ROLE OF 64-SLICE MULTI DETECTOR COMPUTED TOMOGRAPHY FOR NON-INVASIVE VISUALISATION OF CORONARY ARTERY BYPASS GRAFTS FOR FOLLOW UP IN POST CABG PATIENTS

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Background: Coronary artery bypass graft surgery is a commonly performed revascularization procedure in ischemic heart disease patients. Conventional coronary angiography is an invasive method for evaluation of grafts in such patients. Non-invasive evaluation of grafts in post CABG patient has been made possible with the advent of 64-Slice Multi Detector Computed Tomography (MDCT) .The Objective of the study was to non-invasively assess the graft patency with MDCT. **Methods:** Sixty post CABG patients (52 male, 8 female) with atypical chest pain or stable angina were evaluated with MDCT for graft patency. The grafts were considered as patent if there was continuous lumen visualisation at origin, in the body and at its insertion with native recipient vessels. Grafts were defined as blocked when only stumps were seen. They were classified as stenotic if there was ≥50% diameter narrowing. **Results:** The mean age of the patients was 60.1±9.7 years, mean duration since CABG was 8.01±6 years. Total number of grafts assessed was 175 including 124 (71%) venous grafts and 51 (28.9%) arterial grafts. A total of 82/124 (66.1%) venous grafts and 47/51 (92%) arterial grafts were patent. Forty-two (34%) venous grafts were blocked whereas 4 arterial grafts were not developed. Arterial grafts patency was 92% and venous grafts patency was 67.7% after a mean follow up of 8.01±6 years. **Conclusion:** The study shows that 64 slice MDCT can be used for the evaluation of patency and occlusion of venous and arterial grafts in post CABG patients for follow up.

Keywords: Multi Detector Computed Tomography (MDCT), Coronary Artery Bypass Graft (CABG), Graft Patency (GP)

INTRODUCTION

The annual number of patients undergoing Coronary Artery Bypass Graft (CABG) surgery for revascularisation of coronary arteries is around 427,000 in USA.[1] Recurrent ischemic symptoms are frequently seen in patients undergoing CABG due to the progression of atherosclerosis in native coronary arteries and bypass grafts, thereby necessitating a routine follow up.[2] Graft occlusion occurs in about 10-15% of the patients shortly after surgery or during the first year and up to 25% of grafts are found to be occluded in 5 years.[3] This occurs due to the progression of atherosclerosis and has caused venous grafts narrowing resulting in stenosis and ultimately in total occlusion. This process is slow in the case of arterial grafts thus maintaining their patency over a longer period.[4]

A number of techniques have been used for non invasive assessment of ischemia including exercise-ECG, stress-Echocardiography and nuclear imaging but these tests have not been able to determine the site and the extent of Coronary Artery Disease (CAD) and graft potency (GP) in post CABG patients. Myocardial perfusion scintigraphy has also been used as a non-invasive method for risk stratification of patients who have undergone CABG.[5]

The gold standard for the detection of GP as well as graft failure has been the catheter based Conventional Coronary Angiography (CCA). However, CCA is an invasive procedure and has the potential to cause harm.[6] The newer techniques including the Magnetic Resonance Imaging (MRI) and Multi Detector Computed Tomography (MDCT) have been developed which are not only non invasive but are effective for determining patency of grafts and graft occlusion in post CABG patients.[7] MDCT has also been used as a non invasive imaging technique in ambulatory patients for routine follow up in post CABG patients.[8] Earlier generation 4 and 16 slice MDCT have shown good results in the evaluation of grafts for GP, stenosis and total occlusion but their utility was limited for the evaluation of anastamosis site and distal recipient vessels after the graft.[9,10] With the introduction of newer generation 64 slice MDCT in 2005 which offered higher temporal and spatial resolutions than the earlier 16 slice MDCT, there has been much improvement in the visualisation of grafts, their anastamosis to native recipient vessels and distal recipient native vessels after the graft. Diagnostic accuracy of MDCT for the detection of stenosis of ≥50% luminal narrowing of grafts and their anastomotic sites has improved tremendously in post CABG patients.[11,12]

