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Clinical research

Use of 64-slice CT in symptomatic patients after coronary bypass surgery: evaluation of grafts and coronary arteries

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Aims Although previous generations of multislice computed tomography (CT) have demonstrated accurate detection of obstructive bypass graft disease, progression of coronary disease is a more frequent cause for ischaemic symptoms late after bypass graft surgery. We explored the diagnostic performance of 64-slice CT in symptomatic patients after bypass surgery, for the assessment of both grafts and native coronary arteries.

Methods and results The 64-slice CT angiography (Siemens Sensation 64, Germany) was performed in 52 symptomatic patients, 10±5 years after bypass surgery. Two independent, blinded observers assessed all grafts and coronary arteries for stenosis, using conventional quantitative angiography as a reference. A total of 109 grafts (182 graft segments), 123 distal coronary run-offs, and 116 non-bypassed coronary branches (288 segments) were analysed. Per-segment detection of graft disease yielded a sensitivity of 99% (71/72) and specificity of 96% (106/110). Sensitivity and specificity to detect run-off disease were 89% (8/9) and 93% (106/114), positive predictive value was 50% (8/16). In non-grafted coronary segments, CT detected significant stenosis with a sensitivity and specificity of 97% (62/64) and 86% (192/224). Overestimation occurred more frequently in calcified segments ($P = 0.002$).

Conclusion The 64-slice CT allows angiographic evaluation of grafts and coronary arteries, although overestimation of coronary obstruction occurs, particularly in the presence of calcified disease.

Introduction

Restoration of myocardial flow by coronary artery bypass surgery (CABG) is performed in ~300 000 patients in the USA, annually. Often this is not a permanent solution, as up to 10% of grafts occlude during or shortly after surgery, and 59% of venous grafts and 17% of arterial grafts occlude within 10 years.[1] Although symptoms may be the result of graft failure, anginal complaints later after surgery, nearly 50% within 6 years[2,3] are mostly caused by progression of obstructive disease in the native coronary arteries.[4]

Although catheter-based angiography is the reference method for detection of bypass graft disease, it is an invasive procedure that is costly and carries potential risk of harm. Non-invasive tests such as exercise-ECG, stress-echocardiography, and nuclear imaging are useful for detection of myocardial ischaemia, but are unable to exactly determine the site and extent of obstructive disease. Therefore, a number of non-invasive imaging techniques have been explored for non-invasive angiographic assessment of CABGs. Magnetic resonance imaging,[5,6] conventional computed tomography (CT),[7-9] electron-beam computed tomography[10-12] and (multislice) spiral CT[13-22] all allow accurate detection of graft occlusion, and more recently graft stenosis, although assessment of the coronary arteries has rarely been included in these studies. In patients without graft surgery, the diagnostic performance of MSCT coronary angiography (CA) is good[23-32] Only few studies in post-CABG patients have included the assessment of the native coronary arteries, and have shown only modest accuracy (using 4- and 16- slice CT) for the detection of obstructive disease.[16,20]

Improved technical performance of current CT technology,[30,32] may overcome some of the imaging challenges after bypass surgery. Therefore, we evaluated the diagnostic accuracy of 64-slice MSCT angiography in symptomatic patients who previously underwent bypass surgery. In addition to assessment of CABG, distal coronary run-offs and non-grafted coronary arteries were included in this study.

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Methods

Population

Patients with stable symptoms suggesting obstructive graft or coronary artery disease (CAD) that required CA were approached for this study. Exclusion criteria were an irregular heart rate, allergy to iodine contrast media, and renal failure (serum creatinine >100 mmol/L). Between November 2004 and September 2005 a total of 77 stable patients, scheduled for (elective) catheter angiography, were consecutively screened. Seventeen patients had contraindications, whereas another eight potential candidates declined. The remaining 52 patients were enrolled and underwent CT angiography in addition to conventional catheter-based angiography (*Table 1*). The Local Ethical Committee approved the study and all participants gave written informed consent.

The mean interval between bypass surgery and CT angiography was 10.3 ± 5.1 years (range 1–23 years). Forty-five patients had venous bypass grafts and 38 had arterial bypass grafts. Of the 64 venous grafts, 29 were anastomosed to a single coronary branch and 35 were jump grafts with at least two consecutive coronary anastomoses. Of the 45 arterial grafts, 34 were single grafts and 11 had more than one coronary anastomosis. In seven patients, both the right and left internal mammary artery were used. Six patients underwent redo-CABG, as a result of which 12 coronary artery branches were grafted twice on separate occasions. Twenty patients underwent percutaneous coronary intervention (PCI) with stent implantation, with a total of 57 coronary and six graft stents.

