Original Article

Myocardial Perfusion Scan Study before and after On-Pump Coronary Artery Bypass Grafting Surgery – A Single-Center Study

Abstract

Aim: Ischemic cardiac disease is the most common adult heart disease. The primary aim of the study was to analyze the myocardial perfusion status of the patients undergoing coronary artery bypass graft using sestamibi scan and assess the improvement in perfusion status of the myocardium after the surgery. **Materials and Methods:** This study was a descriptive study consisting of a single group of patients undergoing elective surgery for coronary artery disease. The patients underwent myocardial perfusion scan before surgery. Another myocardial perfusion scan was performed 3 months after the surgery. The change in myocardial perfusion status was analyzed. **Results:** Totally, 49 patients were initially included in this study. Seven patients lost their follow-up. Among the 17 patients who had severely reduced tracer uptake preoperatively, 3 (7.1%) had a good outcome, while 14 (33.3%) had a poor outcome, which was statistically significant ($P < 0.001$). Eighteen cases who belonged to the category of moderately reduced tracer uptake while analyzed, it was found that 16 (38.1%) had a good outcome while only 2 (4.8%) had a poor outcome; the difference in proportion among these two groups was statistically significant ($P < 0.001$). The patients who had mildly reduced tracer uptake preoperatively, all 3 (7.1%) had a good outcome, but it was not statistically significant ($P = 0.23$). Four patients had adequate tracer uptake preoperatively, out of which 3 (7.1%) had a good outcome, while the other 1 (2.4%) had a poor outcome and was not statistically significant ($P = 0.63$). **Conclusion:** Surgical revascularization improves perfusion in a selective group of patients.

Keywords: *Coronary artery bypass grafting, coronary artery disease, myocardial perfusion*

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Introduction

Ischemic heart disease is the most common disease of the heart, in which the pathophysiology is the mismatch between the demand and supply of the blood to the heart. In this entity, coronary artery disease (CAD) remains the largest killer causing one-third of all the deaths in people older than 35 years.[1] With the increasing trend of urbanization and sedentary lifestyle, the cardiometabolic diseases are becoming more prevalent.[2] Currently, the disease is managed either conservatively with drugs and lifestyle modifications, percutaneous interventional procedures or by coronary artery bypass graft (CABG) operations. The major factor which decides the outcome of this condition is the extent of viable myocardium remaining in the heart for its function. Although all the patients who are subjected to CABG undergo preoperative coronary angiogram for mapping the pattern of coronary lesions, the actual status of the myocardial perfusion at the target tissue level is mostly assumed than exactly known. Hence, the assessment of the viability of the myocardium plays an important role to determine the outcome of the treatment, especially in patients with left ventricular (LV) dysfunction. The concept of myocardial hibernation was used to describe a state of chronic, sustained abnormal contraction attributable to chronic underperfusion in patients with CAD, and in whom revascularization recovers the LV function.[3] Myocardial stunning has been defined as reversible myocardial contractile dysfunction in the presence of normal resting myocardial blood flow.[4,5] To assess the myocardial function routinely, echocardiogram and ventriculogram are used. The other modalities such as Flurodeoxyglucose-positron emission tomofraphy (FDG-PET), magnetic resonance imaging, and single-photon emission computed tomography (SPECT) are adjuncts in the evaluation of the ventricular function. Nuclear scan techniques, which show preserved tracer uptake and metabolism in

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viable myocardium, is also being useful as a tool in the preoperative workup of the patients with CAD. FDG/PET is considered the reference standard due to its ability to differentiate dysfunctional but viable myocardium from scar formation and normal myocardium. In patients with ischemic cardiomyopathy, CABG offers an important therapeutic option; however, this operative procedure is still associated with significant perioperative mortality. The patients without viable myocardium have increased mortality than those with viable myocardium.[6] Hence, this study was done with the aim to analyze the various patterns of the myocardial perfusion status in various segments before and after CABG.