SUBJECTS AND METHODS

Sixty post-CABG patients (52 males, 8 females) with stable angina or atypical chest pain were included in the study. All patients had undergone 64-slice MDCT angiography between Jul 2007 and Sep 2008. Written and an informed consent was taken from all patients. Exclusion criteria were an irregular heart rate, allergy to iodine contrast, renal failure (serum creatinine >2.0 mg/dl) and an inability to hold breath for about 15 seconds. The pretest history and examination which included the vital signs and systemic examination were recorded. Number of grafts and native recipient vessels to which grafts were inserted was determined by the surgical record of the patient. BMI was also recorded at this stage. The patients were tested for the ability to hold breath for at least 12 to 15 sec. and those who were unable to do so were not enrolled for the study. An 18 gauge canula was placed in anticubital vein for the administration of the iodinated contrast 370 mg/ml. A test bolus of iodinated contrast was given intravenously to test for any hypersensitivity. ECG was obtained to determine the rate and rhythm and those with sinus rhythm were included.

Patients were given beta blockers either 5–10 mg of metoprolol tartrate intravenously or 100 mg of metoprolol orally to maintain the heart rate ≤60/min. Nitrolingual-spray 0.4 mg/spray having an active ingredient of glyceryl trinitrate was given before the start of scan acquisition.

The Computed Tomography Angiography (CTA) images were acquired with a 64-slice MDCT scanner (General Electrics Light Speed VCT, Milwaukee, USA) with a collimation of 64×0.625 mm and total z-axis coverage of 40 mm. The gantry rotation time was 0.35 seconds. The tube voltage was 120 kV and tube current ranged from 350 to 750 mA using ECG modulation with maximum tube current between 40–80% phases and minimum tube current in remaining phases. The pitch ranged from 0.18 to 0.26 depending on the patient's heart rate. After two localization scans, test bolus tracking was carried out with 20 ml of non-ionic contrast agent given through anticubital vein to calculate the exact arrival time of contrast agent in the coronary arteries, with a region of interest in the proximal part of the ascending aorta. An automated CT injection system (Medrad Stellant@ with dual head) was used for IV administration of non ionic iodine contrast and saline chaser.

For MDCT angiography, 80-120 ml of contrast agent was continuously injected into an anticubital vein, followed by a saline chaser bolus of 50 ml at a flow rate of 5.0 ml/s. Thereafter scanning was initiated in craniocaudal direction, covering the distance from the clavicle to include the origin of Left Internal Mammary Artery (LIMA) to the diaphragmatic side of the heart .This was done during a single inspiratory breath hold for an acquisition time of 12–15 sec. For an optimal heart phase selection, retrospective ECG gating was used. Retrospective reconstruction of the image data was performed for acquisition of phase images starting from early systole (10% of the R-R interval) and ending at late diastole (90% of the R-R interval) using 10% increments. All images were reconstructed with a display field of view of 25 cm, a standard soft tissue filter as suggested by the manufacturer and an effective slice thickness of 0.625 mm with an increment of 0.625 mm. The best phase was selected for analysis of grafts and native vessels.

The CT Images were transferred to a dedicated offline computer workstation (GE Advantage 4.3) for reformatting and analysis. The CTA datasets were analysed using axial source images, multiplanar reformations (MPR), thin-slab maximum intensity projections (MIP) and volume rendering with dedicated software. All patients were evaluated by two readers having expertise in CTA and the findings were agreed upon. Image quality was graded as follows: excellent (with no motion or gating artifacts present), good (with minor motion artifacts present), diagnostic (with substantial motion artifacts present, but luminal assessment of significant stenosis still possible) and poor (with significant artifacts making luminal assessment impossible) (Figure-1).

Only the excellent, good or diagnostic quality images were considered for reliable bypass graft patency evaluation and the presence of total occlusion and/or stenosis of ≥50%.

