Diagnostic Performance of Multi-slice Computed Tomography in evaluation of coronary artery bypass grafts

Islam Shawky, Ahmed Yehia, Shady Mansy, MostafaIsmaeil, A-Rahman Sharaf and M. Salim Elbaz.

Cardiology Department, Faculty of Medicine, Al-Azhar University.

Abstract: **Background**. Assessment of bypass grafts body and their anastomotic sites by invasive coronary angiography have a risk of potentially life-threatening complications and often require extra procedure time, contrast load, and radiation exposure. Cardiac CT angiography (CTA) is most frequently performed to assess the presence of coronary artery disease (CAD) and to exclude significant stenosis. The modality shows excellent sensitivity and negative predictive value in patient with low-to-intermediate pretest probability for CAD.[1]We sought that dual-source multi-slice computed tomography (MSCT) angiography will have an excellent role in the assessment of graft patency and degree of stenosis in patients after coronary artery bypass grafting (CABG). **Objective**: The objective of the study is assess the diagnostic accuracy of dual source 64-slice multidetector computed tomography (MDCT) in diagnosis and assessment of severity of stenosis of aortocoronary bypass grafts. **Patients and Methods.** A 64-dual-source MSCT was performed to 51, 49 men and 2 women and their age ranges from 38 to 76 years with a mean of 58.6 ± 8 years. All the patients were symptomatic patients with previous CABG surgery. The time interval between the surgery and enrollment in the study ranged from 3 to 252 months with a mean of 73.41 ±65.84 months.The patients underwent MSCT coronary angiography followed by invasive coronary angiography within four weeks without any coronary attack between the two studies. Heart rate control was done with oral beta blockers. Sublingual nitrates was given 2-3 min before the scan. A total of 142 graft body and 142 anastomotic sites were analyzed by two independent blinded observers. Six grafts were excluded because they were non-evaluable by MSCT. **Results.** MSCT identified non-significant stenosis in 94 grafts body, 103 anastomotic site (total = 197) and significant stenosis in 48 grafts body and 39 anastomotic site (total = 87). ICA identified non-significant stenosis in 92 grafts body, 100 anastomotic site (total = 192) and significant stenosis in 50 grafts body and 42 anastomotic sit (total = 92).There is no statistical significant difference between MSCT and ICA for detection of stenosis and assessment of its severity (P = NS). Thus the MSCT is sensitive (sensitivity = 94.57%) and specific (specificity = 97.52%) for diagnosis and assessment of the severity of stenosis of coronary artery bypass grafts (body and anastomotic site) with a positive predictive value of 94.57%, negative predictive value of 97.52%, and diagnostic accuracy of 96.60%. **Conclusion.** Noninvasive MSCT angiography is an excellent tool for evaluating patency or degree stenosis of bypass grafts body and their anastomotic sites in post-CABG patients.

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1. Introduction

Cardiac CT angiography (CTA) is most frequently performed to assess the presence of coronary artery disease (CAD) and to exclude significant stenosis. The modality shows excellent sensitivity and negative predictive value in patient with low-to-intermediate pretest probability for CAD.[1] Gated cardiac CT offers the ability to obtain cine functional images for assessment of global left ventricular (LV) function and detection of regional wall motion abnormalities (RWMAs), myocardial perfusion images for detection of perfusion defects and delayed contract enhancement (DCE) images for detection of delayed hyper-enhancement. Moreover, CT has long offered the ability to detect signs of remote myocardial infarction (such as wall thinning, fatty metaplasia and myocardial calcifications).[1]

Conventional coronary angiography (CCA) is currently the reference standard technique for evaluation of status of native coronary arteries and coronary artery bypass grafts. CCA, however, is expensive and has a small risk of potentially life-threatening complications, including arrhythmia, stroke, coronary artery or graft dissection, embolic events, and myocardial infarction; the morbidity rate is 0% to 2%, and the mortality rate is 0.14% to 0.28%. Therefore, a reliable, noninvasive imaging modality is preferable for evaluation of patients suspected of having graft stenosis or occlusion.[2] Noninvasive computed tomography angiography (CTA) may be useful for reducing the additional invasive procedure time and contrast load if it was proven to be reliable for evaluating bypass grafts and distal runoffs before invasive coronary angiography (ICA).[3]

Recurrent symptoms after surgical revascularization may be caused by progression of disease in the native coronary arteries, the venous, or more rarely in the arterial grafts.[4]The overall incidence

of graft occlusion within 5 years after surgery is 25%. Although arterial grafts usually remain free of progression of atherosclerotic disease, venous bypass grafts usually develop a stenotic and finally occlusive disease over time, which might result in myocardial ischemia.[5]

Newer generation CT scanners may improve CT reliability. The dual-source 64-slice CT scanner is equipped with 2 tube-detector systems rotating simultaneously, resulting in an improved temporal resolution of 83 ms. Comparative studies demonstrated a high diagnostic performance of dual-source CT coronary angiography to detect significant obstructive coronary artery disease in patients without previous bypass surgery.[3] We hypothesized that dual source CTA allows more accurate detection or exclusion of significant stenoses, in particular, at the graft anastomosis which could be comparable to CCA.