MSCT data acquisition

All patients were examined with a 64-slice spiral CT scanner (Sensation 64®, Siemens, Forchheim, Germany). The Roentgen tube rotation time was 330 ms, resulting in an effective temporal resolution of 165 ms (or less using a bisegmental reconstruction algorithm at higher heart rates). Detector collimation was 32 × 0.6 mm, the pitch was 0.2 (3.8 mm table advancement per rotation). By rapidly alternating the longitudinal position of the focal spot (Z-Sharp® Technology, Siemens), 64 slices could be acquired simultaneously. The tube voltage was 120 kV, and the tube current varied between 800 and 900 mAs. Depending on the presence of arterial grafts or only venous material, the scan range was cranially extended. With a table speed of 11.6 mm/s, the scan time was 15.4 ± 2.3 s (range 11.9–22.4 s). Patients with a heart rate over 65 min^{-1} were given a β-blocker (upto 100 mg of metoprolol) and/or anxiolytic medication (1 mg of lorazepam) 45 min before the scan. In 25 out of 35 patients that received medication, the average heart rate was below 65 min during the scan, average heart rate reduction 8.1 ± 1.1 min^{-1}. Ten patients were scanned with a heart rate over 65 min^{-1}. A bolus of 100 mL of iomeprol 400 mgI/mL (Iomeron®, Bracco, Milan, Italy) was intravenously injected at a rate of 3.5–5 mL/s, depending on the size of the patient. Bolus tracking, i.e. monitoring of contrast enhancement in the aortic root during contrast injection, was applied to synchronize the data acquisition with the contrast enhancement.

ECG-synchronized images were reconstructed at several time points within the diastolic cardiac phase. Occasionally, end-systolic reconstruction offered better image quality. A sharper kernel was applied in addition to the standard medium sharp kernel, in the presence of stents. Generally, the examination, including patient preparation and image reconstruction, required between 20 and 30 min. All examinations were performed without complications.

Table 1 Population characteristics

Population characteristics ($N = 52$)	
Male (*n*)	45 (87%)
Age (years)	65.0 ± 8.1
Body mass index (kg/m^2)	27.8 ± 3.3
History	
Family history of coronary disease (%)	25 (48%)
Nicotine abuse (%)	7 (13%)
Hypertension (%)	39 (75%)
Dislipidaemia (%)	48 (92%)
Diabetes (%)	19 (36%)
Transient ischaemic attack/stroke (%)	4 (8%)
Myocardial infarction (%)	33 (63%)
Interventions with use of stents (%)	20 (38%)
Graft anatomy per patient	
Single graft (*n*)	10 (19%)
Two graft (*n*)	30 (58%)
Three grafts (*n*)	9 (17%)
More than three grafts (*n*)	3 (6%)
Venous and arterial grafts (*n*)	31 (60%)
Venous grafts, no arterial grafts (*n*)	14 (27%)
Arterial grafts, no venous grafts (*n*)	7 (14%)
CT examination	
Heart rate before CT scan (min^{-1})	68.1 ± 8.5
Heart during CT scan (min^{-1})	60.0 ± 7.4
β-blocker (%)	34 (65%)
Benzodiazepine (%)	27 (52%)

MSCT vessels analysis

Two readers independently reviewed the CT data. Readers were informed about the previous surgical procedures, but blinded with respect to the invasive angiographic results. In cases of disagreement, a final decision was made during a joint reading. The following vessels and conduits were assessed:

Arterial and venous grafts

In case of more coronary anastomoses per arterial or venous graft (jump grafts), all graft sections between the proximal anastomoses (aortic root or subclavian artery) and each coronary insertion (graft segment) was separately assessed and classified as occluded, significantly obstructed (50–99% lumenal narrowing), or not (significantly) obstructed (*Figure 1*).

Distal coronary run-offs

All coronary branches that were supplied by a patent bypass graft were assessed for significant lumenal narrowing (>50% lumen diameter reduction).

