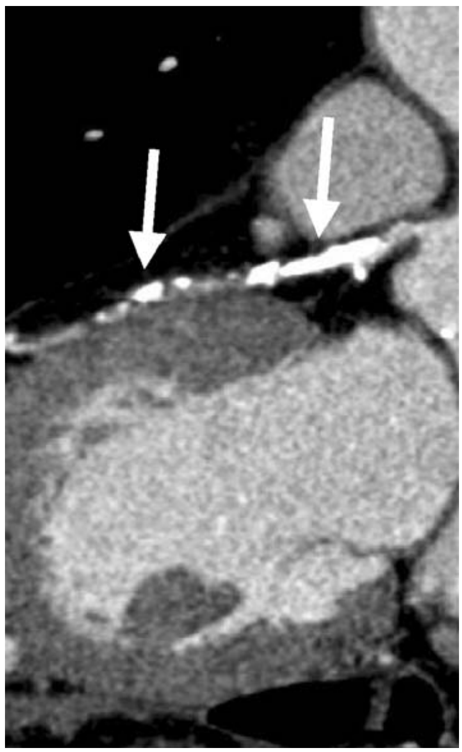

Fig. 1 Left anterior descending artery with severest wall calcifications (*arrows*)

Lesion detection

Arterial bypass grafts

In a total of 80 segments, QCA detected 28 lesions >50% (19 segments were occluded). Among the 80 segments, 62 could be assessed (77.5%). Two lesions were in non-assessable segments. Evaluation of those segments were hampered by vascular clips. MDCT correctly assessed 25/26 (96.2%) lesions in assessable segments. Specificity, positive predictive value and negative predictive value were 97.2% (35/36), 96.2% (25/26), and 97.2% (35/36), respectively (Table 1).

Venous bypass grafts

In 180 segments, QCA detected 68 lesions (57 segments were occluded). Among the 180 segments, 167 (92.8%) could be assessed. Nine segments were the most severely calcified, and four were not included in the scan volume. MDCT correctly assessed 67/68 (98.5%) in assessable segments; however, there were no lesions in nonassessable segments. Specificity, positive predictive value, and negative predictive value were 93.9% (93/99), 91.8% (67/73), and 98.9% (93/94), respectively (Table 2).

Coronary arteries

In 260 coronary artery segments, QCA detected 166 lesions >50%. MDCT could assess 179/260 segments (68.8%); 105/114 (92.1%) lesions in the assessable segments could be detected in MDCT. Fifty-two lesions were in nonassessable segments; 50/52 were in segments with the most severe calcifications. Two lesions were in two segments, which were not covered in the scan volume (segment 4 posterior descending). Overall sensitivity for MDCT in detection of coronary stenosis was 63.3% (105/166) when lesions in nonassessable segments were considered false negative lesions. Specificity, positive predictive value, and negative predictive value were 76.9% (50/ 65), 87.5% (105/120), and 84.7% (50/59), respectively (Table 3). A significantly larger percentage of bypass grafts could be evaluated compared with the coronary arteries ($p<0.001$). Specificity, negative predictive value, and overall sensitivity for detecting 50% or more lesions showed a similar trend (Table 4).

Influence of heart rate

Mean heart rate at the CT examination was on average 66.9±9.0 (range, 52–88) bpm. In the group of nine patients with heart rates below 65 bpm, mean heart rate was 60.0±

Table 1 Diagnostic accuracy of 16-slice multidetector-row computed tomography (MDCT) for detection of 50–100% arterial graft obstruction

Parameter	Results: % (*n*/*n*; lower, upper 95% CI)
Assessability	77.5 (62/80)
Sensitivity	96.2 (25/26; 80.4, 99.9)
Specificity	97.2 (35/36; 85.5, 99.9)
Positive predictive value	96.2 (25/26; 80.4, 99.9)
Negative predictive value	97.2 (35/36; 85.9, 99.9)
Lesions in nonassessable segments	11.1 (2/18)
Overall sensitivity[a]	89.3 (25/28; 71.8, 97.7)