Objective

The objective of the study is assess the diagnostic accuracy of dual source 64-slice multidetector computed tomography (MDCT) in diagnosis and assessment of severity of stenosis of aortocoronary bypass grafts.

2.Methods

Study population

Fifty one patients with history of coronary artery bypass grafting were included in our study. The study was performed at Dar Alfouad hospital, from October 2010 to September 2012. All patients, regardless the results of CTA, underwent invasive coronary angiography (ICA) within 4 weeks after CTA without coronary attack between the two studies.

Exclusion criteria:

Patients having any of the following criteria were excluded from the study:

1. Serum creatinine > 1.5mg/dl.
2. Allergy to iodinated contrast material.
3. Patient with uncontrolled tachycardia, atrial fibrillation or frequent arrhythmia.
4. Patient unable to hold breath for 10-15 seconds.

Multi-slice computed tomography coronary angiography

Patient preparation for CTA:

1. All the patients were subjected for full history taking including history of cardiovascular risk factors (hypertension, diabetes mellitus, dyslipidemia, smoking, family history for CAD), history of bronchial asthma, history of allergy, and full drug history.
2. Full clinical examination was carried out. The resting heart rate and resting blood pressure were recorded. Chest examination was done to rule out patients with reactive airways disease. Cardiac examination was done to rule out patients with heart failure or arrhythmias.
3. The patient's lab investigations were reviewed to make sure that a recent serum creatinine is not more than 1.5 mg/dl.
4. All the patients were instructed to remain fasting for about 4 hours before doing the scan.
5. Heart rate < 70 bpm was achieved before the scan using different doses of beta blockers according to the resting heart rate and resting blood pressure. With heart rate 70-80 bpm the patient was given 50mg atenolol orally, one hour before the procedure. With heart rate > 80 bpm the patient was given 100mg atenolol orally, one hour before the procedure, provided that the blood pressure is sustained. A second dose of atenolol was given one hour after the initial one if the heart rate was not satisfactory. Patients with a resting heart rate less than 65 bpm didn't receive any beta blockers.

CTA procedure:

1. After controlling the heart rate, the patient was transferred to the scanning room and the full procedure was then explained to the patient, breathing exercise was done to make sure the patient can hold his breath adequately.
2. ECG electrodes were placed to connect the patient to continuous ECG monitoring.
3. An intravenous (IV) access was secured with 18 G cannula. The access sites were the right antecubetal vein (to avoid artifacts due to high-concentration contrast medium at the site of the left internal mammary artery take-off), left antecubetal vein and then other sites, in order of preference. This was followed by injection of small amount (5-10cc) normal saline to make sure of the patency of the line and to make sure there was no extravasation. The IV line was then connected to the dual head injector.
4. The patient was then given a tablet of 5 mg isosorbidedinitrate sublingually, 2-3 minutes before the scanning.
5. When the patient was ready and after doing breathing exercise (and observing the heart rate response to the breath hold), the scan procedure was started.

CT scan protocol:

All patients were scanned using a dual-source CT scanner (Somatom Definition, Siemens Healthcare, Forchheim, Germany). The system is equipped with 2 X-ray tubes and 2 corresponding detectors mounted on a single gantry with an angular offset of 90°. The CT angiography scan parameters were as follows: number of X-ray sources 2, detector collimation 32x0.6 mm with double sampling by rapid alteration of the focal spot in the longitudinal direction (Z-flying focal spot), rotation time 330 ms, tube voltage 120 kV. The pitch varied between 0.2 for low heart rates (40-50

beats/min) and 0.33 for higher heart rates (70-80 beats/min). Automatic tube current modulation and adaptive electrocardiography (ECG) pulsing (full tube current during 30% to 80% of the RR interval, reduced tube current: 20% of maximum) was applied in all patients.

