Original article

64 slice computed tomography—a novel diagnostic method for evaluation of patients after coronary artery bypass grafts

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KEYWORDS

Coronary angiogram
Coronary artery bypass grafting
64 slice computed tomography

ABSTRACT

Objective: Multislice computed tomography (CT) is widely used in analysing the native coronary arteries. The usefulness of 64 slice CT in patients with coronary artery bypass grafts (CABG) is analysed in the present study.**Materials and methods:** Sixty-five patients (59 [92%] males and 6 [8%] females with the mean age of 59±9.1 years) underwent 64 slice CT and a total of 186 bypass grafts (62 arterial and 124 venous grafts) were analysed using 64 slice CT. Bypass grafts and native vessels with the diameter of >1.5 mm were evaluated for the presence of significant stenosis of >70%. In all patients invasive coronary angiogram was done.**Results:** On the whole 43 venous grafts and 3 arterial grafts were found to be occluded. Majority of the grafts were occluded at the ostium. It was observed that the 64 slice CT was 90% sensitive and 96% specific for the evaluation of bypass grafts. It had 95% positive predictive value and 93% negative predictive value for predicting the luminal narrowing of grafts. For the assessment of arterial graft, it was 80% sensitive, 100% specific with a positive predictive value of 100% and negative predictive value of 93%. For the evaluation of venous grafts, the sensitivity, specificity, positive, and negative predictive value were 94%, 94%, 93%, and 94%, respectively.**Conclusion:** We conclude that the 64 slice CT is a highly reliable diagnostic tool with a very high negative predictive value for evaluating patients following CABG.

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Introduction

64 slice computed tomography (CT) with electrocardiogram (ECG) gated reconstructed images have been promising in analysing patients with bypass grafts. A 4 slice spiral CT coronary artery evaluation was significantly affected by the presence of metal clips, cardiac motion, and poor opacification.^{1–4} Although after the introduction of 16 and 64 slice CT, these issues were corrected,^{5,6} the analysis of distal anastomosis site was still difficult. Schlosser et al. in his study reported 96% sensitivity with a specificity of 95% for the evaluation of bypass grafts using 16 slice CT.⁷ However, with the improved spatial and temporal resolution, the utilisation of 64 slice CT scan has brought remarkable improvement in

the analysis of grafts especially of the anastomotic site and distal segment evaluation. In this study, we analysed our experience in the first 65 consecutive patients who underwent the 64 slice CT as well as invasive coronary angiogram during their follow-up after coronary artery bypass grafting (CABG).

Methods

Sixty-five consecutive patients with previous CABG who were referred for evaluation of grafts between June 2006 and June 2007 were recruited for the study. In all patients, progression of coronary artery disease (CAD) was suspected either because of the worsening of cardiac symptoms or positive treadmill test or both. Patients with haemodynamically stable cardiac status, in sinus rhythm, without implanted pacemaker or valve prosthesis, and without having any

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contra indication for iodinated compounds were included. Patients with a possible pregnancy and irregular cardiac rhythm were excluded. Invasive coronary angiogram was done in all patients within 3 days after 64 slice CT. Informed consent was obtained from all the patients and the protocol was approved by our local ethical committee.

64 slice computed tomography protocol

Patients with the heart rate >70 beats/min received a maximum of 100 mg of oral beta-blockers (metoprolol) 1 hour prior to scanning. In patients with elevated heart rate, intravenous metoprolol 5 mg stat to the maximum of 15 mg at 5 minutes interval was administered. All patients were examined clinically and enquired about being allergic to any of the iodinated components. The procedures were explained to the patient by our cardiovascular radiologist. The site, type, and number of grafts were made known to the operators prior to the CT imaging. 64 slice CT was performed with the use of a SOMATOM Sensation 64 slice cardiac CT scanner (Siemens Medical Solution, Germany). First a posteroanterior projectional image was acquired to access the scan volume for further imaging and to determine the position of heart and great vessels. Bolus tracking was performed by placing a region of interest (ROI) in the ascending aorta, and image acquisition was automatically started after the signal density reached a predefined threshold of 100 HU. All patients received 110 mL of ioversol (350 mg iodine/mL) injected through a 18 G venflon placed in the cubital vein at a rate of 5–6 mL/sec followed by 50 mL of saline infusion. The following mean parameters were set for all patients. Simultaneous acquisition of 64 slice per rotation was achieved using a detector collimation of $32 \times 0.6 \text{ mm}^2$, slice collimation of $64 \times 0.6 \text{ mm}^2$, employing an oscillating electron beam (z flying focal spot) thereby resulting in two parallel radiographic beams improving the spatial resolution corresponding to the $64 \times 0.3 \text{ mm}^2$ detector. The other parameters included a tube rotation time of 330 ms, tube voltage of 120 KV, tube current of 930 mAs, and fixed pitch of 0.20. Electrocardiogram gated dose modulation was used in patients with slow and steady heart rate.

