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# Utility of Coronary CT Angiography and stress SPECT Myocardial Perfusion Imaging for graft disease assessment in symptomatic patients after coronary artery bypass graft surgery

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## ABSTRACT

**Background:** Graft occlusions are commonly present in symptomatic patients after coronary artery bypass surgery (CABG). The aim of this study was to evaluate the diagnostic accuracy of coronary computed tomography angiography (CCTA) and stress single photon emission computed tomographic (SPECT) myocardial perfusion imaging (MPI) for detecting graft disease in symptomatic post-CABG patients.

**Methods**: This was a prospective, single centre study of 100 symptomatic post-CABG patients with native coronary artery/ graft occlusions on invasive angiography (CAG). Grafts were evaluated for degree of stenosis qualitatively on CCTA. Reversible perfusion defects were graded using summed difference score (SDS) on MPI. Sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV) and accuracy of CCTA and MPI were evaluated against CAG.

**Results**: CCTA identified 17/31 (55%), 30/43 (70%) and 18/19 (95%) patients with ≥50% stenosis of arterial, venous and both grafts respectively with specificity and PPV of 100%. Reversible

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perfusion defects were present in 81% of the patients with a mean SDS score of 5.4 ± 3.39 and sensitivity of 84%. Accuracy of CCTA and MPI for detection of graft occlusions were 99% and 84% respectively. 63/65 (97%) patients with ≥50% stenosis of grafts had ≥ 5 SDS score (moderate to severe grade ischemia) and 64% patients were revascularized.

**Conclusion**: CCTA has a comparable diagnostic accuracy to CAG and can be used as an initial investigation in symptomatic post-CABG patients. Reversible perfusion defects on stress MPI help to risk stratify symptomatic post-CABG patients and guide further treatment. Hemodynamically significant occlusions may benefit from revascularization.

**Keywords: Coronary CT Angiography, SPECT, Myocardial Perfusion Imaging, CABG, Graft disease**

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## INTRODUCTION

Ischemic heart disease (IHD) is the leading cause of death in the most countries worldwide. Factors such as sedentary lifestyles, unhealthy dietary habits, environmental pollution, tobacco use, and increased stress levels contribute to the high prevalence of IHD [1].

IHD affects around 1,655 individuals per 100,000 population and nine million deaths were caused by IHD globally. The number of hospital admissions due to coronary artery diseases (CAD) increase, leading to the increasing number of coronary interventions day by day [2]. Percutaneous coronary intervention (PCI) is the most commonly practiced method of coronary revascularization. Coronary artery bypass graft surgery (CABG) is also a very effective treatment method in patients with severe CAD but its long term effectiveness is affected by occlusion of bypass grafts. Graft occlusions are commonly present in symptomatic patients after CABG surgery. Graft patency is an important predictor of any future major adverse cardiac events. Proportions of saphenous venous graft occlusions are 15%, 25% and 40% by the 1st, 6th and 10th year after CABG respectively; may or may not be associated with ischemic symptoms [3,4]. Only 41-50% of patients experience recurrent ischemic symptoms 5-10 years post-surgery. Thus a non-invasive diagnostic procedure is required to risk stratify and identify patients having high probability for any major cardiovascular events post CABG. [5,6,7].

A comprehensive CAD assessment involves both anatomical and physiological (hemodynamic significance of coronary artery occlusions) aspects in order to guide revascularization procedures [8]. Invasive coronary angiography (CAG) is commonly used as a gold standard investigation for evaluation of CAD. Due to advancements in coronary computed tomographic angiography (CCTA) techniques, temporal and spatial resolutions of coronary occlusions are comparable with CAG [9]. Single photon emission computed tomographic (SPECT) myocardial perfusion imaging

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(MPI) is one of the most suitable noninvasive methods for detecting bypass graft disease and helps in risk stratification of patients after revascularization [10]. The aim of this study was to evaluate the diagnostic accuracy of CCTA and stress SPECT MPI for detecting graft disease in symptomatic patients who underwent CABG.