Arterial and venous grafts were assessed for the origin, the body, the distal anastamosis and the native recipient coronary arteries after the grafts. The grafts were classified as patent if there was continuous lumen visualisation at origin, in the body of graft and at insertion with native recipient vessels. Grafts were categorised as blocked if their stumps were visualised or if grafts were not visualised at all (Figure-2). They were classified as stenotic if there was ≥50% diameter (Figure-3) narrowing as compared to a proximal or a distal normal reference. Native vessel segments after the graft insertion were also assessed.

Descriptive statistics were performed for grafts and patients. Some variables are qualitative and some variable are quantitative, analysis was done using SPSS 12.0 and Microsoft excel. Continuous variables were reported as frequency tables, percentages and bar charts.

Figure-1: MDCT Images of patients having excellent, good, diagnostic, and poor quality images respectively, showing LIMA to LAD, SVG to Obtuse Marginal Branch and SVG to RCA

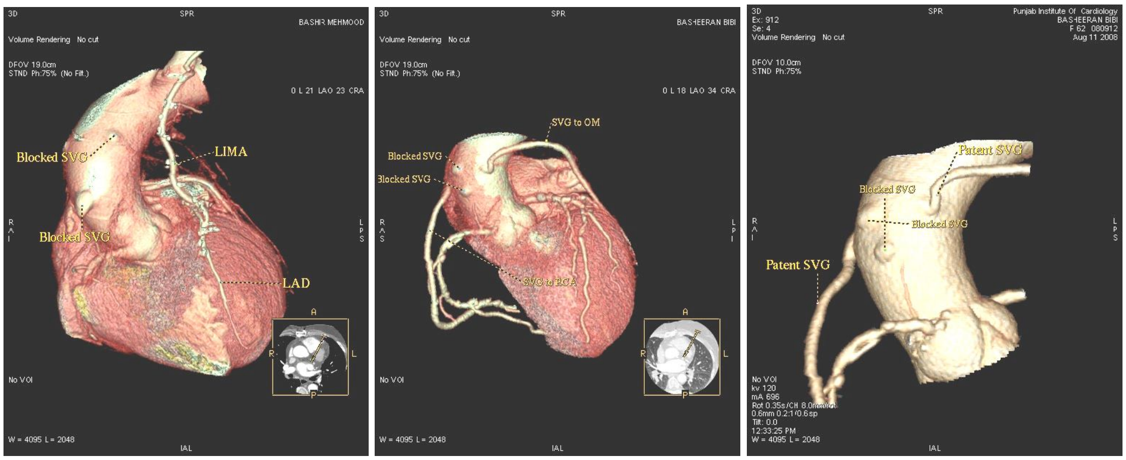

Figure-2: MDCT volume rendering images showing stumps of blocked SVGs

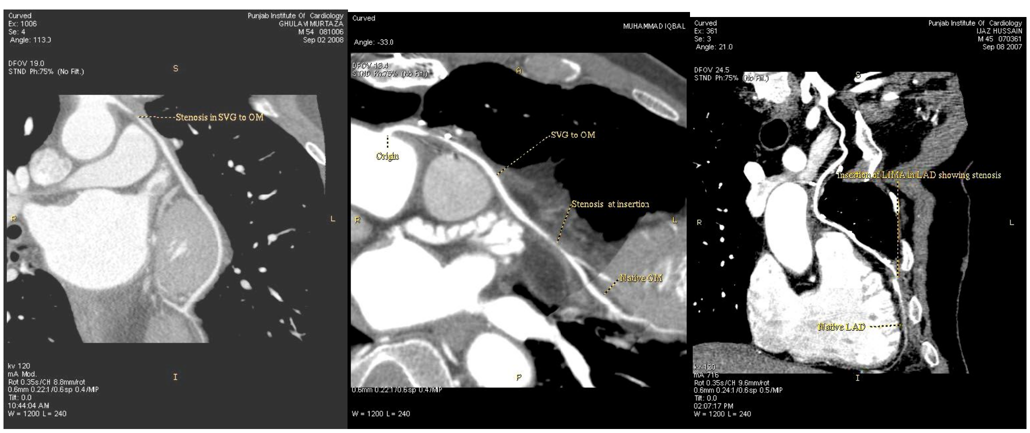

Figure-3: MDCT images showing stenosis of ≥50% in SVGs and in LIMA at insertion

RESULTS

The baseline demographic data of 60 patients is shown in Table1 showing a mean age of 60.1±9.7 years, and a mean duration since CABG of 8.01±6 years. There were 52 males and 8 female patients. Mean BMI was 27.4±4 with a maximum BMI of 37 and minimum of 19.1. All but one patient who had been implanted with an ICD (Implantable Cardioverter Defibrillator) and had a fixed heart rate of 60/min, received beta blockers to achieve a stable heart rate of ≤60/min. The mean heart rate at the time of acquisition was 62.04±7 whereas the mean volume of contrast used was 110±9 ml. Thirty-two patients had stable angina while 28 patients complained of atypical chest pain. Hypertension was the most common risk factor followed by diabetes mellitus and smoking (Figure-4). The maximum number of grafts in one patient was 4 and the minimum number was one.

