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Original Research Article

MSCT coronary angiography in non-invasive assessment of coronary artery bypass grafts patency

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ABSTRACT

Background: Coronary artery disease (CAD) is one of the leading cause of the morbidity and mortality in India and worldwide and last decade has seen a steep rise in incidence of CAD in India and its treatment as bypass surgery. Direct visualization of the grafts and native coronary arteries by invasive catheterization is now being replaced by non-invasive CT coronary angiography with higher slice machines and newer technology as it has good temporal resolution, high scanning speed as well as low radiation dose. We share our experience of graft imaging on 128 slice CT machine.
Methods: This is a retrospective, single-center, observational study. We included 500 symptomatic patients who have undergone CT study between the year 2014 to 2018 post bypass surgery.
Results: Arterial grafts have a better patency rate than venous grafts. (88% vs. 64.1%). Amongst the individual arterial grafts RIMA had the best patency rate (100%) followed by LIMA (90.8%), RA (68.7%). LAD was the most commonly involved artery (91%).
Conclusions: Significant absolute concordance between CT and catheter angiographic findings have been documented for all arterial and venous grafts patency in the literature. The MSCT with retrospective gating permits an accurate and non-invasive evaluation of patent and diseased arterial and vein grafts and could replace conventional angiography for the follow-up of symptomatic, stable patients. Moreover, an optimal diagnostic accuracy was also documented in the appraisal of native vessels distal to the graft anastomoses.

Keywords: MSCT coronary angiography, Non-invasive, Post-CABG

INTRODUCTION

Coronary artery disease (CAD) is one of the leading cause of the morbidity and mortality in India and worldwide and last decade has seen a steep rise in incidence of CAD in India and its treatment as bypass surgery.[1] Coronary artery bypass graft (CABG) surgery is the standard therapeutic management for diffuse coronary artery disease. The success rate of this surgery depends mainly on the patency of these grafts. Patients generally present with the non-specific complaints of dyspnoea and chest pain mimicking angina. Chest pain is common after CABG surgery and can have a variety of etiologies, including recurrent angina secondary to graft occlusion, sternal infection, pleural or pericardial effusion, and less common but potentially lethal complications such as pulmonary embolism or pseudoaneurysm formation. In this setting, multidetector CT can offer a rapid, convenient, and non-invasive means of discerning the correct underlying diagnosis.[2]

CT coronary angiography can be used for the quick evaluation of the patency of the grafts and native vessels as well as to rule out other complications, which may be one of the reasons of the patient's morbidity. Conventionally, invasive coronary angiography is used to assess the patency of the graft. Being an invasive procedure, there is a risk of potentially life-threatening complications like arrhythmia, stroke, coronary artery or graft dissection, embolic events and myocardial infarction.

With the advancement in CT technology, newer CT machines provide many advantages over older models. MSCT has higher spatial resolution and increased ability for anatomic assessment of the vasculature through volume rendered images. With the use of ECG gating, there is minimization of motion artefacts due to cardiac rhythm. Thus, in addition to being a non-invasive procedure, MSCT coronary evaluation has many advantages over conventional invasive procedure.

The purpose of our study was to evaluate patency of various grafts in symptomatic subjects on CT coronary angiography. MSCT coronary angiography is a promising non-invasive diagnostic tool to assess patency and to detect graft disease as well as in evaluation of native vessels distal to the grafts.

METHODS

This is a retrospective, single-center, observational study. Our institute serves a primary population of approximately 5 million inhabitants. The Department of Imaging and Radiology provides a full range of services of diagnostic imaging to all the patients of hospital. We included 500 symptomatic patients who have undergone CT study between the year 2014 to 2018 post bypass surgery. MSCT coronary examinations were retrospectively evaluated. Ethics committee approval was obtained for the study.

We excluded patients with follow up scan in less than 1 year of duration from surgery; Patients with known contrast allergy; Patients with altered renal status (creatinine->1.5mg/dl); Patients with hyperthyroidism and pregnancy; Patients with cardiac arrhythmias and unable to hold breath; Patients contraindicated for beta-blockers i.e. severely deranged left ventricular ejection fraction, history of bronchial asthma, arterio-ventricular conduction block etc.