## MATERIALS AND METHODS

### *Study population and study design:*

This was a prospective, single centre study carried out after approval from the institutional ethics committee. Patients visiting cardiology follow up OPD at a tertiary care centre from January 2019 to June 2024 were screened. Total 168 patients with ischemic heart disease who underwent CABG and presented with dyspnoea/ palpitations/ recurrent angina or angina equivalents on their follow up were screened. Patients with stable clinical condition (New York Heart Association class I to III) and documented native coronary arteries and or bypass grafts occlusions on CAG were included. Hemodynamically unstable patients or patients with high-grade atrioventricular blocks, arrhythmias, severe obstructive lung disease, renal impairment or known allergy to iodinated contrast agents were excluded from this study. A total of 100 patients, enrolled in the study as per the selection criteria after taking written informed consent, further underwent CCTA and stress SPECT MPI. Reporting physicians evaluating reports of imaging modalities were blinded to the clinical history, CAG findings and CCTA/ MPI findings. All patients were informed about additional radiation doses from CCTA and MPI before taking written informed consent.

The primary objective of the study was to determine the diagnostic accuracy of CCTA for detecting graft occlusions in symptomatic post-CABG patients at follow up. The secondary objective was

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to evaluate the correlation between CAD on CAG with reversible perfusion defects on stress SPECT MPI in symptomatic post-CABG patients at follow up.

***CT angiography image acquisition and interpretation:***

All scans were performed on a 128-slice CT scanner (Somatom Definition AS+; Siemens Healthcare). Oral Metoprolol (50-100 mg) 1 hour prior/ intravenous Metoprolol (5–20 mg) immediately prior to the CT scan was given to patients with heart rates > 70 bpm. Contrast enhanced CT angiographic images were acquired using retrospective ECG gated method and various image reconstruction parameters were used to generate images. CT angiography image interpretation was performed on axial source images, multi-planar and curved reformations, and maximum intensity projections [11]. Arterial and venous bypass grafts were evaluated for stenosis on at least two planes, one parallel and one perpendicular to the course of the vessel. On these images, the degree of diameter stenosis was qualitatively graded by two independent readers. A significant stenosis was defined as narrowing of the lumen ≥50% [12].

***Stress SPECT MPI image acquisition and interpretation:***

Myocardial perfusion scintigraphy was performed following the one-day rest followed by stress protocol on dual head gamma Camera (SIEMENS Symbia S-Series IQ SPECT). Patients were told to refrain from tannin/ caffeine-containing beverages for at least 24 hours before the MPI study. 99mTc-Sestamibi (148-222 MBq) was administered intravenously for rest SPECT MPI. Adenosine infusion (140 mcg/kg/min) over a period of 6 minutes was used for pharmacological stress and 99mTc-Sestamibi (444-666 MBq) was injected at 3 minutes for stress SPECT MPI according to standard ASNC protocol [13]. MPI images were interpreted on short axis, horizontal long axis and vertical long axis slices. 17 segments polar map was used for assessment of territory wise fixed/ reversible perfusion defects and Summed Difference Score (SDS) was calculated using

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a 5 point (0-4) scoring system by Cedars-Sinai Medical Center software; QPS– Quantified Perfusion SPECT. SDS score of 0–1 indicates no ischemia; 2–4 points indicate mild grade ischemia; 5–6 points indicate moderate grade ischemia; while ≥7 indicate severe grade ischemia [14].

***Statistical analysis***

The Quantitative data was expressed as mean and standard deviation. Qualitative data was expressed as number and percentage. Sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV) and accuracy were obtained from 2 x 2 contingency tables. All analyses were performed using IBM SPSS statistics, version 20, for Windows.

## RESULTS

In the present study, 168 patients with ischemic heart disease who underwent CABG and presented with dyspnoea/ palpitations/ recurrent angina or angina equivalents at follow up were screened. Out of these 100 patients were enrolled in the study as per the selection criteria. Mean ± SD age of the patients was 58.27 ± 10.33 years. Male: female ratio for the study participants was 2.1:1. Hypertension and diabetes mellitus were the most common risk factors, each of which were seen in about 70% of the study participants. About 68% of the patients suffered from anterior wall myocardial infarction and 30% patients suffered from inferior wall myocardial infarction, as evaluated from the history (Table 1).