Graft anatomy and type of grafts per patient are shown in Table-2 and 3. Left Anterior Descending (LAD) was the most commonly grafted vessel (58 in number). The second most commonly grafted vessel was Left Circumflex (LCx) artery (n=51), followed by Right Coronary Artery (RCA) (n=43) and diagonal branch (n=23) respectively. In case of a single graft, LIMA was the only graft and there were 6 such patients. Total number of grafts assessed was 175 which included 124 (71%) SVGs and 51 (28.9%) arterial grafts. A total of 82/124 (66.1%) SVGs and 47/51 (92%) arterial grafts were patent. Forty-two (34%) venous grafts and 4 (7.8%) arterial grafts were blocked.

Fifty-one patients (85%) had a LIMA graft to LAD whereas seven patients had SVG to LAD. LIMA did not develop in 4 patients, in one patient it was blocked at origin and in rest of the three it was not developed/small calibre. Post graft native LAD was normal in 48 (82.7%) of the patients (Figure-5). Metal clips in LIMA hindered the luminal interpretation in 15 patients either in the main body of the graft or at insertion with LAD (Figure-6).

The LCx was the second most common venous graft: 51 in number (85%) out of which 37 (72%) were patent and 14 (28%) stumps of blocked venous grafts to LCx were visualised. There was a stenosis of ≥50% in 6 grafts to LCx: one graft had stenosis at origin, three grafts had stenosis in mid-SVG to LCX and two had stenosis at insertion (Figure-6). Post graft native LCx was normal in 32 (62.7%) patients. RCA had SVG in 43 (71%) patients, out of which patent grafts to RCA were in 27 (63%) patients and 16 (37%) patients had SVGs to RCA blocked. Six grafts to RCA had ≥50% stenosis. A total of 15 SVG's showed stenosis (Figure-6) of ≥50%, the distribution is shown in Table-4. The image quality was excellent in 23 (38.3%), good in 16 (26.6%) and adequate/ acceptable for interpretation in 21 (35%) of the patients. All grafts were patent in 28 (46.6%) patients and one graft was occluded in 16 (26.6%) patients. Only 28% of the patients had more than two grafts occluded at their routine follow up. The over all patency rates for arterial and venous grafts in this patient population were 92% and 66% respectively. The distribution of good quality grafts is shown in Figure-7. There were 90.1% arterial and 54% venous good quality grafts which did not show any stenosis at origin in the body or at insertion with native vessel.