Native coronary arteries

Coronary arteries that were not, or not completely revascularized at the time of surgery, were assessed per coronary segment, irrespective of the vessel diameter (17-segment ACC/AHA model).[33] The following coronary segments, unless anatomically absent, were assessed: proximal, middle, and distal right coronary artery (RCA), posterior descending artery and (right) posterolateral branch, LM coronary artery, proximal, middle, and distal left anterior descending (LAD) coronary artery and (largest) first and second diagonal branch, the proximal and distal circumflex coronary artery with three obtuse marginal and/or posterolateral branches (and posterior descending branch in case of left dominance), and the intermediate branch, if present. In addition, a per-vessel analysis (limited to segments without bypass graft anastomoses) was performed: RCA, LM coronary artery, LAD coronary artery, and left circumflex branch (LCX) (including intermediate branch).

Coronary arteries with occluded grafts

Obstructive coronary disease proximal to the insertion of a patent graft was not included in the analysis. However, because of the therapeutic relevance in terms of amenability to percutaneous

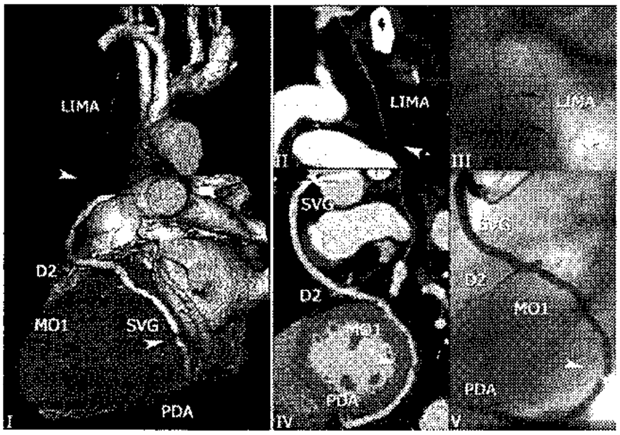

Figure 1 Arterial and venous graft disease. Volume-rendered reconstruction (I) and curved multiplanar reformations (II, IV) of a CT scan and corresponding conventional angiography (III, V), which show an occluded left internal mammary artery (LIMA, arrow in I, II, III) and obstructed vein graft (SVG). The venous graft has three coronary anastomoses (and three graft segments): second diagonal branch (D2), first marginal branch (MO1), posterior descending artery (PDA), of which the terminal segment is significantly stenosed (arrow I, IV, V). See online Supplementary material for a colour version of this figure.

intervention, patency of coronary segments proximal and distal to occluded graft insertions was assessed.

Different post-processing tools were applied to locate lesions and classify luminal narrowing of the grafts and coronary branches. Double oblique, maximum-intensity projections were useful to locate suspect segments, particularly in the absence of severe calcifications or metal (stents, vascular clips). To assess stenosis severity axial slices and interactive (double-oblique) multiplanar reformation were used.

Stenosis severity was visually estimated by comparing the luminal diameter at the narrowing with (relatively) non-diseased locations immediately proximal and/or distal to the lesion. A stenosis was classified as significant if the minimal lumen diameter appeared <50% of the expected diameter, based on the proximal and distal reference site. Subjective confidence of assessment, which could be affected by calcification, stents, vascular clips, motion artifacts, and so on was evaluated per coronary/graft segment and classified as high (without doubt), moderate, or low (insufficient image quality). Segmental coronary calcification was classified as absent, modest (isolated spots), or severe (extensive, dense, and/or circumferential calcification). Coronary arteries or grafts with stents were not excluded from evaluation.

Conventional CA

The median interval between the CT examination and CA was 7 days (0.5–18.5). Selective X-ray angiography of the coronary arteries and bypass grafts was performed according to standard techniques. An experienced cardiologist, who was unaware of the CT results, analysed the angiographic findings. Using quantitative coronary angiography (QCA) evaluation (CAAS, Pie Medical Systems, Maastricht, The Netherlands), maximum diameter stenosis was determined out of at least two (orthogonal) projections. A quantitatively determined diameter stenosis of ≥50% was considered significant.[34,35] Classification criteria for segments and lesions were identical to those used for CT.