Data are percentages; data in parentheses are numbers of segments and 95% CIs

[a]To determine overall sensitivity, lesions in nonassessable segments were considered false negative

Table 2 Diagnostic accuracy of 16-slice multidetector-row computed tomography (MDCT) for detection of 50–100% venous graft obstruction

Parameter	Results: % (*n*/*n*; lower, upper 95% CI)
Assessability	92.8 (167/180)
Sensitivity	98.5 (67/68; 92.1, 100)
Specificity	93.9 (93/99; 87.3, 97.7)
Positive predictive value	91.8 (67/73; 83.0, 96.9)
Negative predictive value	98.9 (93/94; 94.2, 100)
Lesions in nonassessable segments	0
Overall sensitivity[a]	98.5 (67/68; 92.1, 100)

Data are percentages; data in parentheses are numbers of segments and 95% CIs

[a]To determine overall sensitivity, lesions in nonassessable segments were considered false negative

Table 3 Diagnostic accuracy of 16-slice multidetector-row computed tomography (MDCT) for detection of 50–100% coronary artery obstruction

Parameter	Results: % (*n*/*n*; lower, upper 95% CI)
Assessability	68.8 (179/260)
Sensitivity	92.1 (105/114; 87.1, 97.1)
Specificity	76.9 (50/65; 64.8, 86.5)
Positive predictive value	87.5 (105/120; 81.6, 93.4)
Negative predictive value	84.7 (50/59; 73.0, 92.8)
Lesions in nonassessable segments	64.2 (52/81)
Overall sensitivity[a]	63.3 (105/166; 56.0, 70.6)

Data are percentages; data in parentheses are numbers of segments and 95% CIs

[a]To determine overall sensitivity, lesions in nonassessable segments were considered false negative

Table 4 Comparison of diagnostic accuracy of 16-slice multidetector-row computed tomography (MDCT) for detection of coronary artery and graft obstruction

Parameter	Coronary artery obstruction: % (*n*/*n*)	Arterial graft obstruction: % (*n*/*n*)	Venous graft obstruction: % (*n*/*n*)	*p* value*
Assessability	68.8 (179/260)	77.5 (62/80)	92.8 (167/180)	<0.001
		88.1 (229/260)		<0.001
Sensitivity	92.1 (105/114)	96.2 (25/26)	98.5 (67/68)	NS
		97.9 (92/94)	NS	
Specificity	76.9 (50/65)	97.2 (35/36)	93.9 (93/99)	0.001
		94.8 (128/135)		<0.001
Positive predictive value	87.5 (105/120)	96.2 (25/26)	91.8 (67/73)	NS
		92.9 (92/99)		NS
Negative predictive value	84.7 (50/59)	97.2 (35/36)	98.9 (93/94)	<0.001
		98.5 (128/130)		<0.001
Overall sensitivity	63.3 (105/166)	89.3 (25/28)	98.5 (67/68)	<0.001
		95.8 (92/96)		<0.001

The first lines show arterial and venous grafts separately; the second lines contain total bypass grafts
Data are percentages; data in parentheses are numbers of segments
To determine overall sensitivity, lesions in nonassessable segments were considered false negative
NS not significant
*Determined with the Fisher-Freeman-Halton test (three categories) and Fisher's exact test (two categories)

4.2 (range, 52–64). In comparison, mean heart rate was 72.5±7.9 (range, 65–88) in the group of 11 patients with high heart rates. Only the specificity for coronary artery lesion detection showed a significant difference between the two patient groups (91.2% vs 61.3%; p=0.007) (Table 5).