**Table 1: Demographic details and baseline patient characteristics (n= 100)**

| **Characteristic** | **No. of patients** |
|---|---|
| Age (mean ± SD, years) | 58.27 ± 10.33 |
| Male, n | 68 |
| Female, n | 32 |
| **Risk Factors, n** | |
| Hypertension | 77 |

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| | |
|---|---|
| Diabetes mellitus | 71 |
| Dyslipidemia | 46 |
| Current/ Ex- smoker or Tobacco chewer | 31 |
| Family history of CAD | 25 |
| **Cardiovascular History** | |
| **Previous MI/ ACS, n** | |
| AWMI | 68 |
| IWMI | 30 |
| LWMI | 2 |
| **Previous PCI, n** | 24 |
| **Duration since CABG (mean ± SD, years)** | 5.76 ± 4.2 |
| **LVEF on Echocardiography (mean ± SD, %)** | 38.6 ± 8.74 |

In the present study, patients were evaluated using CAG, CCTA and stress SPECT MPI. The median time interval between CAG and CCTA was 4 days (range, 3 to 8 days), between CAG and MPI was 5 days (range, 4 to 10 days), and between CCTA and MPI was 2 days (range, 1 to 6 days).

Native vessels evaluation on CAG showed Left anterior descending (LAD) artery involvement in 100% patients; and left circumflex (LCx) artery and right coronary artery (RCA) involvement in 95% patients each. Graft vessels evaluation on CAG showed involvement of arterial, venous; and both arterial and venous in 32%, 44% and 19% respectively.

Grafts evaluation on CCTA revealed that 17/31 (55%), 30/43 (70%) and 18/19 (95%) patients had ≥ 50% stenosis of arterial, venous and both grafts respectively.

Reversible perfusion defects were seen in 81% of the patients and LAD artery was affected the most in 25/81 (31%) patients. Mean ± SD of SDS score was 5.4 ± 3.39, with 33% patients having severe grade ischemia. Revascularization was carried out in 64% of the patients (Table 2).

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**Table 2: CAG, CCTA and MPI Results (n= 100)**

| | | |
|---|---|---|
| **Conventional Angiography (CAG), n** | | |
| Left Anterior Descending (LAD) stenosis | | 100 |
| Left Circumflex (LCx) stenosis | | 95 |
| Right Coronary Artery (RCA) stenosis | | 95 |
| Left Main Coronary Artery (LMCA) stenosis | | 30 |
| Patent Graft | | 5 |
| Arterial graft | | 32 |
| Venous graft | | 44 |
| Arterial + Venous graft | | 19 |
| **Coronary CT Angiography (CCTA), n** | | |
| Patent Graft | | 7 |
| Arterial graft (31) | ≥ 50% stenosis | 17 |
| | < 50% stenosis | 14 |
| Venous graft (43) | ≥ 50% stenosis | 30 |
| | < 50% stenosis | 13 |
| Arterial + Venous graft (19) | ≥ 50% stenosis | 18 |
| | < 50% stenosis | 01 |
| **Myocardial Perfusion Imaging (MPI), n** | | |
| No defects | | 19 |
| Reversible perfusion defects (81) | LAD territory | 25 |
| | LCX territory | 2 |
| | RCA territory | 16 |
| | LAD + LCx territories | 3 |
| | LCx + RCA territories | 18 |
| | RCA + LAD territories | 7 |
| | LAD + LCx + RCA territories | 10 |
| SDS (mean ± SD) | | 5.4 ± 3.39 |
| No ischemia (SDS 0-1) | | 19 |
| Mild grade ischemia (SDS 2-4) | | 17 |
| Moderate grade ischemia (SDS 5-6) | | 31 |
| Severe grade ischemia (SDS ≥ 7) | | 33 |
| **Management, n** | | |
| Medical Management | | 36 |
| Revascularization | | 64 |

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Sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV) and accuracy of CCTA and MPI were evaluated against CAG. Specificity and PPV of CCTA for detection of arterial and venous graft occlusions were 100%. Sensitivity of MPI for detection of reversible perfusion defects was 84%. Accuracy of CCTA and MPI for detection of graft occlusions were 99% and 84% respectively (Table 3).

**Table 3: Comparison of CCTA and MPI with CAG**

| | **Sensitivity** | **Specificity** | **PPV** | **NPV** | **Accuracy** |
|---|---|---|---|---|---|
| **CCTA for arterial graft** | 98.04% | 100% | 100% | 98% | 99% |
| **CCTA for venous graft** | 98.41% | 100% | 100% | 97.37% | 99% |
| **MPI** | 84.21% | 80% | 98.77% | 21.05% | 84% |

The trend of graft involvement on CCTA was evaluated against MPI SDS grading. 34 out of 35 patients with < 50% stenosis of grafts had 0 to 4 MPI SDS grading i.e. no or mild grade ischemic changes. Whereas 63 out of 65 patients with ≥ 50% stenosis of grafts had ≥5 MPI SDS grading i.e. moderate to severe grade ischemic changes (Figure 1).