Statistical analysis

Descriptive statistics were performed for coronary segments and main coronary branches, graft segments and entire grafts, and patients. A coronary artery or graft was considered diseased if at least one segment was significantly obstructed. The diagnostic accuracy of CT for the detection of significant disease was expressed as sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), and accuracy. Precision of the diagnostic parameters was presented using a 95% CI. Continuous variables were reported as means and SDs or median and interquartile ranges, as appropriate. Inter-observer variability for the assessment of significant coronary artery and graft obstruction was determined by κ-statistics. Comparison between different groups was calculated using Fisher's exact test. When appropriate, a Mantel–Haenszel χ^2 test was used in ordinal group comparisons. *P*-values below 0.05 were considered significant. Because of potentially interdependent observations, i.e. multiple coronary segments in the same patient, descriptive statistic parameters were performed for a random selection of single observations per patient.

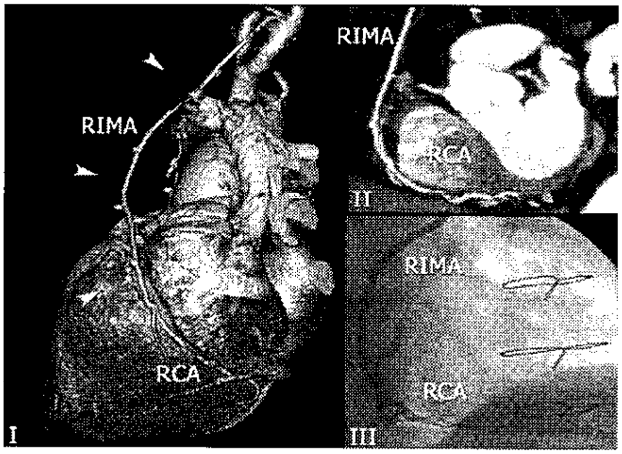

Figure 2 Patent right internal mammary artery graft. CT [volume-rendered reconstruction (I), multiplanar reconstruction (II)] and conventional angiogram (III) of a patent right internal mammary artery (RIMA, arrows) connected to the RCA without obstructive disease. See online Supplementary material for a colour version of this figure.

Results

Bypass grafts

A total of 45 arterial grafts with 57 coronary anastomoses (representing 57 arterial graft segments) and 64 venous grafts with a total of 125 graft segments were analysed. CT correctly assessed all arterial grafts and detected 14 occluded segments in 10 completely occluded grafts (*Figures 1* and 2). CT detected 41/43 occluded and 15/15 stenosed venous graft segments (*Figures 1–3*). One missed segmental occlusion belonged to a stented graft, which contained additional occluded graft segments that were correctly detected by CT. CT incorrectly considered another completely occluded segment significantly stenosed but patent. Thus, sensitivity to detect obstructive graft disease (stenosis or occlusion) per-segment and per-graft was 99 and 100%, respectively (*Table 2*). Overestimation of disease occurred in four graft segments, of which two contained stents, and resulted in misclassification of one venous graft. There was complete agreement between observers for the detection of graft disease (*Table 2*), and confidence of assessment for both arterial and venous grafts was high (89%) (*Table 3*).

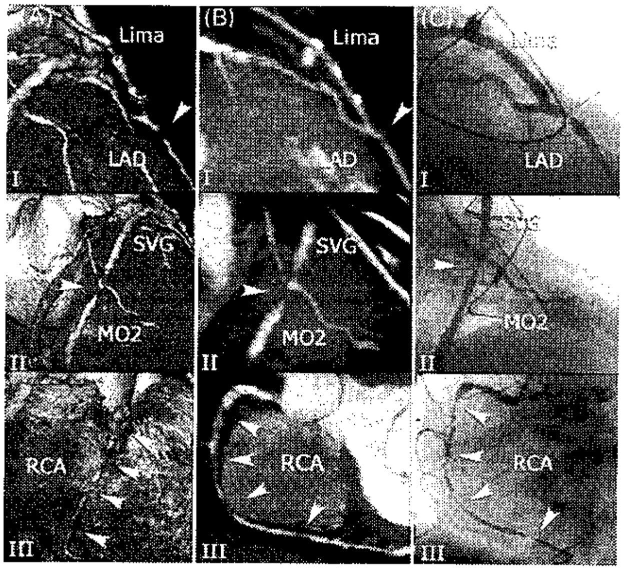

Figure 3 CABG and coronary run-off disease. CT [3D volume rendering (*A*); maximum intensity projection (*B*)] and conventional angiography (*C*), of a patent LIMA anastomosed to the LAD. Distal tot the anastomosis is a significant lesion (arrow) in the run-off branch (I). An SVG is significantly obstructed (arrow) proximal and distal to the anastomosis with a marginal branch (MO2) (II). The (bypassed) RCA is diffusely diseased with extensive calcification and several sites of significant narrowing (III, arrows). See online Supplementary material for a colour version of this figure.