Image reconstruction

Electrocardiogram gated reconstruction permits the reconstruction of the entire data sets collected at different points of the R–R cycle. Previous studies have revealed that the optimal reconstruction window in which the entire coronary artery segments can be seen without much of motion artefacts falls into 60–70% of the R–R interval.^{8,9} In patients with higher heart rates reconstruction window was positioned in 25–35% of the R–R interval for optimal image quality. In our study, the image reconstruction was performed at 65% R–R interval for all patients. Additionally, in the case of cardiac motion artefact a preview function was used to assess the optimal reconstruction phase with the least cardiac motion and that phase was chosen for image reconstruction and analysis.

A smooth reconstruction filter (B25f++) was used for image reconstruction.

Data analysis

The reconstructed image data were analysed using an offline workstation (Syngo Siemens Medical Solutions Germany). All coronary segments were analysed separately by a cardiologist and a radiologist as per the American Heart Association (AHA) guidelines. Other than the number and location of grafts, which were made known to them, both these specialists were blinded to the patient's identity, history, and results of invasive coronary angiogram. Each of the grafts analysed were first labelled as either evaluable or non-evaluable grafts due to calcification, metal clip artefact, and stepdown artefacts. The evaluable grafts were further classified as occluded or patent and were analysed for the presence, severity, and location of stenosis. Those with >70% luminal narrowing were termed as significant stenosis. The significance of the luminal narrowing of the grafts as well as the native coronary arteries were analysed in the original transaxial slices, thin and thick slab max intensity projection, multiplanar, curved multiplanar, reconstructive images, and three-dimensional volume rendered images.

Invasive coronary angiography

Using the Seldinger technique through the right femoral access, selective coronary angiogram of native coronary arteries and the grafts was done in all patients, within 3 days after the 64 slice CT procedure. Standard views were taken and all the coronary artery segments were analysed, which included coronary arteries with a diameter of >1.5 mm and all arterial and venous grafts. The severity of the lesion was analysed in two orthogonal views.

Statistical analysis

Descriptive statistical analysis was performed for native coronary arterial segments and for all grafts. Continuous variables were expressed as mean ($\pm$ standard deviation). The diagnostic accuracy of 64 slice CT for the detection of significant disease was expressed as sensitivity, specificity, positive predictive value, and negative predictive value. *P* values <0.05 were considered significant.

Results

Table 1 revealed the demographic profile of our study population. Sixty-five patients had undergone 64 slice CT in our institute between June 2006 and July 2007. All patients had invasive coronary angiography. The mean age of our study population was 59 ± 9.1 years. Majority of the patients in the study population were males (92%) and the mean interval

period between CABG and 64 slice CT was 5.8 ± 4.2 years. A high incidence of dyslipidaemia was noted in our study population. Forth-five patients (70%) had dyslipidaemia, 53 patients (82%) received beta-blockers, and the remaining 18% were on diltiazem to control the heart rate during CT evaluation. The mean heart rate was 62 ± 9 /min during the CT scan imaging.

Table 2 revealed the characteristics of the grafts in our study population. Largely 186 grafts were analysed and out of them 124 were venous and 62 were arterial. Out of the 62 arterial grafts 3 (4%) were occluded and of the 124 venous grafts, 43 (35%) were occluded. Overall 46 grafts were found to be occluded in our study population. Majority of the venous grafts were occluded at the ostium. Thirty-three venous grafts were occluded at the ostium and 10 were occluded at the mid segment of the graft. In the arterial grafts two were occluded at the ostium and one at the mid segment.

Table 1
Demographic profile in our study population.

Total	65
Mean age (yr)	59 ± 9.1
Sex	
Male	59 (92%)
Female	6 (8%)
Interval after CABG (yr)	5.8 ± 4.2
Hypertensive	26 (40%)
Diabetic	30 (47%)
Smoker	7 (12%)
Dyslipidaemia	45 (70%)
Mean heart rate during CT	62 ± 9
Beta-blocker used	53 (82%)
Family history of CAD	35 (54%)

CABG: coronary artery bypass grafts, CAD: coronary artery disease, CT: computed tomography.

Table 2
Characteristics of grafts in our study population.

	Arterial	Venous
Total number of grafts	62	124
Occluded grafts	3 (4%)	43 (35%)
Site of occlusion		
Ostium	2	33
Shaft	1	10
Distal anastamotic site	0	0

Table 3
Predictive accuracy of 64 slice computed tomography.