Table-1: Patients' Characteristics

Gender Male Females	 52 8
Age	60.1±9.7 years
Body mass index	27.4±4 Kg/m^2
Interval from CABG procedure to 64-Slice CTA	8.01±6 years
Stable Angina/Atypical symptoms	32/28

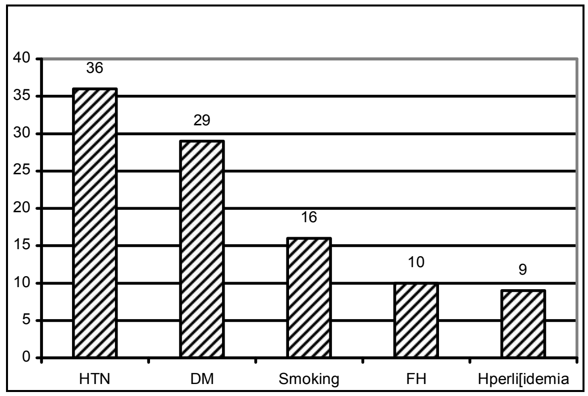

Figure-4: Distribution of Risk Factors

Table-2: Graft anatomy per patient

Single graft (n) **Single graft (n)**	6 6
Two graft (n)	10
Three grafts (n)	26
More than three grafts (n)	18
Venous + arterial grafts (n)	47
Only Venous grafts (n)	7
Only Arterial grafts (n)	6

Table-3: Graft Types (n=175)

Arterial Grafts	51/175
LIMA to left anterior descending artery	51/175 (29%)
Saphenous venous Grafts	124/175 (71%)
Saphenous venous graft to left anterior descending artery	7 (5.6%)
Saphenous venous graft to diagonal branch	23 (18.5%)
Saphenous venous graft to circumflex artery	51(41.1%)
Saphenous venous graft to RCA	43 (34%)

Table-4: Graft occlusion/stenosis/patency

Type of Grafts	No of Grafts	Occluded Grafts	Patent Grafts	Stenosis	Good Quality Grafts	Recipient Native Vessel
Arterial						
LIMA	51	4/51 (7.8%)	47/51 (92%)	1	46 (90.1%)	44 (86.27%)
Venous						
Saphenous venous graft to LCX/OM	51 (85%	14 (28%)	37 (72%)	6	31 (61%)	32 (62.7%)
Saphenous venous graft RCA	43 (71%)	16 (37%)	27 (63%)	6	21 (49%)	26 (48.8%)
Saphenous venous graft to Diagonal	23 (38.3%)	10 (39%)	13 (56%)	2	11 (48%)	11 (47.8%)
Saphenous venous graft to LAD	7 (11.6%)	2 (28%)	5 (71%)	1	4 (57%)	4 (57.1%)
Total	51+124=175	4+42=46	47 (92%)/82 (66%)	16	46 (90.1%)/67 (54%)	44+73=117 (67%)

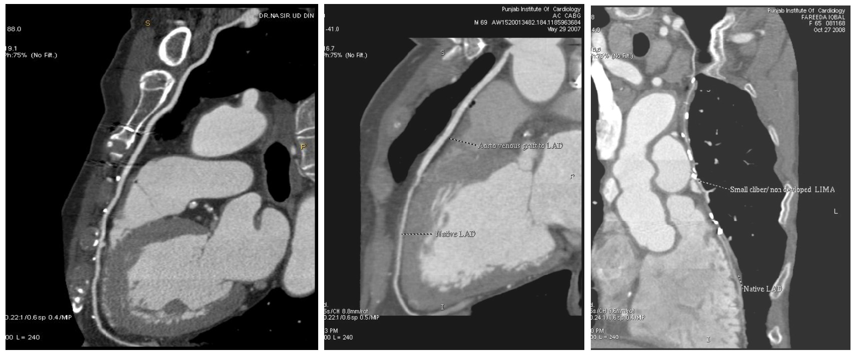

Figure-5: MDCT MPR images of patents with LIMA, SVG and undeveloped /small caliber LIMA to LAD