The scan was carried out according to following steps:

1. Acquisition of a conventional chest topogram. **(Figs 1 and 2)**
2. The test bolus consists of 10–12 ml of iodine-based contrast medium, followed by 50-ml saline flush (injection rate: 5-5.5 ml/s). Radiation exposure is minimized by starting the scan 10–14 second after injection and stopping acquisition once the contrast medium peak has been reached. A dedicated software tool, DynEva, is available for automatic analysis of the test bolus series. The time to start scan after contrast injection was calculated from the test bolus. **(Fig 3)**

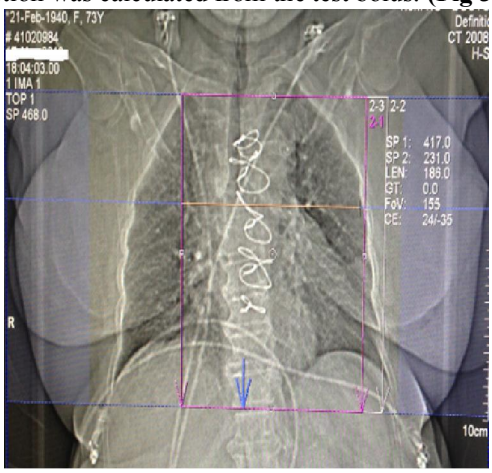

Figure 1: The first step is the acquisition of a chest topogram (scanogram), typically acquired from top to bottom. To minimize the scan area, the acquisition can be stopped as soon as the entire heart has been scanned

3. The scan delay (the time interval between the start of the test bolus injection and image acquisition) is the individual test bolus time plus an additional 2-4 s. The additional 2-4 s delay time is needed to obtain optimal arterial contrast in the ascending aorta and the coronary arteries on one hand and low contrast in the right ventricle and the right atrium on the other, in order to avoid inflow artifacts that may hamper the evaluation of the right coronary artery as well as its graft. To minimize the inferior extension of the scan field, scanning can be manually discontinued as soon as the real-time images showed the entire heart.
4. Then 90-100 ml of a non ioniciso-osmolar iodine contrast was then injected through the IV line using the dual head injector, followed by a 50 ml of saline chaser. The injection rate was set at 5-5.5 ml/sec for both the contrast and the saline.
5. The contrast enhanced cardiac scan used was a helical retrospectively ECG gated scan.

Image reconstruction:

1. The first step in image reconstruction is to check the recorded ECG. If there are isolated extrasystoles, the corresponding reconstruction intervals can be deactivated or deleted for image reconstruction (Perform ECG editing if necessary). **(Fig. 4)**

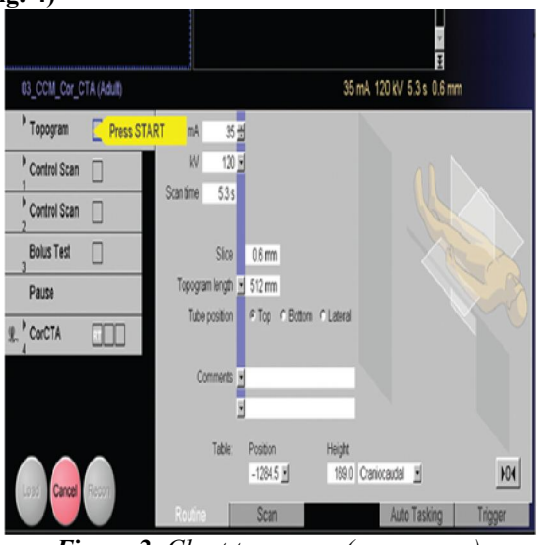

Figure 2: *Chest topogram (scanogram)*

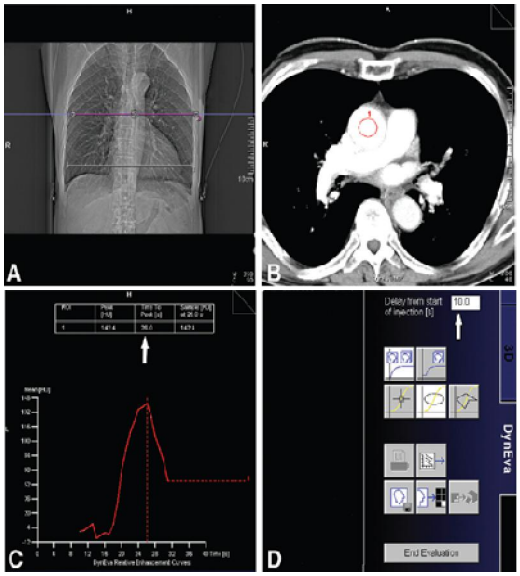

Figure 3: Bolus test scan: It is started 10–14 second after the beginning of the contrast medium injection. The test bolus series can be analyzed visually or with the DynEva software (**Panel B–D**). A region of interest (ROI) is defined in the ascending aorta for analysis (**Panel B**). The time to peak can be read in a table (arrow in **Panel C**) after entering the delay used for image acquisition (arrow in **Panel D**)