Table 5 Influence of heart rate on diagnostic accuracy of 16-slice multidetector-row computed tomography (MDCT) for detection of obstructive disease

Obstruction and parameter	Heart rate <65 bpm: % (*n*/*n*)	Heart rate ≥65 bpm: % (*n*/*n*)	*p* value*
Venous graft obstruction			
Assessability	91.2 (62/68)	93.8 (105/112)	NS
Sensitivity	100 (25/25)	97.7 (42/43)	NS
Specificity	97.3 (36/37)	91.9 (57/62)	NS
Overall sensitivity	100 (25/25)	97.7 (42/43)	NS
Arterial graft obstruction			
Assessability	75.0 (36/48)	81.3 (26/32)	NS
Sensitivity	92.9 (13/14)	100 (12/12)	NS
Specificity	95.5 (21/22)	100 (14/14)	NS
Overall sensitivity	81.3 (13/16)	100 (12/12)	NS
Graft obstruction (arterial + venous)			
Assessability	84.5 (98/116)	91.0 (131/144)	NS
Sensitivity	97.4 (38/39)	98.2 (54/55)	NS
Specificity	96.6 (57/59)	93.4 (71/76)	NS
Overall sensitivity	92.7 (38/41)	98.2 (54/55)	NS
Coronary artery obstruction			
Assessability	72.6 (85/117)	65.7 (94/143)	NS
Sensitivity	96.1 (49/51)	88.9 (56/63)	NS
Specificity	91.2 (31/34)	61.3 (19/31)	0.007
Overall sensitivity	72.1 (49/68)	57.1 (56/98)	NS

Data are percentages; data in parentheses are numbers of segments
To determine overall sensitivity, lesions in nonassessable segments were considered false negative
bpm beats per minute, *NS* not significant
*Determined with the Fisher's exact test

Discussion

The most important findings of this study are that 16-slice MDCT technology provides excellent image quality and diagnostic accuracy in the detection of bypass graft and native coronary artery lesions. Current remaining limitations seem to be severe calcifications and vascular clips artifacts.

Lesion detection

Noninvasive follow-up of patients who have undergone CABG should include visualization of bypass grafts and coronary arteries. Results of several studies concerning the use of MDCT for noninvasive coronary and bypass angiography have been published [16–23, 25–27]. Since the beginning of the 1980s, CT has been used for the assessment of bypass grafts. First investigations without using spiral technique could give information regarding patency only [11]. A technological progress in CT diagnostics was development of the spiral technique. For single-slice spiral CT, sensitivities were 76% (internal mammary artery) and 100% (venous graft) [12]. Imaging of jumped grafts was insufficient. Evaluation of graft stenosis or distal anastomosis was not possible.

Electron beam tomography (EBT) revealed sensitivity for graft patency ranging between 92% and 100% and specificity between 83% and 100% [13–15] whereas results were similar for arterial and venous grafts. Detection of venous-graft stenosis is possible in a high percentage of patients, but only 84% of venous-graft segments were evaluative [13]. What remains unclear is detection of relevant stenosis in arterial grafts and in distal graft anastomoses.

With ECG-gated MDCT, delineation of coronary arteries [25] and bypass grafts is directly possible [19]. The use of MDCT for evaluating bypass grafts was examined in several studies. Results are summarized in Table 6. In spite of using a 4×1-mm collimation and a reconstruction of 0.5 mm, evaluation of graft stenosis and distal anastomoses remains problematic. Ropers et al. could only evaluate 62% of patent graft segments for graft stenosis [18]. Major contributors to noninterpretability were motion artifacts caused by residual cardiac motion, the 4-slice MDCT scanning required a long breath-hold that could not be performed by a number of patients, extensive calcifications of coronaries and degenerated grafts, as well as vascular clips [19]. Limitations due to motion artifacts for that scanner type are substantially reduced for the 16-slice MDCT used in this study, but severe calcifications and vascular clips remain a disadvantage, which seems not to be possible to reduce in the near future.