MSCT coronary angiography was performed on 128 slice SIEMENS Somatom definition AS+CT scanner machine. Non-ionic contrast material was administered with a dual-chamber mechanical power injector (Medtron, Germany) via an 18-gauge cannula inserted into an antecubital vein.

A high iodine concentration (≥350mg/mL) contrast agent was administered at rate of 5ml/s. Following intravenous administration of the contrast agent, 40ml saline chaser was administered as bolus at a rate of 5ml/s. Technical parameters during the examination were as follows-ECG-controlled tube flow modulation was used; gantry rotation time was 300ms; collimation 0.6mm, kV 120; mAs automatically estimated by the device was 180-200; and field of view (FOV) ranged between mean 19 and 22cm.

RESULTS

A total 500 patients were studied. We found MSCT to be 93.3% sensitive and 99% specific with negative predictive value of 99% and positive predictive value of 93% for evaluation of graft patency.

Maximum numbers of patients were seen in age groups up to 51-55 years of which youngest patient was 34 years old and oldest patient was 87 years old. Total 415 men and 85 women were studied.

Total 1200 grafts were analysed. Different types of grafts include left internal mammary artery (LIMA), right internal mammary artery (RIMA), radial artery (RA), saphenous vein (SV) and sequential grafts (Table 1, Figure 1, 2). Out of 1200 grafts studied, 550 grafts were arterial; of which 484 grafts were patent (88%) and of 650 venous grafts, 416 grafts were patent (64 %) (Table 2).

Table 1: Total 1200 grafts analysed.

Type of graft	Number	Percentage
LIMA	450	37.5%
RIMA	24	2%
Radial artery	76	6.3%
Saphenous Vein	650	54.2%
Total	1200	100%

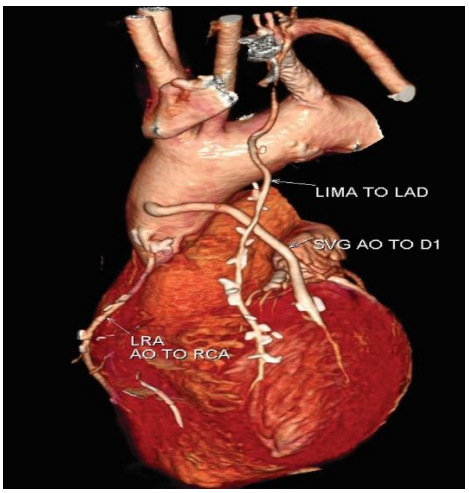

Figure 1: 3D VRT image of a post CABG patient showing patent LIMA to LAD, SVG to diagonal and left radial artery to RCA grafts.

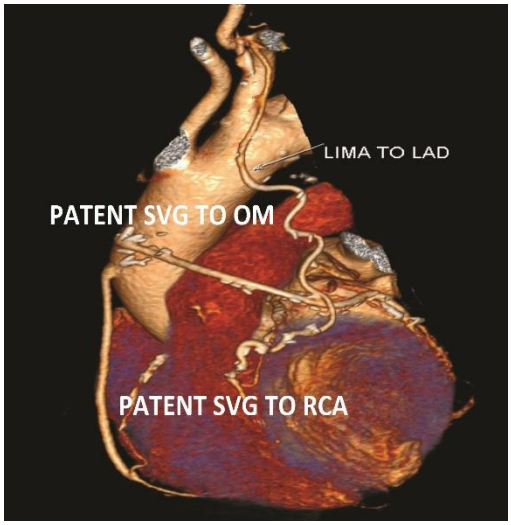

Figure 2: 3D VRT image showing three patent grafts: LIMA to LAD, SV graft from aorta to OM and SV graft from aorta to PDA.

Table 2: Patency of grafts.

Type of Graft	Number of patent grafts	Total Number	Percentage of patent grafts
Arterial	484	550	88%
Venous	416	650	64%
Total	900	1200	75%

Table 3: Patency of individual arterial grafts.