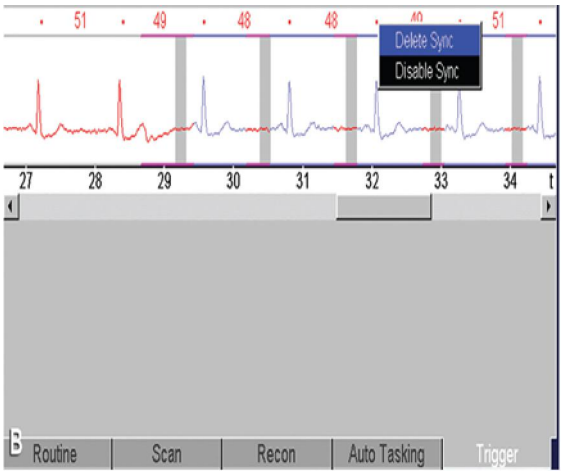

Figure 4: The first step in image reconstruction, the ECG signal recorded during scanning is checked in the triggercard. If isolated extrasystoles are present, the corresponding reconstruction intervals can be deactivated or deleted

2. Reconstruction can be done throughout the cardiac cycle at 10% intervals, resulting in 10 phases. Most of the suitable reconstruction phases (intervals) within the cardiac cycles are mid-diastolic phases and end-systolic phases. Reconstruction of several phases throughout the RR interval has the advantage that the resulting data can be used for high-resolution analysis of regional and global cardiac function without having to perform any additional reconstructions.

3. Heart rate is crucial in determining the position of the minimal cardiac motion phase that is most suitable for reconstruction. In patients with higher heart rates, end-systolic phases (e.g., 30–40%) are often superior todiastolic phases in terms of image quality. Selection of the reconstruction phase has considerable influence on the diagnostic accuracy of coronary CT angiography.

4. The datasets were reconstructed at a slice thickness of 0.6-0.75 mm with 0.4-0.5 mm increments.

5. Axial images, multi-planar reformation (MPR), curved MPR and MIP (maximum intensity projection) were used to identify and to calssify lesions, at coronary bypass grafts into mild, moderate, and severe.

6. Volume–rendering technique (VRT) images were initially used to visualize the course of the grafts in relation to the coronary arteries.

7. Reconstruction is usually done using a soft tissue reconstruction algorithm (B26f), while a sharper kernel (B46f) may be used to improve the evaluation of graft segments with calcified plaques, stents or multiple surgical clips.

8. All graft segments between the proximal anastomoses and each coronary insertion were evaluated. A semi-quantitative (visual) assessment of the graft stenosis severity was done according to the recommendation of the Society of Cardiovascular Computed Tomography (SCCT) as the following:[6]

1. Normal: Absence of plaque and no luminal stenosis.
2. Mild: Plaque with < 39% stenosis.
3. Moderate: 40% – 69% stenosis.
4. Severe: 70% – 99% stenosis.
5. Occluded.

9. Scans were analyzed by two observers unaware of the clinical data. If there was a disagreement related to the severity of stenosis of a certain coronary segment, a third opinion was taken to reach a final agreement.

Invasive coronary angiography (ICA)

1. ICA which is the standard of reference for the diagnosis and assessment of the severity of coronary artery stenosis was carried out for both native coronary arteries and bypass grafts. It was carried out through the standard trans-femoral approach and was evaluated by an observer blind to the MSCT results. Lesions with >50% lumen diameter reduction in 2 orthogonal planes were considered as significant stenosis.

2. Selective cannulation of bypass grafts may be more challenging than cannulation of the native coronary arteries because the locations of graft ostia are more variable, even when surgical clips or ostia markers are used. The number, course, and type of bypass graftsobtained from the operative report are valuable for the identification of the location of the bypass grafts during ICA.

3. The left internal mammary artery (LIMA) arises inferiorly from the left subclavian artery approximately 10 cm from its origin. Catheterization of the LIMA is performed with a specially designed J-tip IMA catheter.

4. Saphenous vein grafts (SVGs) from the aorta to the distal RCA or PDA originate from the right anterolateral aspect of the aorta approximately 5 cm superior to the sinotubular ridge. SVGs to the LAD artery (or diagonal branches) originate from the anterior portion of the aorta about 7 cm superior to the sinotubular ridge. SVGs to the obtuse marginal branches arise from the left anterolateral aspect of the aorta 9 to 10 cm superior to the sinotubular ridge. In most patients, all SVGs can be engaged with a single catheter, such as a Judkins right 4.0 or a modified Amplatz right 1 or 2.

3.Results

Study Population

Fifty-one patients, forty-nine men (96%) and two women (4%) were enrolled in the study. Their age ranged from 38 to 76 years, with a mean ± SD of 58.5 ± 8 and a median of 59 years.

Twenty-nine of these patients (56.9%) were smokers, twenty-eight (54.9%) were diabetics, twenty-one (41.2%) were hypertensive, nine (17.6%) were dyslipidemic, and twenty-four patients (47.1%) had positive family history of CAD (Table 1).

*Table 1:*The prevalence of different cardiovascular risk factors among the studied population.