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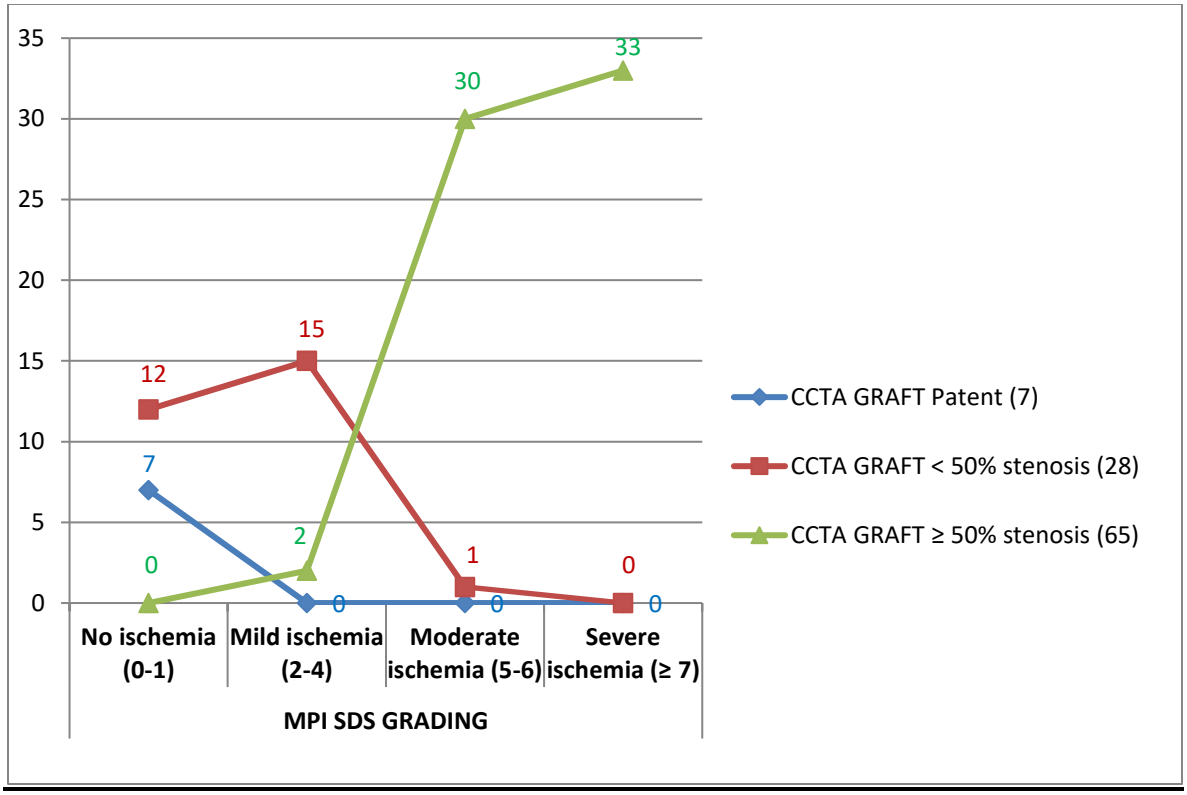


**Figure 1: Trend of CCTA Graft involvement findings against MPI SDS grading**

## DISCUSSION

In present study arterial graft occlusions were present in 32% of the patients; venous graft occlusions in 44% of the patients and 19% of the patients had both arterial and venous graft occlusions on CAG. Venous grafts were more affected than arterial grafts (63% and 62% of the patients on CAG and CCTA respectively). Study conducted by Gaudino et al [15] reported 10 years patency rate for venous of 50-60%. However we observed the higher number of arterial graft involvement (51% and 50% of the patients on CAG and CCTA respectively) than 10 years patency rate stated by Gaudino et al (5 to 15%).

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On graft evaluation using CCTA, we found comparable results with CAG with sensitivity, specificity, PPV and NPV for detecting graft disease of 98%, 100%, 100% and 98% respectively. Moore et al. [16] reported similar findings in their study.

In the present study, sensitivity and specificity of MPI for detection of reversible perfusion defects were 84% and 80% respectively. Similar findings were reported by Al Aloul et al. [17]. We observed higher PPV and lower NPV because we included only symptomatic patients and 95% of them had graft involvement on CAG.