Type of graft	Number of patent grafts	Total number	Percentage
Lima	405	450	90%
Rima	24	24	100%
Ra	55	76	72.4%
Total	484	550	88%

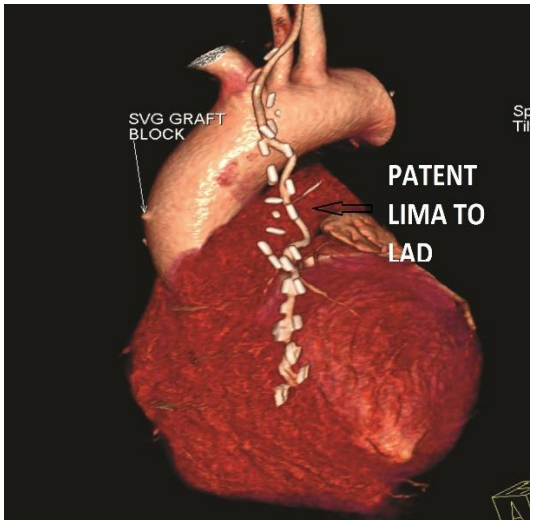

Figure 3: 3D VRT image showing patent LIMA – LAD graft and a blocked SV graft from aorta just after its origin.

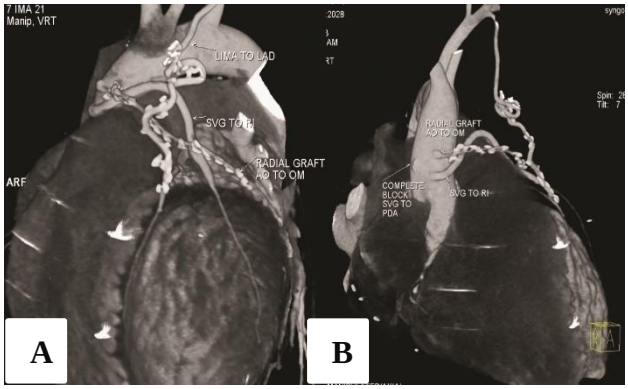

Figure 4: Reconstructed CT images (A) and (B): Two different views showing patent LIMA-LAD, SVG-RI and radial-OM grafts; blocked SVG graft from aorta to PDA.

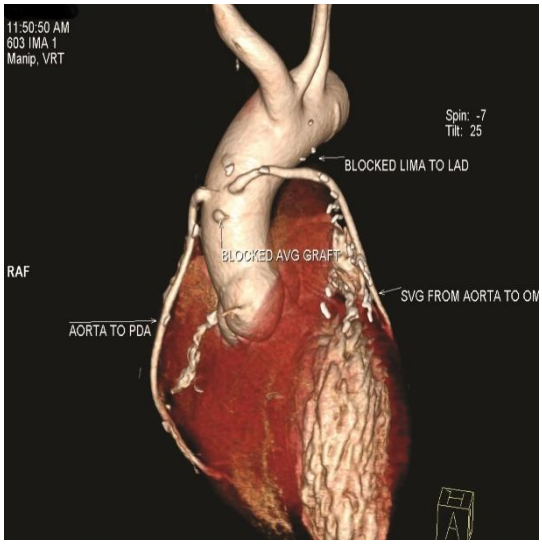

Figure 5: 3D VRT image showing blocked LIMA to LAD graft, patent SVG grafts from aorta to OMA and PDA and another blocked graft just after its origin from aorta.

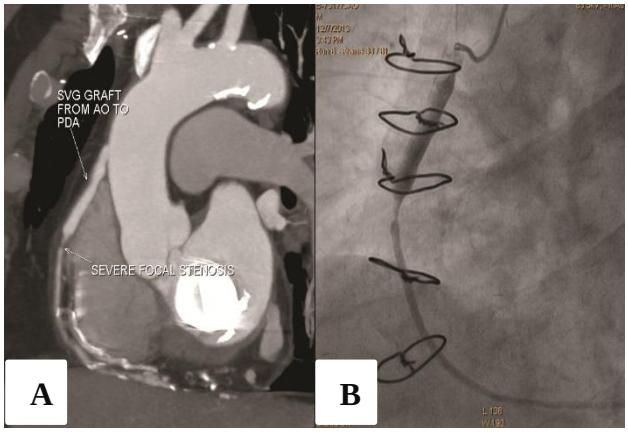

Figure 6: Stenosis in mid segment of SVG graft to PDA. (A): MPR image of CT, (B): Corresponding catheter angiography image.