Risk factors		**No**	**%**
Gender	Male	49	96.1%
	Female	2	3.9%
DM	Yes	28	54.9%
	No	23	45.1%
HTN	Yes	21	41.2%
	No	30	58.8%
DLP	Yes	9	17.6%
	No	42	82.4%
Smoking	Yes	29	56.9%
	No	22	43.1%
FH	Yes	24	47.1%
	No	27	52.9%

All the patients were symptomatic patients with previous CABG surgery. The time intervalbetween the surgery and enrollment in the study ranged from 3 to 252 months with a mean of 73.41 ± 65.84 months.

All the patients underwent MSCT coronary angiography followed by invasive coronary angiography within four weeks without any coronary attack between the two studies.

The fifty-one patients have 148 grafts. Six grafts were excluded as cannot be evaluated by the MSCT because of the surgical clips. So, only 142 grafts were subjected to the study. The 142 grafts enrolled in the study include 56 (39.43%) arterial (48 LIMA, 3 RIMA, 5 radial) and 86 (60.57%) were venous. Each graft was studied regarding two points of interest; the graft body and the distal anastomotic site. Thus we studied 142 graft bodies and 142 distal anastomotic sites (Figure 5).

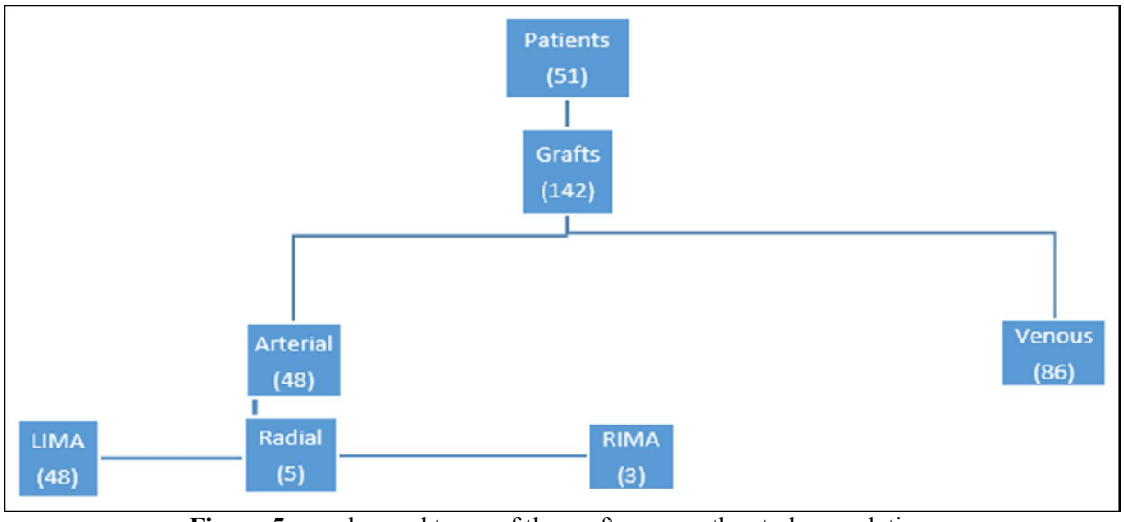

Figure 5: number and types of the grafts among the study population

MSCT coronary angiographic findings

The MSCT coronary angiographic findings of the studied 142 graft bodies and 142 anastomotic sites regarding the patency, occlusion, and degree of stenosis are presented in table 2.

Invasive coronary angiographic findings

The invasive coronary angiographic findings of the studied 142 graft bodies and 142 anastomotic sites regarding the patency, occlusion, and degree of stenosis are presented in table 3.

Table 2: MSCT findings

			Occluded	Mild	Moderate	Severe	Patent	Total
BODY	LIMA	N	10	8	0	0	30	48
		%	7.04	5.63	0.00	0.00	21.13	33.80
	RIMA	N	0	1	0	0	2	3
		%	0.00	0.70	0.00	0.00	1.41	2.11
	RADIAL	N	0	1	0	0	4	5
		%	0.00	0.70	0.00	0.00	2.82	3.52
	SVG	N	24	26	4	14	18	86
		%	16.90	18.31	2.82	9.86	12.68	60.57
	Total	N	34	36	6	14	52	142
		%	23.94	25.35	4.23	9.86	36.62	100.00
Anastomosis	LIMA	N	10	2	0	2	34	48
		%	7.04	1.41	0.00	1.41	23.94	33.80
	RIMA	N	0	0	0	0	3	3
		%	0.00	0.00	0.00	0.00	2.11	2.11
	RADIAL	N	0	0	0	0	5	5
		%	0.00	0.00	0.00	0.00	3.52	3.52
	SVG1	N	24	2	0	3	57	86
		%	16.90	1.41	0.00	2.11	40.14	60.57
	Total	N	34	4	0	5	99	142
		%	23.94	2.82	0.00	3.52	69.72	100.00

Comparison between ICA and MSCT findings

1. ***Total occlusion:***

MSCT detected 34 (23.94%) totally occluded grafts (10 arterial grafts and 24 venous grafts) and 108(76.06%) patent grafts. These findings were the same detected by ICA. Thus the sensitivity, specificity, and diagnostic accuracy of MSCT for detection of total graft occlusion is 100%.