On CCTA graft evaluation, we identified 55%, 70% and 95% of the patients had ≥ 50% occlusion of arterial, venous and; both arterial and venous grafts respectively. We further evaluated the severity of graft involvement in CCTA against MPI SDS grading. 34/35 (97.14%) of the patients with < 50% occlusion of grafts had no or mild grade ischemic changes, whereas 63/65 (96.92%) of the patients with ≥ 50% occlusion of grafts had moderate to severe grade ischemic changes on MPI. We observed reversible perfusion defects in 81% of the patients out of which 8 patients had both fixed and reversible perfusion defects. 64% patients had moderate to severe grade ischemia and ischemia guided revascularization was carried out in these patients. Tamarappoo BK et al. [18] also reported a strong association between the severity of coronary artery stenosis and the area of ischemic myocardium; 87% patients had stress-induced ischemia in areas corresponding to their supplying arteries with ≥ 50% stenosis.

Notable strengths of our study are its prospective study design and median time interval of less than a week between CAG, CCTA and MPI. We considered pharmacological stress MPI in all patients due to higher prevalence of beta-blocker use in our patient population.

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***Limitations***

This study included only symptomatic post-CABG patients presenting at a tertiary care center thus detection of higher numbers of grafts failure. Patients' treatment decisions (medical management vs. revascularization) based on stress MPI findings needs further long term follow up studies for better understanding.

## CONCLUSIONS

CCTA is a non-invasive, rapid, reliable and readily available investigation. Findings from our study favor the use of CCTA as an initial investigation instead of CAG in symptomatic post-CABG patients due to its comparable diagnostic accuracy for detecting graft disease.

SPECT MPI showed a good sensitivity, specificity and accuracy for detecting angiographic bypass graft disease in this prospective cohort study. Thus reversible perfusion defects on SPECT MPI help to risk stratify symptomatic post-CABG patients and guide further patients' treatment strategies. Hemodynamically significant coronary artery occlusions may benefit from revascularization.

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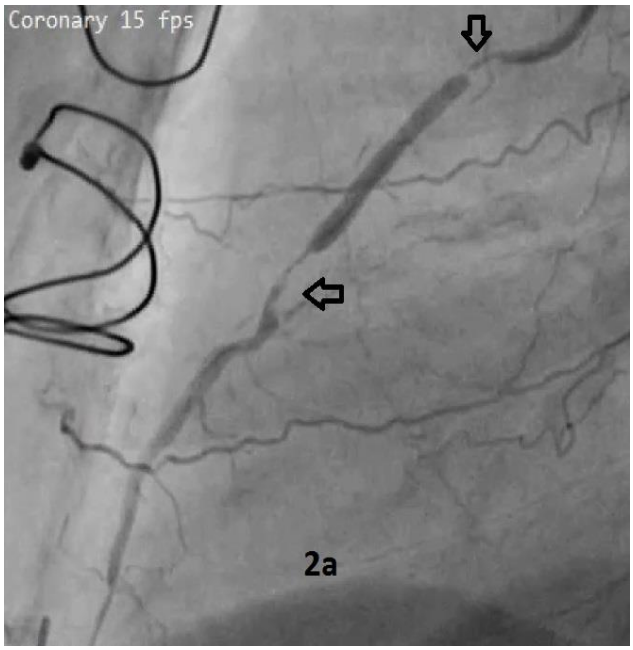