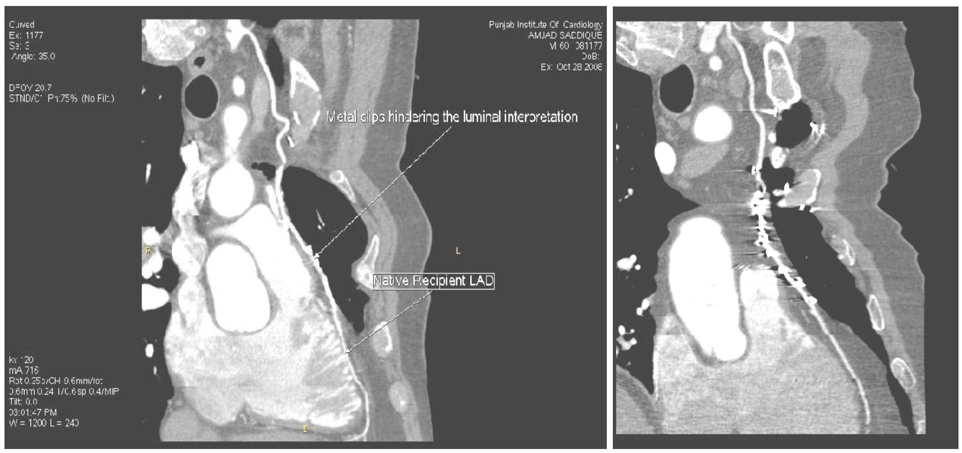

Figure-6: Showing the metal clips in the course of LIMA hindering luminal interpretation

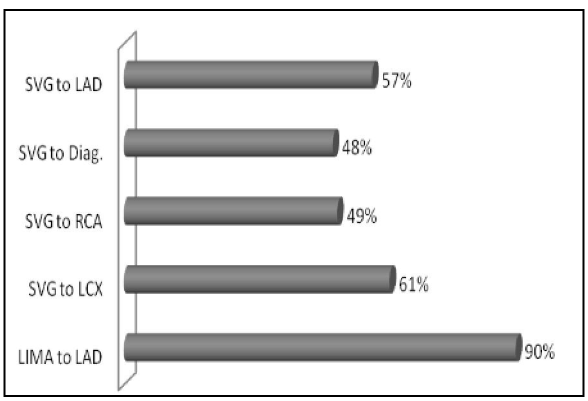

Figure-7: Distribution of good quality grafts

DISCUSSION

Conventional coronary angiography is a gold standard test for the evaluation of native coronary arteries and bypass grafts in symptomatic post CABG patients. However, CCA is an invasive procedure which has a small but definitive risk of complications associated with it.[6] Moreover it is, at times, technically difficult for the operator to visualise all grafts resulting in more radiation exposure to the patient as well as to the operator himself. A lot of time and a considerable amount of iodinated contrast may be wasted in localising the stumps of blocked grafts thus making the patient more vulnerable to contrast induced nephropathy.[13] There are other non-invasive methods like exercise ECG, stress myocardial imaging, stress echo and MRI available for the assessment of post CABG patients .Although all these techniques provide information about myocardial perfusion but lack the anatomical details of grafts and the native vessels. MDCT coronary angiography is a non invasive method for the assessment of coronary arteries and bypass grafts. MDCT has also shown a fairly high degree of accuracy for the detection of significantly obstructive coronary artery lesions in both native vessels and arterial or venous grafts.[8,9,14–16] It has a high sensitivity, specificity, positive and negative predictive values.[17] It has also been used for evaluation of arterial and venous grafts with very good diagnostic accuracy.