Materials and Methods

All consecutive patients aged >18 years who underwent elective coronary artery bypass surgery for CAD in the department of cardiothoracic and vascular surgery under general anesthesia were included in the study. Endarterectomy was done with CABG for patients who had diffusely diseased CAD. Patients belonging to the American Society of Anesthesiologists Grade III or less were included in the study. Those patients who underwent emergency CABG were excluded from the study. This study was a descriptive study consisting of a single group of patients undergoing elective surgery for CAD. Sample size was calculated using OpenEpi software version 3.01 (Andrew G. Dean and Kevin M. Sullivan, Atlanta, GA, USA). With the expected proportion of participants before CABG as 88% and with the expected decrease in the positivity after CABG to be 62% based on a previous study, the sample size was calculated to be 49 (both intervention and control arm are the same) with 95% confidence interval (CI) and 80% power.[7]

Written informed consent was taken from all the eligible participants before the commencement of the study. All diagnosed CAD patients planned for elective CABG were referred for myocardial viability assessment using technetium-99m (99mTc)-sestamibi SPECT myocardial perfusion imaging (MPI) to the department of nuclear medicine. The Rest MPI SPECT was performed by administering 99mTc-sestamibi of 10 mCi dose intravenously. Images were acquired using hybrid SPECT-computed tomography dual-head gamma camera fitted with parallel-hole, low-energy high-resolution collimators. Acquisition was done instep and shoot mode, using contoured orbit, rotation arc of 180°, 64 projections, and 20 s per projection time. The image acquisition matrix was 64 × 64 and acquired in technetium window with 140 KV peak and 20% window. Eight frames per cardiac cycle were acquired using electrocardiogram gating. The images were reviewed by an experienced nuclear medicine physician and interpreted qualitatively and semiquantitatively. The images were evaluated based on 17-segment model, and myocardial segments with abnormal perfusion were recorded for segment sites, number of segments, and degree of reduction in uptake as normal, mild, moderate, severe, and absent uptake. The summed rest score was also evaluated, and the following scale was used for scoring perfusion in each segment. (0 = Normal, 1 = Mildly reduced uptake, 2 = Moderately reduced uptake, 3 = Severely reduced uptake, and 4 = Absent uptake). The segments with severely reduced perfusion and absent perfusion were considered scarred myocardium. Myocardial segments with mild-to-moderate perfusion defect were considered hibernating myocardium. The evaluation with MPI at rest was repeated after 3 months of CABG to assess any change in the degree of myocardial perfusion [Figures 1 and 2]. Those patients who had normalized perfusion scintigraphy compared to preoperative abnormal scintigraphy on their follow-up were considered to have complete improvement. Those who had improvement in their perfusion, but with residual perfusion defect, were considered to have a partial improvement. Patients were considered to have no change when their perfusion status remained the same after surgery. Those who had worsened perfusion scintigraphy were considered to have been deteriorated. Data were collected using a pro forma which included the details to be collected. Preoperatively, patient's age, sex, body mass index (BMI), comorbidity status, angiogram, and echocardiogram reports were collected. The intraoperative details such as the number of grafts placed, number of arterial and venous grafts placed, duration of cardiopulmonary bypass and aortic cross-clamp, whether with or without endarterectomy, and duration of stay in the hospital were noted. Patients were followed up after the surgery. Myocardial perfusion scan was repeated during the 3rd month of their follow-up. The primary outcome measure was the change in the myocardial perfusion status after coronary artery bypass procedure compared to preoperative perfusion scan was assessed. The secondary outcome measures were association of other factors considered preoperatively and intraoperatively, with the postoperative perfusion status in patients undergoing elective surgery

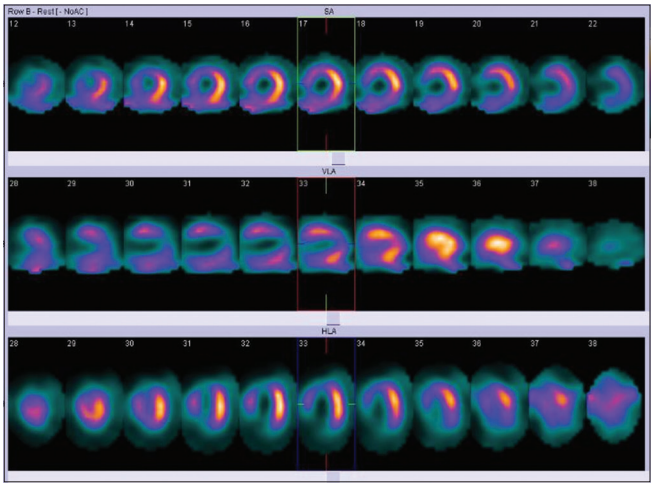

Figure 1: Myocardial perfusion scan taken preoperatively

for CABG. The association of other factors such as BMI, comorbidities, and presenting complaints with severity of perfusion uptake before surgery was analyzed. The association of intraoperative factors such as endarterectomy procedure, aortic cross-clamp time, and cardiopulmonary bypass time with change in perfusion status was also studied.