Distal run-off

According to CA there were 125 patent graft segments, supplying 123 distal coronary run-offs. Of these, 92 could be assessed with good or moderate confidence (75%). Small vessel size (diameter) contributed to reduced interpretability. CT detected nearly all lesions (8/9), although overestimation of stenosis frequently occurred (*Table 2*, *Figure 3*).

Coronary arteries

A total of 116 coronary arteries (including 288 segments) were not or incompletely revascularized by bypass surgery (*Figure 4*). Significant stenosis was correctly detected in 62/64 coronary artery segments. Two undetected lesions by CT were located in vessels that contained additional lesions that were correctly detected by CT. Overestimation of stenosis severity frequently occurred resulting in a modest PPV (66%).

Severe, modest, and absent calcification was noted in 71 (25%), 100 (35%), and 117 (41%) of coronary segments. Of the 133 proximal and middle segments of the main branches [left main (LM), right, LAD, and LCX branch] severe, moderate, and absent calcification was detected in 46, 55, and 32 segments, respectively. Of the distal main and side branches (diagonal, marginal, posterolateral, and posterior descending branches) severe, moderate, and absent calcification was detected in 25, 45, and 85 segments, respectively. Severe calcification was found in LM, right, LAD, and LCX coronary territory (including side branches) in 16/42 (38%), 17/81 (21%), 14/49 (29%), and 24/116 (21%) segments, respectively. The accuracy of CT angiography for coronary segments with severe, moderate, or absent calcification was 77.5, 88, 94.9%, respectively ($P = 0.0004$). Accuracy was also significantly lower in the presence of stents: 75.0% with and 90.1% without stents ($P = 0.02$). For the detection of coronary stenosis, as well as run-off disease, accuracy was significantly lower in segments assessed with poor subjective confidence (*Table 3*).

In cases of confirmed graft occlusion by CA, patency of dependent proximal and distal coronary artery segments was evaluated. Sensitivity, specificity, PPV, and NPV for detection of occlusion per coronary segment were 83.3% (45/54), 92.2% (59/64), 90%, and 86.8%, respectively.

Per-patient graft or coronary obstruction

In 16 patients CA showed no graft disease. Disease in one, two, or three grafts was found in 25, 9, and 2 patients, respectively. The accuracy to detect or exclude any graft disease per patient was 98% (51/52) (*Table 4*). Although in 43 patients the coronary run-offs showed no significant stenosis, seven patients had disease in a single run-off, and one had double run-off disease. Accuracy per patient for the distal run-off disease was 86% (42/52). Although CT identified all 28 patients with significant stenosis in (partially) non-grafted coronary arteries, coronary obstruction was overestimated in 8/19 (42%) patients without significant disease.

Discussion

Detection of graft disease

The diameter size, relative immobility, and sparse presence of calcifications make grafts relatively approachable by non-invasive imaging techniques, such as computed tomography. Modest temporal resolution and long acquisition times restricted clinical use of earlier CT technology. Current technology with faster X-tube rotation and more, thinner detectors has resolved some of the practical limitations of CT imaging after bypass surgery. Using 16-slice CT technology (420-ms rotation time, 0.75-mm slice thickness), Schlosser *et al.*,[18] reported a sensitivity of 96% and specificity of 95% for the detection of obstructive graft disease. Martuscelli *et al.*[17] compared 16-slice CT (rotation time 500 ms, 0.625-mm slice thickness) with conventional angiography in a large population ($N = 96$), and reported a sensitivity of 97% and specificity of 100%, after exclusion of nine examinations with insufficient image quality. Preliminary results with the latest generation 64-slice CT by Pache *et al.*,[22] yielded a sensitivity of 98% and specificity of 89% for the detection of obstructed graft disease.

In the present study, the latest 64-slice CT technology demonstrated comparable, accurate assessment of grafts, without exclusion of examinations because of image quality. Artifacts caused by metal within the vicinity of the graft (vascular clips, proximal anastomosis indicators, sternal wires) occurred, but likely because of the relatively large graft diameter and fewer motion artefacts these high-density artefacts did not affect assessment accuracy. In addition to graft occlusion, CT accurately detects stenosis. In case of jump grafts, variable degrees of obstruction can be identified in consecutive graft segments, which has therapeutic consequences (*Figures 1–3*).