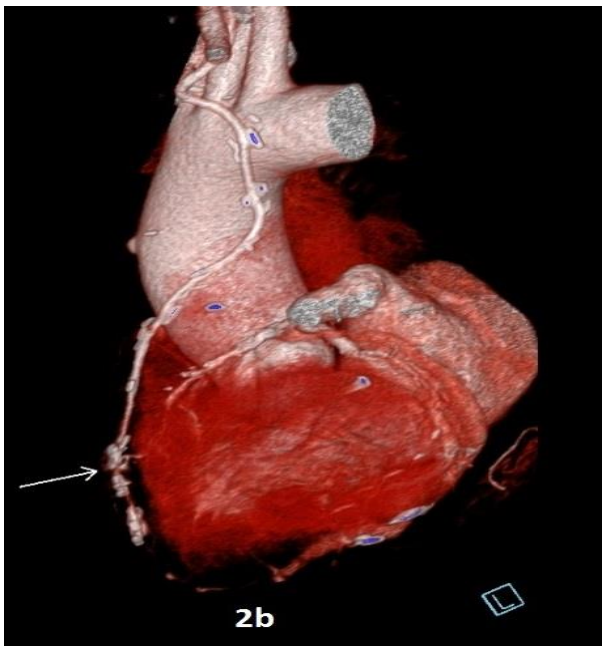

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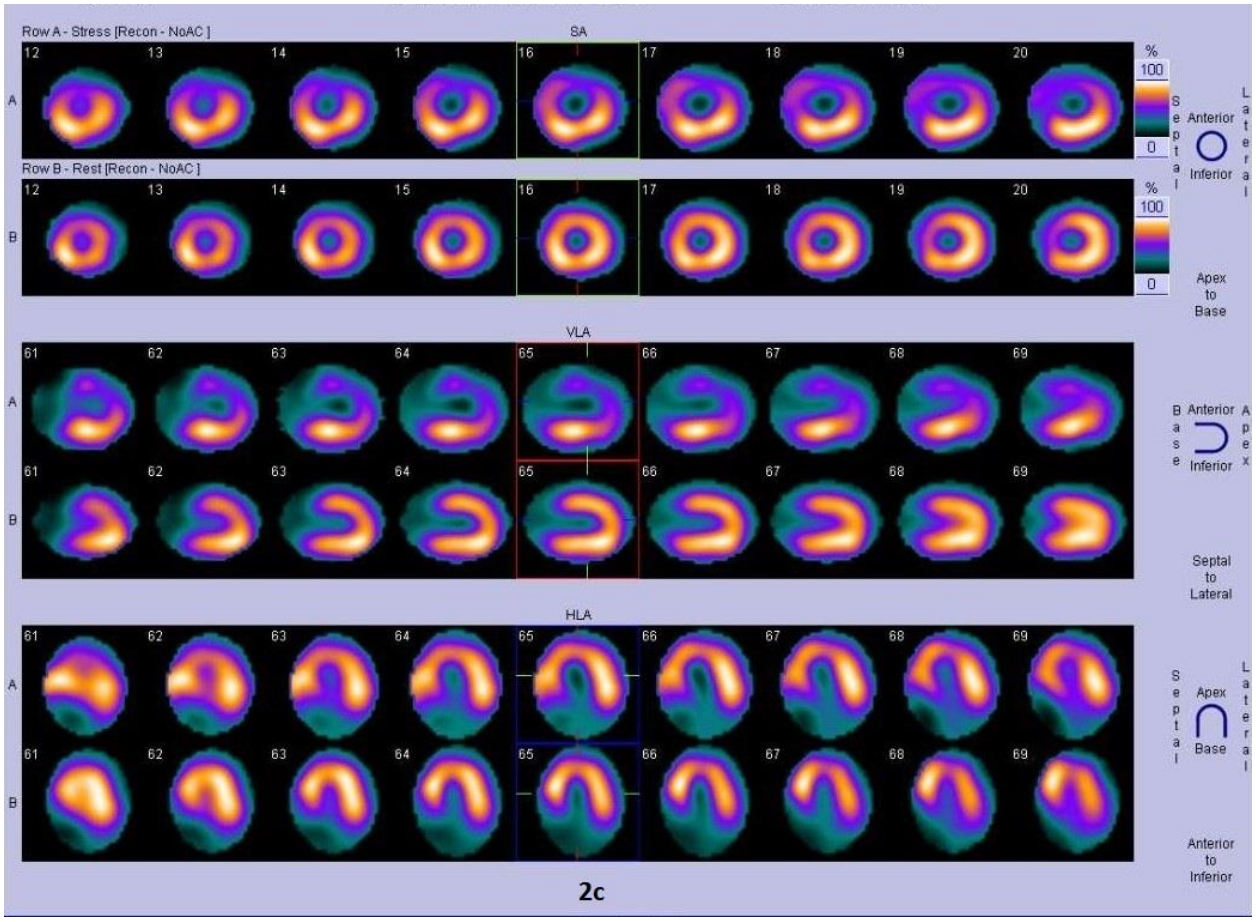


**Figure 2:** Illustration of a patient who presented with recurrent angina post-CABG. **Invasive angiography (2a)** and three-dimensional volume-rendered **Coronary CT Angiography** (**2b)** images demonstrating occlusions of Left internal mammary artery (LIMA) graft (arrows). **SPECT stress Myocardial Perfusion Imaging** (**2c)** image showing LAD artery territory severe grade stress inducible ischemia (SDS- 7).