In comparison to Nieman et al. [17], our data showed an improvement of sensitivity, specificity, and overall sensitivity for detection of arterial-graft obstruction. Diagnostic accuracy of MDCT in detection of venous-graft obstruction was already excellent with 4-slice scanners [19]. Our data demonstrate the efficiency of 16-row scanner in detection of venous-graft obstruction, with a sensitivity of 98.5%, a specificity of 93.9%, and overall sensitivity of 98.5%. Results are comparable with data published recently by Schlosser et al. and Martuscelli et al. [22, 23].

Diagnostic accuracy of MDCT in detection of coronary artery obstruction remains problematic. The previously reported promising results on noninvasive lesion detection in coronary arteries [20, 21, 26, 27] could be reproduced in our study, where MDCT obtained a sensitivity of 92.5% and a specificity of 76.9%, but assessability was only 68.8%, resulting in overall sensitivity of 63.3%. However, although MDCT imaging is becoming more accurate, complete visualization of the entire coronary tree still cannot be expected.

Image quality and Influence of heart rate and radiation exposure

Nevertheless, some limitations and drawbacks of the CT technique in comparison to catheterization remain. A total of 78.5% segments (88.1% graft segments) showed fully diagnostic image quality. Extensive calcification of coronary arteries and degenerated grafts, as well as vascular clips in the proximity of arterial grafts, cause beam hardening and partial volume artifacts that hamper the assessment of graft patency. These artifacts have been reduced since the introduction of 16-slice scanners with an increased rotation speed, but severe calcification remains

Table 6 Use of 4-slice multidetector-row computed tomography (MDCT) for evaluation of bypass graft patency

Author (year)	Silber (2003)	Nieman (2003)	Ropers (2001)
Patients/grafts	74/220	24/41	65/182
Arterial/venous grafts	88/132	18/23	20/162
Assessability	220/220	79/86 O1 72/86 O2	182/182
Sensitivity total/arterial/venous	100/100/100	100/100/100 O1 95/67/100 O2	97%/n.p./n.p.
Specificity total/arterial/venous	96/75/100	97/93/98 O1 94/83/98 O2	98%/n.p./n.p.
Detection of stenosis	n.p.	57/68 (84%) O1 52/65 (80%) O2	77/124 (62%)

n.p. not provided, *O1* observer 1, *O2* observer 2

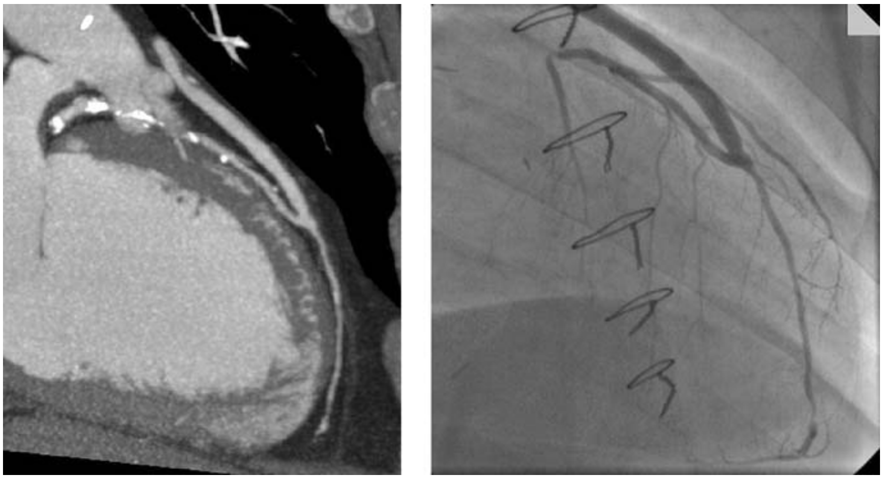

Fig. 2 Venous bypass graft to the left anterior descending artery (LAD) in multidetector-row computed tomography (MDCT) (*left*) and conventional coronary angiography (CCA) (*right*)

problematic and unfortunately is a drawback of CT. In our study population, 16.5% (86/520) of all segments (5.4% of all graft segments) were hampered by severe calcification.