Patients were divided into four groups: severely reduced uptake, moderately reduced uptake, mildly reduced uptake, and adequate uptake. The presenting complaints and the changes in the perfusion status among the different groups were analyzed. The final outcome was divided into good and poor. The status of completely improved or partially improved myocardial perfusion was considered a good outcome and that with no change or worsened tracer uptake was categorized as a poor outcome, except those with preoperative adequate tracer uptake and had no postoperative changes in the status of myocardial perfusion, were included under a good outcome category. The statistical analysis was done using the Chi-square test. The variables considered were analyzed among the four groups. For testing the statistical difference of continuous variables among the four groups, the independent *t*-test was used. A difference in the proportion of these categorical variables was considered statistically significant with $P < 0.05$. Independent effect of those factors found significant on this univariate analysis on the postoperative outcome was analyzed using multivariate logistic regression analysis.

Results

Out of the 49 patients ($n = 49$) of CAD included in the study, 43 patients were male and six patients were female. The mean age in the study was 55 ± 8.5 years [Table 1]. Among 49 patients, 12 patients had only diabetes, nine patients had systemic hypertension, 21 patients had both diabetes and hypertension, and 21 patients had hypercholesterolemia. The mean duration of stay in hospital after surgery was 12 ± 6.5 days. The mean age of males and females was 55.5 ± 8.8 and 51.5 ± 8 years, respectively. The difference in the mean age was not statistically significant ($P = 0.286$). The male-to-female ratio was 7.1:1. The average number of grafts used per person was 3.1 ± 0.91, out of which the average number of arterial grafts and venous grafts was 0.91 ± 0.32 and 2.16 ± 0.92, respectively. The average cardiopulmonary bypass time was 238.73 ± 101.75 min, while the average aortic across-clamp time was 169.08 ± 79.35 min. The left internal mammary artery was used in 42 patients (85.7%); radial graft was used in one patient, and the right internal mammary artery was used in one patient.

The majority of the patients had severely reduced tracer uptake before CABG: 46.9% had a score 3, while the other groups with score 2 (moderately reduced tracer uptake), score 1 (mildly reduced tracer uptake), and score 0 (with adequate tracer uptake) formed 38.7%, 6.2%, and 8.2%, respectively, as shown in Table 2.

Among the 4 (8.2%) patients who had rest angina, 2 (4.1%) had severely reduced tracer uptake, while the other 2 (4.1%) had moderately reduced tracer uptake; exertional angina was found in 39 (79.5%) patients, of which 20 (40.8%) had severely reduced tracer uptake, 13 (26.5%) had moderately reduced tracer uptake, 3 (6.1%) patients revealed mildly reduced tracer uptake, and the other 3 (6.1%) had adequate tracer uptake; exertional dyspnea was the complaint in 39 (79.5%) patients, out of which 19 (38.7%) had severely reduced tracer uptake, 15 (30.6%) had moderately reduced

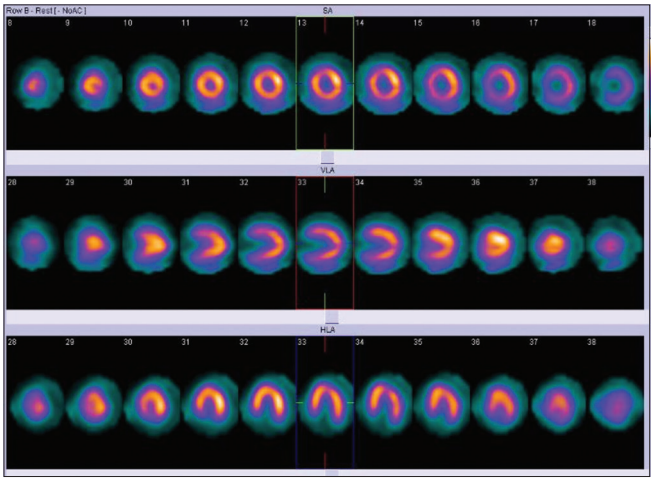

Figure 2: Myocardial perfusion scan taken postoperatively showing improvement in uptake