2. ***Graft stenosis:***

1. ***Graft bodies:***

Out of the 142 studied graft bodies, the ICA showed that there are 92 (64.8%) non-significant stenoses and 50 (35.2%) significant stenoses. The MSCT showed that there are 94 (66.20%) non-significant stenoses and 48 (33.8%) significant stenoses (Figure 6). There is no statically significant difference between MSCT and ICA for diagnosis and assessment of the severity of stenosis of graft body (*P*-value = 1).

Thus the MSCT is highly sensitive (sensitivity = 96%) and specific (specificity = 97.87%) for diagnosis and assessment of the severity of stenosis of graft body with a positive predictive value of 96%, negative predictive value of 97.87%, and diagnostic accuracy of 97.22% (Table 4).

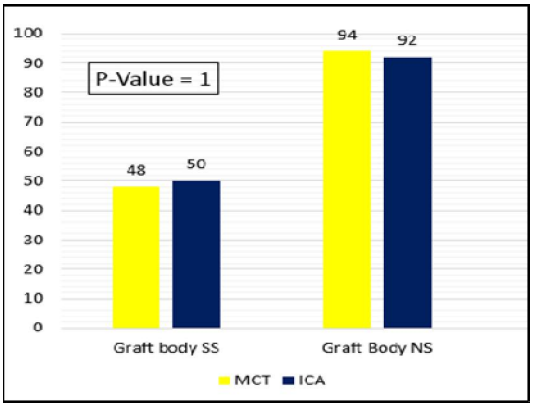

Figure 6: comparison between MSCT and ICA regarding detection and assessment of severity of the graft body stenosis

2. ***Anastomotic sites:***

Out of the 142 studied anastomotic sites, the ICA showed that there are 100 (70.43%) non-significant stenoses and 42 (29.58%) significant stenoses. The MSCT showed that there are 103 (72.54%) non-significant stenoses and 39 (27.46%) significant stenoses (Figure 7). There is no statically significant difference between MSCT and ICA for diagnosis and assessment of the severity of stenosis of anastomotic site (*P*-value =1).

Table 3: ICA findings

			Occluded	Mild	Moderate	Severe	Patent	Total
BODY	LIMA	N	10	8	0	0	30	48
		%	7.04	5.63	0.00	0.00	21.13	33.80
	RIMA	N	0	1	0	0	2	3
		%	0.00	0.70	0.00	0.00	1.41	2.11
	RADIAL	N	0	0	0	0	5	5
		%	0.00	0.00	0.00	0.00	3.52	3.52
	SVG	N	24	27	2	16	17	86
		%	16.90	19.01	1.41	10.56	11.97	60.57
	Total	N	34	36	2	16	54	142
		%	23.94	25.35	1.41	11.27	38.03	100.00
Anastomosis	LIMA	N	10	0	0	2	36	48
		%	7.04	0.00	0.00	1.41	25.35	33.80
	RIMA	N	0	0	0	1	2	3
		%	0.00	0.00	0.00	0.70	1.41	2.11
	RADIAL	N	0	0	0	0	5	5
		%	0.00	0.00	0.00	0.00	3.52	3.52
	SVG1	N	24	0	0	5	57	86
		%	16.90	0.00	0.00	3.52	40.14	60.57
	Total	N	34	0	0	8	100	142
		%	23.94	0.00	0.00	5.63	70.43	100.00

Table 4: Sensitivity, specificity, positive predictive value, negative predictive value,and diagnostic accuracy of MSCT for assessment of graft body in reference to ICA. Negative = non-significant stenosis and positive = significant stenosis

Group	MSCT		ICA		
			Negative	Positive	Total
BODY	Negative	N	92	2	94
		%	63.4	1.4	64.8
	Positive	N	0	48	48
		%	1.4	33.8	33.8
	Total	N	92	50	142
		%	64.8	35.2	100.00
	Sens.	Spec.	PPV	NPV	Accuracy
	96	97.87	96	97.87	97.22

Thus the MSCT is highly sensitive (sensitivity = 92.86%) and specific (specificity = 97.09%) for diagnosis and assessment of the severity of stenosis of anastomotic site with a positive predictive value of 92.86%, negative predictive value of 97.09%, and diagnostic accuracy of 95.96% (table 5).

The sensitivity, specificity, and diagnostic accuracy of the MSCT for detection of significant and non-significant stenosis were higher for the graft body (96%, 97.87%, 97.22% respectively) than the graft anastomotic site (92%, 97.09 %, 95.96% respectively), however it was statistically non-significant (P = 0.48).