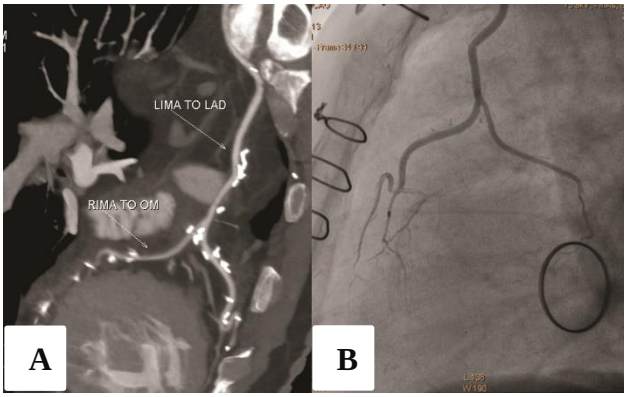

Figure 7: Patent LIMA to LAD with Sequential Y-graft of RIMA from LIMA to OM graft, (A): MPR image of CT, (B): Corresponding catheter angiography image.

Out of 550 arterial grafts studied, 450 grafts were LIMA; of which 405 grafts were patent (90%), 24 grafts were RIMA; of which all grafts were patent (100%) and 76 grafts were radial grafts; of which 55 grafts were patent (72.4%) (Table 3, Figure 3-5) CT also predicted focal significant stenosis within graft (Figure 6). Out of 100 sequential graft segments studied, 10 grafts were LIMA; of which all grafts were patent (100%), 20 grafts were RIMA; of which all grafts were patent (100%) , 55 grafts were radial; of which 35 grafts were patent (63.6%) and 15 grafts were SV grafts; of which 5 grafts were patent (33.3%) (Table 4, Figure 7).

Table 4: Types of sequential grafts used.

Type of graft	Number of patent grafts	Total Number	Percentage
LIMA	10	10	100%
RIMA	20	20	100%
RA	35	55	63.6%
SV	5	15	33.33%
Total	70	100	70%

Table 5: Incidence of complications.

Finding	Number	Percentage
Pleural Effusion	50	10%
Pericardial Effusion	20	4%
Pneumothorax	10	2%

Table 6: Incidental findings.

Finding	Number	Percentage
LVH	50	10%
LVD	30	6%
Old infarct	50	10%
Hiatus Hernia	15	3%
LV Clot	15	3%
Small VSD	5	1%
Left atrial myxoma	5	1%

Table 7: Status of native coronary arteries.

Vessel	Incidence of significant stenosis	Percentage
LAD	455	91%
LCx	365	73%
RCA	355	71%
OM	105	21%
Diagonal	90	18%
LMCA	70	14%

Incidence of complications like pleural effusion, pericardial effusion and pneumothorax are shown in Table 5 and incidental findings were noted in Table 6, which include left ventricular hypertrophy (LVH), left ventricular dilatation (LVD), old infarct, hiatus hernia, left ventricular clot (LV clot), Ventricular septal defect (VSD) and left atrial myxoma.

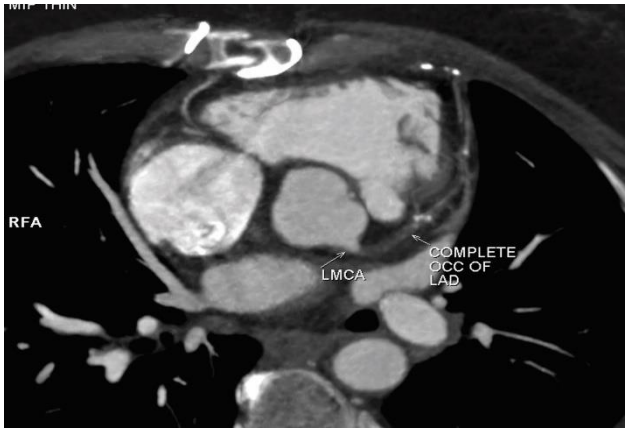

Figure 8: CT image of native vessel evaluation showing complete occlusion of proximal LAD.