Table 1: General characteristic of patients undergoing coronary artery bypass graft

Parameter	Total (*n*=49)
Age (years), mean±SD	55±8.5
Gender	
Male	43
Female	6
Comorbidities	
Diabetes	33
Hypertension	30
Both DM SHT	21
Hypercholesterolemia	15
Duration of stay	12±6.5

DM: Diabetes mellitus, SHT: Systemic hypertension, SD: Standard deviation

Table 2: Myocardial perfusion analysis

Perfusion status	Before CABG (*n*=49), *n* (%)
Score 0	4 (8.2)
Score 1	3 (6.2)
Score 2	19 (38.7)
Score 3	23 (46.9)

CABG: Coronary artery bypass graft

tracer uptake, only 1 (2%) had mildly reduced tracer uptake, and 4 (8.2%) patients had adequate tracer uptake.

Table 3 shows the comparison of preoperative myocardial perfusion status with postoperative myocardial perfusion status categorized as cases of good and poor outcome. Among the 17 patients who had severely reduced tracer uptake preoperatively, 3 (7.1%) had a good outcome, while 14 (33.3%) had a poor outcome; the difference in proportion among these two groups was statistically significant ($P < 0.001$). Eighteen cases who belonged to the category of moderately reduced tracer uptake while analyzed, it was found that 16 (38.1%) had a good outcome, while only 2 (4.8%) had a poor outcome; the difference in proportion among these two groups was statistically significant ($P < 0.001$). The patients who had mildly reduced tracer uptake preoperatively, all 3 (7.1%) had a good outcome, but it was not statistically significant ($P = 0.23$). Four patients had adequate tracer uptake preoperatively, out of which 3 (7.1%) had a good outcome, while the other 1 (2.4%) had a poor outcome; the difference in proportion among these two groups was not statistically significant ($P = 0.63$) [Figure 3].

Eight patients underwent endarterectomy; among them, 3 (7.1%) had a good outcome, while 5 (11.9%) had a poor outcome; the difference in proportion among these two groups was not statistically significant ($P = 0.44$). On univariate analysis, the patients who had preoperative hypertension were associated significantly ($P = 0.042$, relative risk-0.41, CI-0.16–1.04) with a poor outcome as seen in the postoperative myocardial perfusion scan. Among the study group of 49 patients, 30 patients had systemic hypertension. Other factors such as obesity, diabetes mellitus, and diabetes with hypertension, rest angina, and exertion angina were not significantly associated with a poor outcome.

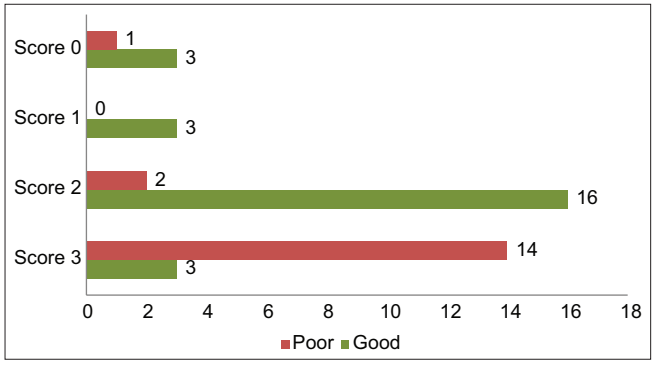

Figure 3: Myocardial perfusion analysis after CABG. CABG: Coronary artery bypass graft

Discussion

Coronary artery bypass surgery has been an effective means of revascularization procedure for patients with CAD. Myocardial perfusion scan plays a cardinal role in assessing the microvascular flow status of the myocardium. In our study, we have used 99mTc-sestamibi nucleotide to evaluate the perfusion status. The nucleotide uptake is based on the integrity of the cell membrane. The perfusion status is analyzed based on the tracer uptake during the study.