3. ***All graft segments:***

Regarding the 284 assessed graft segments (142 graft body and 142 anastomotic site), the MSCT showed 197 (69.37%) non-significant stenoses and 87 (30.63%) significant stenoses while the ICA showed 192 (67.61%) non-significant stenoses and 92 (32.39%) significant stenoses (Figure 8). There is no statically significant difference between MSCT and ICA for diagnosis and assessment of the severity of stenosis of coronary artery bypass grafts (*P*-value =1).

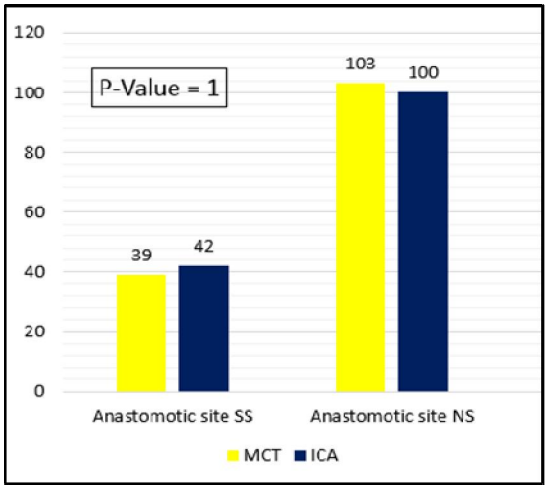

Figure 7: comparison between MSCT and ICA regarding detection and assessment of severity of the graft anastomotic site

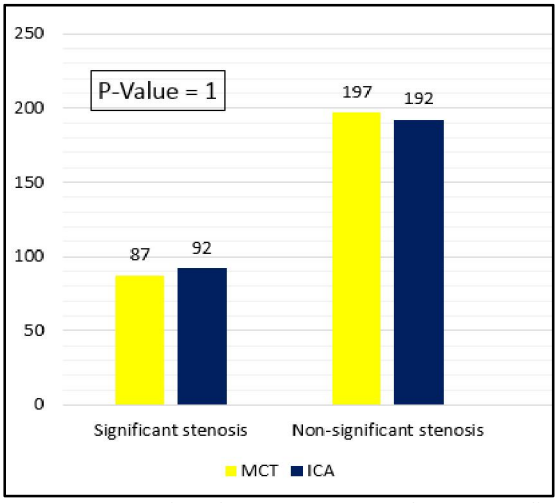

Figure 8: comparison between MSCT and ICA regarding detection and assessment of severity of the aortocoronary bypass grafts

Table 5: Sensitivity, specificity, positive predictive value, negative predictive value,and diagnostic accuracy of MSCT for assessment of anastomotic site in reference to ICA. Negative = non-significant stenosis and positive = significant stenosis

Group	MDCT		ICA		
			Negative	Positive	Total
Anastomosis	Negative	N	100	3	103
		%	69.7	2.8	72.5
	Positive	N	0	39	39
		%	0.00	27.5	27.5
	Total	N	100	42	142
		%	71.74	28.26	100.00
	Sens.	Spec.	PPV	NPV	Accuracy
	92.86	97.09	92.86	97.09	95.96

Thus the MSCT is highly sensitive (sensitivity = 94.57%) and specific (specificity = 97.52%) for diagnosis and assessment of the severity of stenosis of coronary artery bypass grafts with a positive predictive value of 94.57%, negative predictive value of 97.52%, and diagnostic accuracy of 96.60% (table 6).

Table 6: Sensitivity, specificity, positive predictive value, negative predictive value,and diagnostic accuracy of MSCT for assessment of coronary artery bypass grafts in reference to ICA. Negative = non-significant stenosis and positive = significant stenosis

MSCT		ICA		
		Positive	Negative	Total
Positive	N	87	0	87
	%	30.63	0.00	30.63
Negative	N	5	192	197
	%	1.76	67.61	69.37
Total	N	92	192	284
	%	32.39	67.61	100.00
Sens.	Spec.	PPV	NPV	Accuracy
94.57%	97.52%	94.57%	97.52%	96.60%

4.Discussion

The diagnostic work-up of patients with recurrent angina after CABG remains challenging and should include complete assessment of bypass grafts and native coronary arteries. Noninvasive 64-slice CTA demonstrated a very high diagnostic

performance for the detection of obstructive graft disease, with sensitivities of 100% for occluded grafts and sensitivities ranging from 80% to 100% for the detection of significant stenosis.[7]

The 64-slice dual-source CT scanner allows acquisition of images during a shorter time window (83 ms) of the heart cycle, resulting in images with less residual coronary motion and more precise delineation of stenoses, in particular at the graft distal anastomosis site and smaller distal runoffs. In addition, fast scanning of the whole thorax can be performed in short manageable breath holds (10 to 15 s), which is, in particular, important in the assessment of arterial grafts.[3]