Status of the native coronary arteries were noted (Table 7, Figure 8). Significant stenosis of the artery is defined by >70% narrowing of the vessel. Total occlusion is defined by absence of contrast opacification of the artery. LAD was the most commonly involved native vessel (Figure 4). Overall diagnostic accuracy of CT for graft patency was 98.3% (Table 8).

Table 8: Overall accuracy.

Vessel	CT accuracy in percentage
Overall accuracy	98.3 %
For LIMA	97.2 %
For RIMA	97.2 %
For Radial grafts	100 %
For venous grafts	98

DISCUSSION

Amongst various types of coronary artery bypass grafts, saphenous vein grafts are the earliest and most widely used grafts for CABG. Saphenous vein conduits are

harvested from legs and grafted from ascending aorta (usually anterior aspect) to distal coronary artery beyond the obstructive lesion. Saphenous grafts are most convenient, however most prone to occlusion. Nevertheless, continued improvements in surgical techniques, combined with use of antiplatelet or anticoagulant agents and lipid-lowering drug therapy, have allowed SVGs to remain an important, convenient, and readily available choice for bypass grafting[3].In CT imaging, it may not be possible to see the distal anastamosis, however, continuous contrast column in graft, can be taken as patent graft. Most grafts are directly sutured to aorta, however, recently aortovenous connector devices have also come.

Amongst IMA grafts, left internal mammary artery (LIMA) grafts have emerged as preferred bypass graft due to its excellent graft patency and close proximity to LAD. The advantages of IMA conduits over SVGs are now well documented and include decreased postoperative mortality, improved cardiac event-free survival rates, and long-term patency rates well above 90% at 10 years.[3,4] It is seen on imaging, as proximal end from normal anatomical origin (left subclavian artery), and distal end usually anastomosed to LAD. Right internal mammary artery (RIMA) graft can also be used in similar fashion. In two-vessel disease, LIMA is connected to the LAD, and RIMA is attached proximally to LIMA and distally to the second target vessel. In this case, both arterial grafts have better patency rates than venous grafts.

Other arterial grafts include Radial artery and Gastroepiploic artery; while radial artery is used after harvesting from forearm, gastroeiploic artery is used by extended sternotomy. It is dissected from greater curvature of stomach and anastamosed to the target vessel. However, this is a difficult and rare surgery.

For systemic evaluation of the graft, it is divided into three different segments: the origin or proximal anastomosis, the body, and the distal anastomosis of the graft. Usually, the proximal anastomosis of the graft is accurately assessed than the distal anastomosis due to its better visualization by CTA. In some cases where the distal anastomosis is not well visualized, the bypass graft is considered patent if there is homogeneous contrast enhancement. An important aspect of this is flow in native vessel distal to anastomosis. This is very important in decision making. Hence it is important to evaluate and mention the condition of the vessel distal to anastomosis.

Outcome of the graft patency differs according to its type and anastomosis. General patency of IMA grafts was better than for SVGs, and patency of SVG graft in LAD or D1 was better than its placement in PDA or OM artery. The patency of the grafts and presence of significant stenosis (>50% reduction in graft diameter at any point along its length by visual estimation) were evaluated. Recognize artefacts associated with surgical clips as blooming and beam hardening.

Failures of the graft can occur early or late after CABG surgery. Early graft failure usually occurs within 1 month after surgery, and its main reason is vessel thrombosis from platelet dysfunction at the site of focal damage of the lining endothelium during surgical intervention. There are other factors that also initiate early venous graft failure such as the hypercoagulability state of the patient and the high-pressure distension or stretching of the venous graft, with its intrinsically weaker antithrombotic features. Graft closure from thrombosis at 1 month is a recognized complication in 10-15% of cases.[5] The cause of delayed venous graft failure is due to progressive physiopathological changes related to the exposure of their wall to the systemic blood pressure which results in neointimal hyperplasia. By itself neointimal hyperplasia does not produce luminal occlusion or stenosis. But later on it will be the seat for development of atheroma and thrombosis of the venous graft. One year after surgery, the main cause of graft failure is atherosclerosis. The arterial grafts, specifically IMA grafts, are more resistant to formation of atheroma than the venous grafts. However, the main reason for late IMA graft failure is progression of atherosclerotic disease in the native coronary artery distal to the graft anastomosis.