Earlier disadvantages in examination of patients with arrhythmias and high heart rates decreased substantially with the introduction of new algorithms and the use of β-receptor-blocking medication. In our study, only the specificity (91.2%) for coronary artery lesion detection showed a significant difference between the group of patients with lower heart rates compared with those with high heart rates (61.3%; p=0.007) (Table 5). It should, however, be mentioned that only four patients had a heart rate >70 bpm during the examination, and the mean heart rate was on average 66.9±9.0 (52–88) bpm.

Limitations of MDCT are radiation exposure (4–6 mSv for the contrast-enhanced scan [28]), the need for iodinated contrast agents, and the fact that a reduction of heart rate by using β-blockade is still recommended. The initially high radiation dose was significantly decreased to 4–6 mSv with the introduction of ECG-triggered scan modulation algorithms and is comparable to CCA. Dose measurements of the protocol used in this study revealed an effective dose of 5.4 mSv (male) using an ECG-dependent tube-current modulation at 60 bpm and 10.1 mSv (male) without tube-current modulation [29]. Published data of CCA radiation exposure vary considerably and is examiner dependent. However, it is generally agreed that CCA has a lower radiation exposure than MDCTA [30].

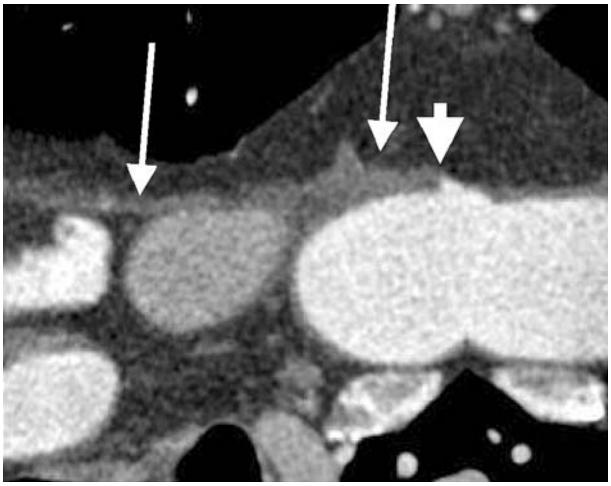

Fig. 3 Proximal occluded venous bypass graft with well-detectable abruption of contrast medium (*short arrow*) at the proximal anastomosis. The occluded graft can be visualized over a long distance (*thin arrows*)

Despite these technical limitations, MDCT allows accurate assessment of graft patency and, in addition, provides relevant information concerning the presence of substantial obstructive disease in bypass grafts, including distal anastomosis and coronary artery disease progression (Fig. 2). The technique is easy to perform, well tolerated, and provides information regarding coronary arteries. Therefore, MDCT can be used as a noninvasive examination for graft patency prior to catheterization in the majority of the patients.

Study limitations

Limitations of our study are the small number of graft stenosis in comparison with occluded grafts. Most pathological findings, especially in venous grafts, were occlusions (Fig. 3). Therefore, results of sensitivity and specificity are potentially brushed up due to the excellent accuracy of MDCT in detecting graft obstructions. However, the frequency of graft stenosis is reported to be significantly lower than that of occlusion [31]. Another limitation is the low assessability of native coronary arteries in the study population. In this study, evaluation of the coronary tree was possible in two patients only due to the fact that most patients who undergo bypass surgery have advanced atherosclerotic disease with small, diffusely narrowed vessels, with an opulent presence of calcifications in the arterial wall (Fig. 1), which hamper assessment of vessel lumen.

In conclusion, noninvasive MDCT imaging is becoming increasingly accurate, meaning that this technology can be routinely used clinically as a noninvasive examination in patients with suspected graft dysfunction. However, assessment of native coronary arteries remains poor.

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