In the present study, the male population was found to be more. The mean age was 55 years. Diabetes was predominant comorbidity in our study population. Patients with preoperative severely reduced tracer uptake in perfusion study were high when compared to the other group. The main symptoms in our study were dyspnea on exertion and exertional angina. Patients with severely reduced tracer uptake in our study had poor outcomes. Patients with moderately reduced tracer uptake had good outcomes. Endarterectomy procedure was not associated with poor outcomes. Systemic hypertension was found to be an important risk factor in our study.

Myocardial perfusion uptake helps in differentiating a viable myocardium from a nonviable myocardium based on the Radionuclide tracer uptake. Nonviable myocardium is usually identified by the presence of scar. Viable myocardium can either be functional or nonfunctional. Hibernating and stunned myocardium are classified as nonfunctional viable myocardium. Nonfunctional myocardium can be identified in myocardial perfusion scan based on the tracer.[8] In our study, we classified the reduced tracer uptake into severe, moderate, and mild. We found out that the patients with severely reduced uptake of tracer did not improve after CABG. It indicates the presence of nonviable myocardium in majority of this group of patients. Patients with moderate and mildly reduced uptake had improvement in perfusion status implying that these patients had nonfunctional and viable myocardium which improved after CABG. The study has mainly helped in identifying the set of patients who will benefit from CABG. To the best of our knowledge, so far, there is no Indian study comparing the preoperative perfusion status with that of the postoperative period, which could guide for appropriate patient selection.

Table 3: Myocardial perfusion analysis after coronary artery bypass graft

Preoperative perfusion status	*n*=49	Good outcome, *n* (%)	Poor outcome, *n* (%)	*P*
Adequate reduced uptake (Score 0)	4	3 (7.1)	1 (2.4)	0.63
Mildly reduced uptake (Score 1)	3	3 (7.1)	0	0.236
Moderately reduced uptake (Score 2)	18	16 (38.1)	2 (4.8)	<0.001*
Severely reduced uptake (Score 3)	17	3 (7.1)	14 (33.3)	<0.001*

*Chi-square test

The mean age of patients in the western population was somewhat higher than in our study group. The mean age in a study done by Stipac *et al*. from Serbia and Chalela *et al*. from Brazil was 59 years; whereas it was 55.5 years in our study group. The male preponderance of the study group was as similar in the study of Chelala *et al*.[7,9] Among the routine risk factors for CAD, diabetes was the major comorbid condition in our study; whereas it was hypercholesterolemia in the report from the study published by Stipac *et al*. Rest angina was the most common symptom followed by dyspnea on exertion in the study done by Paluszkiewicz *et al*.; whereas most of the patients in our study had dyspnea on exertion as the most common symptom, followed by exertional angina.[10] According to Chalela *et al*., most of the patients had triple-vessel disease, and the left anterior descending artery was the most commonly grafted vessel similar to the observation in our study.[7]

According to Eckardt *et al*., most of the patients (70%) with irreversible defects in perfusion study had no change in perfusion in their postoperative follow-up;[11] this finding was similar to that in our study, which revealed that most of the patients who had severely reduced tracer uptake in the preoperative evaluation showed no changes in the perfusion after CABG. Moreover, 75% of the patients with reversible perfusion defects normalized in myocardial perfusion after CABG in the study of Eckardt *et al*., and similar results were observed in our study; however, their study reported deterioration in patients with partially reversible perfusion defects in contrary to our study which showed patients with moderately reduced tracer uptake improving after the revascularization similar to that reported by Schinkel *et al*., in which dobutamine stress echocardiogram was used to assess the viability.[12] A similar study done by Auerbach *et al*. also reported 27% of the study population improving after revascularization.[13]