Table 2 Detection of significant graft and CAD

		TP	TN	FP	FN	κ	Sensitivity (%)	Specificity (%)	PPV (%)	NPV (%)
All grafts	109	49	59	1	0	0.96	100 (90.9–100)	98.3 (89.9–99.9)	98.0 (88.0–99.9)	100 (92.4–100)
Arterial grafts	45	10	35	0	0	1.0	100 (65.5–100)	100 (87.7–100)	100 (65.5–100)	100 (87.7–100)
Venous grafts	64	39	24	1	0	0.93	100 (88.8–100)	96.0 (77.7–99.8)	97.5 (85.3–99.9)	100 (82.8–100)
All graft segments	182	71	106	4	1	0.95	98.6 (91.5–99.9)	96.4 (90.4–98.8)	94.7 (86.2–98.3)	99.1 (94.2–99.9)
Arterial segments	57	14	43	0	0	1.0	100 (73.2–100)	100 (89.8–100)	100 (73.2–100)	100 (89.8–100)
Venous segments	125	57	63	4	1	0.93	98.3 (89.5–99.9)	94.0 (84.7–98.1)	93.4 (83.3–97.9)	98.4 (90.5–99.9)
Distal run-offs	123	8	106	8	1	0.92	88.8 (50.7–99.4)	93.0 (86.2–96.7)	50.0 (25.5–74.5)	99.0 (94.2–99.9)
Non-grafted native coronary arteries										
Coronary segments	288	62	192	32	2	0.86	96.9 (88.2–99.5)	85.7 (80.3–89.9)	66.0 (55.4–75.2)	99.0 (95.9–99.8)
Coronary vessels	116	42	50	24	0	0.83	100 (89.6–100)	68.4 (55.6–77.7)	63.6 (50.8–74.9)	100 (91.1–100)

True positive (TP); true negative (TN); false positive (FP); false negative (FN); interobserver variability (κ); Between brackets: 95% CI.

Table 3 Diagnostic accuracy related to subjective confidence of assessment

	Assessment confidence			*P*-value
	High	Moderate	Low	
Graft segments	161/162 (99.4%, 98.2–100%)	12/16 (75.0%, 53.8–96.2%)	4/4 (100%)	<0.001*
Arterial	46/46 (100%)	8/8 (100%)	3/3 (100%)	–
Venous	115/116 (99.1%, 97.4–100%)	4/8 (50.0%, 15.4–84.6%)	1/1 (100%)	<0.001*
Distal coronary run-off	30/30 (100%)	59/62 (95.2%, 89.9–100%)	25/31 (80.6%, 66.7–94.5%)	0.01*
Coronary segments	58/63 (92.1%, 85.4–98.8%)	117/126 (92.9%, 88.4–97.4%)	79/99 (79.8%, 71.9–87.7%)	<0.01

Accuracy in absolute numbers (percentage, 95% CI). Mantel–Haenzel χ^2 test.
*Fisher's exact test in case of insufficient group size.

Detection of coronary artery and run-off disease

For complete angiographic evaluation of symptomatic post-CABG patients, both coronary arteries and grafts need to be assessed. Assessment of non-grafted coronary artery segments yielded a sensitivity and specificity of 97% and 86%, respectively. CT detected most lesions in the distal coronary run-offs, although overestimation of stenosis severity frequently occurred in these small coronary branches. Most publications on the diagnostic accuracy of 64-slice CT angiography in patients without previous coronary bypass surgery reported superior sensitivity and specificity.[29-32] This discrepancy between the accuracy of CT in non- and post-CABG patients was previously described with 4- and 16-slice CT, and appears maintained with current state-of-the-art CT technology.[16,20] Post-surgical patients are generally older and have more advanced atherosclerotic disease. Diffuse degeneration prevents distinction between non-obstructive vessel changes and significant coronary narrowing. Contrary to the assessment of CABG, inaccurate assessment of coronary stenosis occurred significantly more frequently in vessels with stents or severe calcification.

Forty percent of patients underwent PCI before or after bypass surgery. Artifacts related to blooming and beam hardening in the vicinity of stent struts significantly affected assessment of stented coronary arteries.

In case of graft failure, the difference between stenosis and complete occlusion of the native coronary artery affects interventional options for treatment. We found that CT could exclude occlusion in the majority of previously surgically revascularized coronary arteries.