When a bypass graft is done in a native vessel which does not have significant stenosis-then there is preferential or competitive flow through the native vessel resulting in absent flow through the bypass graft.

Approximately 2-20% of CABGs are complicated by a surgical site infection.[6] Diagnosis of sternal dehiscence is usually made clinically; imaging plays an important role to confirm diagnosis. A midline vertical lucency over the sternum of greater than 3mm is usually abnormal and should raise the suspicion for dehiscence.

CT can diagnose normally united sternum by the presence of new bone formation at the sternotomy site without definite bone remodelling in both the anterior and posterior plates. On the other hand, complete sterna nonunion can appear as definite visible sternal separation of both the anterior and posterior plates of the sternum, while incomplete sternal fusion was defined as fusion of one plate and separation of the other.

Risk factors for post-coronary artery bypass graft infection include diabetes mellitus, obesity, complexity of surgery, length of surgical time, and blood transfusion. Three different compartments may be affected by sterna infection: the presternal (cellulitis, sinus tracts, abscess), sternal (osteomyelitis, dehiscence), and retrosternal (mediastinitis, hematoma, abscess). MSCT allows multiplanar reconstruction and windowing, contributing particularly to the evaluation of the sternum. The sagittal plane is useful for determining the disease extent.

Post-contrast CT scan is important in diagnosis of the extension of infection and help in guidance of treatment. The detection of clear fat planes of the mediastinal structures in CT scan excludes the presence of infection. Mediastinitis can be diagnosed by the presence of diffuse soft tissue infiltrations with or without gas loculi, obliteration of mediastinal fat planes, and formation of hypodense fluid collections. CT is a useful prognostic tool as it can be used for follow-up of patients after medical and surgical management. CT can also help in guidance of percutaneous drainage of intrathoracic abscess or significant fluid collections.

Table 9: Patency rates in various studies.

Study	Arterial graft patency	Venous graft patency
Engelmann MG et al[7]	36/42 (86%)	68/92 (74%)
Dai R et al[8]	27/29 (93%)	97/123 (78.9%)
Houslay E et al[9]	30/35 (85.7%)	51/77 (66.2%)
Campbell et al[10]	-	294/305 (76.5%)
Naveed T et al[11]	47/51 (92%)	82/124 (66.1%)
Luca C et al[12]	52/54 (96.3%)	105/146 (71.9%)
Our study	484/550 (88%)	416/650 (64%)

Table 10: Patency rates in various studies for different arterial grafts.

Study	RIMA	LIMA	Radial
Possati G et al[13]	97%	-	91.6%
Kyung-Jong Yoo et al[14]	100%	97.6%	92%
Desai ND et al[15]	-	-	93.8%
Khot UN et al[16]	-	90.3%	51.3%
Crusco F et al[17]	-	94%	79.4%
Collins P et al[18]	-	-	98.3%
Schwann TA et al[19]	-	94.2%	71%
Hortmann HC et al[20]	-	84.8%	58.5%
Tranbaugh RF et al[21]	-	86.4%	80.7%
Hata M et al[22]	-	-	74.3%
Deb S et al[23]	-	-	88%
Tsai FC et al[24]	95.2%	98.1%	-
Our Study	100%	90%	72.4 %

Comparison of patency of arterial versus venous grafts in our study and other studies is 95/108 (88%) for arterial grafts and 100/156 (64.1%) for venous grafts (Table 9 and 10).

CONCLUSION

The 128 -slice CT with retrospective gating permits an accurate and non-invasive evaluation of patent and diseased arterial and vein grafts and could replace conventional angiography for the follow-up of such patients. Moreover, an optimal diagnostic accuracy was also documented in the appraisal of native vessels distal to the graft anastomoses.

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Conflict of interest: None declared
Ethical approval: The study was approved by the Institutional Ethics Committee

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