Surgical Treatment for Ischemic Heart Failure trial, a randomized control trial, demonstrated that patients with CAD and LV dysfunction would have a better outcome than those being treated with aggressive medical therapy; however, a sub-study did not show a significant relation of viability scan in selecting patient management with respect to mortality;[6] this study had a few limitations like nonavailability of the viability study for many of the patients; revascularization procedures were not based on viability study; however, the viability testing was done based on clinical decisions. A case–control cohort study by Stpiac *et al*. analyzed 115 patients on their LV function using dobutamine stress echocardiogram; in this, the beneficial effects of CABG were observed even in patients with LV dysfunction and nonviable myocardium.[9] A meta-analysis of 24 prognostic studies was done by Allman *et al*., comparing the annual death rate of patients with viable myocardium, who underwent revascularization surgery, with those treated medically; the annual death rate was 3.2% among those who underwent CABG, while it was 16% in those who were treated with medical management.[14]

In a long-term study done by Qiu *et al*., coronary endarterectomy (CE) with CABG offered good midterm results in patients with diffuse CAD; whereas no significant postoperative complications were observed in the study published by Nemati *et al*., which compared CE plus CABG with just CABG.[15,16] In a meta-analysis of 30 studies done by Wang *et al*., CE plus CABG is associated with an increased postoperative mortality and morbidity when compared to just CABG.[17] As far as we know, our study is the only study to compare the changes in the myocardial perfusion status in patients undergoing CE plus CABG; we observed that there was no significant difference in the perfusion status among this group of patients. However, our study population is too small to make a confirmed statement.

Afridi *et al*. noted that LV myocardium can take 7 days to 12 months for full recovery from hibernation after revascularization, and chronic hibernating myocytes may take more time for recovery.[18] The follow-up period of our study with myocardial perfusion scan was 3 months after the operation.

Within the limits of our search, this is the first viability study done to assess the perfusion status after revascularization in Indian population. The study successfully demonstrated a significant improvement in patients with moderately reduced tracer uptake and no change in patients with severely reduced tracer uptake. This is important in predicting the perfusion changes after revascularization. It also revealed that endarterectomy did not affect the myocardial perfusion status of the patients postoperatively.

Limitations of the study

The use of nitrates is known for augmented detection of viable myocardium. However, we have not used nitrates during the perfusion scan. The sample size of our study was not large enough to recommend nuclear perfusion studies routinely for all the patients undergoing CABG; more such studies when culminate for meta-analyses, stronger guidelines or recommendations can be made in future. The follow-up period of our study was limited to only the first 3 months of surgery. As myocardial recovery may take 12 months or more, studies designed for a longer period may help in knowing the long-term effects of these operations with respect to the myocardial perfusion. Hence, the group of patients who had severe perfusion defect on 99mTc-sestamibi MPI scan may show delayed improvement in perfusion and LV function, and those patients who did not have any change in tracer uptake in the present study may be followed up further.

As there was no coronary angiogram performed in each stage of evaluation during myocardial perfusion scan to

compare and correlate the arterial anatomy except being done once in the preoperative period, we may miss to acquire a holistic picture of the coronary perfusion pattern and function. Our study involved only the patients who are being prepared for elective operations, and most of them having chronic stable angina. Hence, more studies are required to analyze the changes happening in the myocardial perfusion in patients presenting with acute conditions undergoing emergency operations.

Conclusion

This study was a single-center, prospective study to assess the myocardial perfusion status as the primary outcome before and after elective CABG, and also to find the association of risk factors with the grades of changes in the myocardial perfusion status in these patients. We used 99mTc-sestamibi scan for our study, which was performed initially before the operation, and it was repeated at the time of follow-up period at 3 months after surgery. With the study involving 49 patients in the age group of above 18 years, we found that those with severely reduced tracer uptake, which is suggestive of nonviable myocardium, remained status quo in perfusion after surgery; those with moderately reduced tracer uptake had a good outcome; the majority of the patients in both the groups – those with mildly reduced uptake and those with adequate tracer uptake, had a good outcome; however, as the number of patients was least in these groups, this observation was not statistically significant. We also found that CE during CABG did not affect the perfusion status significantly. As far as the univariate analysis is considered, among the variables studies, systemic hypertension was the only one which was significantly associated with a poor outcome. We need further studies with multicentric trials and meta-analysis to confirm our observation and to recommend nuclear perfusion scan for the cardiac evaluation as a routine method to decide on the outcome with respect to the risk versus benefit of surgical procedures.

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Nil.

Conflicts of interest

There are no conflicts of interest.

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