The present study has shown its promise for the assessment of patency of venous and arterial grafts in stable patients after CABG with the latest technology of 64-slice MDCT. With more than 90% sensitivity and a high negative predictive value shown in various studies, it has demonstrated that it can be used as a routine test for follow up in asymptomatic or stable angina post CABG patients for GP. A recent meta analysis with 64-slice MDCT has shown that graft assessability which also included distal anastamosis ranged from 78%–100% (mean=92.4%). And assessment of graft obstruction (occlusion and or >50% stenosis) had showed a 97.6% sensitivity and a 96.7% specificity , a positive predictive value of 92.7% and a negative predictive value of 98.9%.[18] This has been achieved because of a high temporal and spatial resolution and a relatively shorter breath hold time on 64-slice MDCT as compared to the 4-slice and 16 slice CT scanners used in earlier studies.[19] The metallic artifacts such as vascular clips, proximal anastamosis indicator clips and metallic sternal wires did not hinder the luminal interpretation in the grafts which had been a problem in earlier 4-slice and 16-slice CT systems. The diameter and the relative immobility of the grafts as compared to native coronary arteries have made this technique of non invasive assessment of grafts an acceptable option in stable patients.[4,5] Sixty-four slice MDCT because of its higher temporal and spatial resolution and relatively shorter breath hold time as compared to earlier generation 4 or 16 slice CT scanners has shown that the entire course of LIMA from origin to the insertion including the native coronary artery after the graft, can be evaluated by this technique.[20] Non-selective injection of contrast on MDCT, which as compared to the selective injection of contrast in bypass graft on conventional angiography and is considered to be the current gold standard to evaluate bypass grafts for GP and stenosis, abolishes the serious risks such as arrhythmia, graft dissection, myocardial infarction, and embolic events.[21,22]

Graft occlusion occurs mainly due to the progression of atherosclerosis and is observed more commonly in venous grafts as compared to arterial grafts. Present study has shown patency of 66% in SVGs and 92 % for arterial grafts at their mean follow up of 8.01±6 years. Nineteen percent of the patent venous grafts showed stenosis which resulted in 54% of the good quality patent venous grafts and 90% arterial grafts which did not show any narrowing. Various studies have shown that 10–15 year post CABG graft patency is 50–60 % for venous grafts and 85 % for the arterial grafts.[2,3,23,24]

The current technology of 64-slice MDCT has been able to evaluate higher number grafts for GP and stenosis as compared to the earlier technology of 4 and 16 slice MDCT. The artifacts due to respiratory motion, surgical clips and cardiac motion which caused difficulty in image interpretation in earlier generation MDCT, has caused less problems with new generation 64 slice MDCT.[25]

In some patients who do not have any surgical procedural record, CT angiography has been a better option for the visualization of the grafts thereby avoiding the risks of invasive angiography. In such patients MDCT angiography has been able to determine the total number of grafts, GP, occlusion and stenosis in grafts and recipient native vessels. So CT graft imaging can be done prior to planned conventional angiography for graft visualization. MDCT also has an important role in redo CABG to preoperatively plan for not only the vessels to be grafted, but also for the course and condition of the internal mammary graft.

Asymptomatic patients are not routinely followed by conventional invasive angiography as it involves certain hazards.[23] MDCT has provided an opportunity for the graft surveillance in asymptomatic patients for monitoring future cardiac events. Despite this, MDCT still can not be called a risk free investigation as it also involves the administration of the iodinated contrast and considerable exposure to radiation though the radiation exposure is less with ECG dose modulation which lowers the tube out put during systole.

Magnetic resonance angiography (MRA) which is used as a non invasive modality for the evaluation of grafts has shown limitations because of its poor image resolution, long scan times, claustrophobia, and pacemakers but it still retains the advantage of no radiation exposure.[26,27]

LIMITATIONS OF CT ANGIOGRAPHY AND OF STUDY

Radiation exposure is more as compared to conventional angiography. 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. 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.[28] CT angiography cannot be performed without the use of potentially nephrotoxic contrast media. There is a need for pharmacological heart rate control to avoid motion and gating artifacts.

One of the major limitation in this study was that these findings were not confirmed on conventional invasive angiography.

CONCLUSION

The study shows that 64 slice MDCT can be used for the evaluation of patency and occlusion of venous and arterial grafts in post CABG patients for follow-up.

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