Limitations of the study

Conventional CA is still the gold standard in the evaluation of both coronary artery and graft status, but its use is restricted by the invasive nature of the procedure. CT angiography lacks some of the practical disadvantages, such as the requirement for selective contrast injection. Particularly when the exact surgical history is incomplete, CT allows comprehensive graft visualization, including the site and identity of distal run-offs. Therefore, CT graft imaging is increasingly used prior to planned invasive angiography, to assure optimal angiography of both coronary arteries and grafts. Despite advantages in terms of safety, comfort, and cost, CT angiography is not without risk. It involves considerable exposure to Roentgen radiation, recently reported to be 14.8 ± 1.8 mSv without and 9.4 ± 1.0 mSv with ECG-triggered tube output modulation, i.e. lowering tube output during the systole.[36] Compared with an average coronary CT, the scan range was extended by 37% (10–65% depending on whether venous and/or arterial grafts were investigated), which will result in a proportionally higher radiation dose. Currently CT angiography cannot be performed without use of potentially nephrotoxic contrast media. Finally, pharmacological heart rate modulation is still recommended to avoid motion artifacts, though may become obsolete with the development of faster scanner technology.

Because our population consisted of symptomatic patients long after surgery with a high incidence of graft and/or CAD, our results may not be applicable to a lower-risk (non-symptomatic) population. Graft occlusion may occur

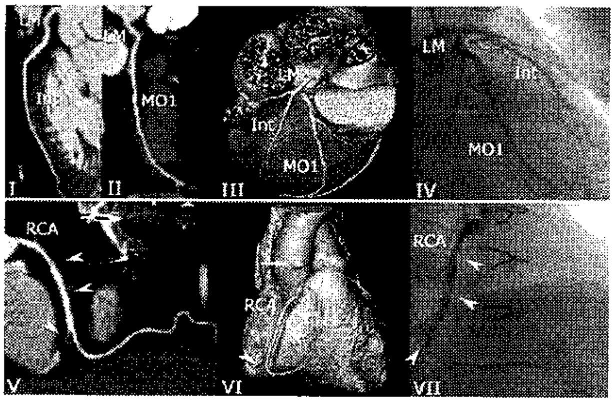

Figure 4 Non-grafted coronary arteries. Patient with an occluded vein graft to the distal RCA (arrow, VI), and occluded arterial graft to the LAD coronary artery. The proximal and mid-segment of the RCA shows plaque without significant narrowing (arrow heads), and the distal RCA is completely occluded. (V–VII). The LM coronary artery (LM), intermediate branch (Int), and MO1 are all without significant disease (I–III). See online Supplementary material for a colour version of this figure.

Table 4 Diagnostic performance of CTA per patient

	TP	TN	FP	FN	Accuracy (95% CI)*
Any graft disease	36	15	1	0	98.1% (94.4–100%)
Any distal run-off disease	7	38	6	1	86.5% (77.2–95.8%)
Any non-grafted coronary disease	28	11	8	0	83.0% (72.3–93.7%)
Any obstructive coronary/graft disease	50	1	1	0	98.1% (94.4–100%)

True positive (TP); true negative (TN); false positive (FP); false negative (FN). Accuracy: (TP + TN)/(TP + TN + FP + FN).

without ischaemic consequences in case of competitive flow or in the presence of non-vital myocardial scar tissue. Particularly in these patients with chronic coronary insufficiency it may not be possible to determine the need for revascularization based on angiographic assessment alone.

Observations (segments) within the same patient are not statistically independent (nesting). We recalculated descriptive statistic parameters in randomly selected, single observations per patient. Accuracy (95% CI) for detection of significant stenosis was 100% for arterial grafts, 96% (90–100%) for venous grafts, 94% (88–100%) for run-offs, and 87% (78–97%) for coronary artery segments. Fewer observations resulted in wider confidence intervals.

Conclusion

The 64-slice MSCT allows accurate detection and detailed imaging of obstructive graft disease, and may be of particular practical use when knowledge about previous surgery is incomplete. Complete angiographic evaluation of post-CABG patients includes assessment of the coronary arteries, which is challenging in the presence of calcium and stents. Nevertheless, the high NPV, CT may be clinically useful for exclusion of significant stenosis in the distal run-offs and (non-grafted) coronary branches, in addition to the evaluation of the CABG.

Supplementary material

Supplementary material is available at *European Heart Journal* online.

Conflict of interest: none declared.

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