In selected patients, CT and particularly MDCT have shown high diagnostic precision in the evaluation of aortocoronary grafts, with values even higher than those recorded for detection of lesions in native coronary vessels. This high performance is mainly attributable to the fact that grafts are less mobile and relatively large (especially true for venous grafts). Nonetheless, there remains some difficulty related to the presence of metal clips in arterial grafts, which are also smaller in size. To determine the utility of MDCT in these patients, however, an evaluation of the native coronary vessels is also needed, and in this case, the task is more difficult due to the poor quality of these vessels in patients with advanced atherosclerosis.[8]

In the present study fifty-one symptomatic post-CABG patents were evaluated by 64-MDCT angiography followed by ICA within 4 weeks. After exclusion of six grafts (non-evaluable because of surgical clips), the fifty-one patients have 142 grafts.

In our study the MDCT angiography was comparable to the ICA for assessing graft patency with 100% sensitivity, specificity, and diagnostic accuracy.

The same results have been reported by ***Dikkers*** *et al.*[9] as they found that the sensitivity, specificity, and diagnostic accuracy of 64-MDCT angiography were 100% in 34 post-CABG patients scanned on a 64-MDCT prior to ICA.

In ***Tobias*** *et al.*[10] study the 64-MDCT angiography had 97.9% sensitivity, 100% specificity, and 98.5% diagnostic accuracy. Tobias et al. did not control HR before the procedure and 25% of the cases had irregular HR and this could explain the lower rates they achieved.

We found that the diagnostic accuracy for detection of significant and non-significant grafts stenosis was 96.60%**.** The MDCT successfully identified 94 non-significant stenoses and 48 significant stenoses of 142 grafts body in comparison to 92 non-significant stenoses and 50 significant stenoses detected by ICA. Also MDCT identified 103 non-significant stenoses and 39 significant stenoses of142 grafts anastomotic sitein comparison to 100 non-significant stenoses and 42 significant stenoses detected by ICA. Thus the sensitivity, specificity, positive predictive value, and negative predictive value for detection aortocoronary bypass graft stenosis and assessment of its severity were 94.57%, 97.52%, 94.57% and 97.52 % respectively. There was no any statistically significant difference between MDCT and ICA for detection of significant and non-significant stenosis per graft segment (P = 1).

The results of ***Dikkers*** *et al.*[9] were nearly comparable to our results. The sensitivity, specificity, and diagnostic accuracy of 64-MDCT for detection of graft stenosis were 100%, 98.7%, and 98.7% respectively.

Also ***Weustink***et al.[3] studied 52 post-CABG symptomatic patients with MDCT and ICA. The diagnostic accuracy of MDCT for detection of significant stenosis in arterial and venous grafts was 100%. Sensitivity, specificity, positive predictive value, and negative predictive value to detect significant stenosis were 95%, 100%, 100%, and 99% respectively. In this study they diagnose significant stenosis as ≥50% luminal narrowing which is not matching our consideration for diagnosis of significant stenosis (≥70 luminal narrowing).

Laynez-Carnicero *et al.*[8] investigated the diagnostic Performance of 64-detector CT for Noninvasive Assessment of Aorto-coronary grafts in detection of significant stenosis. The study included 36 patients, 103 grafts (49 arterial and 54 venous). The overall diagnostic accuracy of arterial and venous grafts was 97.9%, which is in close relation to our diagnostic accuracy (99.28%). The sensitivity, specificity, positive predictive value and negative predictive value were100%, 96.9%, 93.8% and 100% respectively. The only difference between our study and ***Laynez-Carnicero*** *et al.* study is that we had six non-evaluable segments because of surgical clips, but in ***Laynez-Carnicero*** *et al.* the all grafts segments was evaluable with no surgical clips affection for assessment of the lumen patency. We think that this difference mostly, is not related to defect in data acquisition or interpretation but related to the CABG operation technique (surgical clips positioning).

Study limitations

1. The general limitations of cardiac CT include the radiation exposure, use of potentially nephrotoxic contrast agent and exclusion of patients with irregular heart rate.
2. In addition, only a semi-quantitative (visual) study of the lesions was carried out, because there are currently no precise tools to perform a quantitative evaluation in the specific case of MDCT.

3. The radiation exposure was not routinely calculated in the study.

4. Difficulties in the evaluation of graft segments with metal clips encroachment (especially at the anastomotic site), remain a drawback in the CT evaluation of patients after bypass surgery and these artifacts are often aggravated by motion. In our study we had six non-evaluable segments (two grafts body and four anastomotic sites) because of surgical clips.

5. The relatively small number of patients included in the study.

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