	Sensitivity (%)	Specificity (%)	Positive predictive value (%)	Negative predictive value (%)
All grafts	90	96	95	93
Arterial	80	100	100	93
Venous	94	94	93	94
Native vessels	96	93	96	100

Table 3 revealed the predictive accuracy of multislice CT. It was observed that the 64 slice CT was 90% sensitive and 96% specific for evaluation of all grafts with 95% of positive predictive value and 93% of negative predictive value. For the evaluation of the arterial grafts it was 80% sensitive and 100% specific with positive predictive value of 100% and negative predictive value of 93%. For the venous grafts evaluation the sensitivity, specificity, positive predictive value, and negative predictive value were 94%, 94%, 93%, and 94%, respectively. Sensitivity, specificity, positive predictive value, and negative predictive value for evaluation of native coronary segments were 96%, 93%, 96%, and 100%, respectively (Figure 1).

Discussion

The principal objective of the study was to evaluate the usefulness of multi detector CT in patients after bypass surgery. Large size of the graft, relative immobility as well as sparse calcium makes this CT evaluation relatively easier especially after CABG. Improvements in the imaging field, especially the faster radiographic tube rotation and more thinner detectors has solved most of the practical issues of graft evaluation by 64 slice CT. Artefacts caused by metal clips in the vicinity of the grafts, proximal anastomotic indicators, and sternal wires do not really affect the accuracy of CT assessment in the prediction of luminal narrowing (Figure 2).

In this article, we have shared our own experience with 64 slice CT evaluation in the first 65 consecutive patients with coronary bypass grafts. The mean interval of evaluation after CABG was 5.8 ± 4.2 years. The mean heart rate maintained during the CT evaluation was 62 ± 9 beats/min. Fifty-three (82%) patients from our study population were treated with beta-blocker and the remaining required diltiazem. We also noticed a higher number of occluded venous grafts than arterial grafts in our study population (43 venous grafts and three arterial occluded grafts). Majority of the grafts were occluded at the ostium (Figure 3).

64 slice CT evaluation of all grafts in our study revealed a sensitivity of 90%, specificity of 96%, positive predictive value

Figure 1 Normal sequential grafts to LAD and OM. LAD: left anterior descending, OM: obtuse marginal.

Figure 2 Native left anterior descending lesion distal to left internal mammary artery graft.

Figure 3 Stenotic venous graft (SVG) to obtuse marginal (OM).

of 95%, and negative predictive value of 93%. Malagutti et al. in his study on 52 patients, had noticed sensitivity of 99% and 98% specificity. Sensitivity and specificity for the evaluation of distal runoff were 89% and 92%, respectively. He noticed a positive predictive value of 50%.¹⁰ Ropers et al. analysed 50 patients with a total of 138 grafts.¹¹ He found that the sensitivity of the graft stenosis detection was 100%, with a specificity of 94%.

We also observed a higher specificity of 64 slice CT while evaluating arterial grafts compared to venous grafts. In contrast, Meyer et al. in his series analysed 128 patients with a total of 412 bypass grafts and observed 97% sensitivity and specificity and 93% positive predictive value with the negative predictive value of 94%.¹² He found that there was no significant difference in diagnostic accuracy between arterial and venous grafts.

In our study, the sensitivity and specificity of 64 slice CT evaluation for native coronary artery was 96% and 92%, respectively, with a positive predictive value of 96% and negative predictive value of 100%. The initial experience of Leschka et al. using 64 slice CT for evaluating native coronary

segments, revealed sensitivity of 95%, specificity of 97% with a very high negative predictive value of 99%.

Limitations

A major limitation in our study was the small sample size for comparison of usefulness of 64 slice CT with invasive coronary angiogram in evaluating bypass grafts.

Conclusion

64 slice CT is a highly reliable and valuable diagnostic method with a very high negative predictive value used in the evaluation of patients with CABG.

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Images in cardiology

A case of restrictive cardiomyopathy evaluated by cardiac magnetic resonance imaging

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A 66-year-old woman, known to have hypertension, hypothyroidism, and atrial fibrillation for the last 8 years, presented with ankle swelling, abdominal distention, and worsening of breathlessness for the last 4 months. She was evaluated and found to have features of heart failure on clinical examination. Two-dimensional (2D) echo revealed global

hypokinesia with left ventricular (LV) dysfunction and mild pericardial effusion. The cardiac magnetic resonance imaging study showed all the characteristic features of amyloidosis (Figure 1).

The delayed gadolinium kinetics was highly suggestive of amyloidosis.

Figure 1 (A) Biatrial dilatation with normal sized ventricles. (B) Concentric left ventricular hypertrophy (LVH) with mild pericardial effusion. (C) There is late gadolinium enhancement in the IAS and the entire subendocardium of the LV not conforming to any coronary territory (arrow). (D) There is late gadolinium enhancement in the short axis section of the LV suggestive of global infiltration (arrow).