Original Article

Fluorine 18-Fluorodeoxyglucose Positron Emission Tomography/Computed Tomography Cardiac Viability Risk Stratification in Comparison with EuroSCORE II for Revascularization in Patients with Left Ventricular Dysfunction

Brithika Yoganayaki Thangamuthu, Indirani Elangovan, Patel Asra, Shelley Simon, Immaneni Sathyamoorthy[1]

Departments of Nuclear Medicine and [1]Cardiology, Apollo Hospitals, Chennai, Tamil Nadu, India

Abstract

Background: Diagnostic value of fluorine 18-fluorodeoxyglucose positron emission tomography/computed tomography (F18-FDG PET/CT) in the assessment of myocardial viable segments is well known; hence, it can identify patients with left ventricular (LV) systolic dysfunction who may benefit from revascularization. The presence of significant myocardial viable segments before revascularization will offer better prognosis with reduced mortality and morbidity. However, the usage of F18-FDG PET/CT myocardial viability study in the presurgical risk stratification is limited. **Objective:** The objective of the study is to predict perioperative mortality with hibernating viable myocardial (HVM) segments established by F18-FDG PET/CT in comparison with EuroSCORE II in patients with LV dysfunction undergoing coronary artery bypass grafting surgery. **Materials and Methods:** A prospective, observational study included 75 patients of chronic ischemic coronary artery disease with ejection fraction ≤40%. Tc-99m sesta-methoxyisobutylisonitrile myocardial perfusion single photon emission CT/CT and myocardial viability with F18-FDG PET/CT at rest were performed. Mortality risk stratification was done according to the EuroSCORE II. Patients were followed for post-coronary artery bypass graft surgery (CABG) 30-day mortality. Mortality observed by HVM segment groups were compared with EuroSCORE II predicted mortality. **Results:** Receiver operating curve for 30-day mortality prediction with HVM segments and EuroSCORE II was constructed. It showed that a cutoff of <4 HVM segments (area under the curve [AUC] = 0.7) had a sensitivity of 85%, whereas EuroSCORE II (AUC = 0.4) had only 28.6% sensitivity. EuroSCORE II underestimated perioperative risk in patients with <4 viable segments, that is 5 times higher risk was observed in patients with <4 viable segments. **Conclusions:** HVM segments established by F18-FDG PET/CT had independently predicted mortality postoperatively. Hence, including F18-FDG PET/CT for viability assessment along with EuroSCORE II in preoperative risk assessment for revascularization by CABG in patients with LV dysfunction provided better risk stratification.

Keywords: *EuroSCORE II, fluorine 18-fluorodeoxyglucose positron emission tomography/computed tomography, hibernating*

Introduction

Ischemic heart disease (IHD) is one of the major causes of cardiovascular death.[1,2] Proper identification is essential for choosing appropriate treatment. Coronary artery bypass graft surgery (CABG) in patients with multivessel disease and left ventricular (LV) dysfunction provides improved quality of life with minimal operative risks.[2] Cardiac risk scoring systems provide pre- and peri-operative risk assessment with surgical triage, thereby facilitating easy understanding of operative risk, cost–benefit ratio, and choice of therapy for a patient and his/her families.[3,4] One of the most widely used risk scoring systems, EuroSCORE II, predicts both morbidity and mortality.[4-6] Myocardial viability is a vital prognostic predictor in patients with coronary artery disease.[7-9] Patients with significant number of hibernating viable myocardial (HVM) segments have shown improvement following revascularization with reduced mortality and morbidity.[7-9] Positron emission tomography (PET)/computed tomography (CT) using fluorine 18-fluorodeoxyglucose

How to cite this article: Thangamuthu BY, Elangovan I, Asra P, Simon S, Sathyamoorthy I. Fluorine 18-fluorodeoxyglucose positron emission tomography/computed tomography cardiac viability risk stratification in comparison with EuroSCORE II for revascularization in patients with left ventricular dysfunction. Indian J Nucl Med 2023;38:110-4.

Address for correspondence:
Dr. Shelley Simon, Department of Nuclear Medicine, Apollo Hospitals, Chennai, Tamil Nadu, India.
E-mail: shelleysimon@rediffmail.com

Received: 25-04-2022
Accepted: 08-08-2022
Published: 08-06-2023

Access this article online

Website: www.ijnm.in

DOI: 10.4103/ijnm.ijnm_74_22

Quick Response Code:

(F18-FDG) myocardial viability study recognizes patients who may benefit from revascularization, in regard to improvement in LV function, symptoms, and long-term prognosis.[7-9] However, myocardial viability is not included in any of the risk scoring systems. Therefore, the objective of the present study is to assess HVM segments in chronic ischemic LV dysfunction patients undergoing coronary artery bypass surgery to predict perioperative morbidity and mortality in comparison with EuroSCORE II prediction.

Aim

The aim of the study is to predict perioperative mortality with HVM segments established by F18-FDG PET/CT in comparison with EuroSCORE II in patients with LV dysfunction CABG surgery.

Materials and Methods

This is a prospective, observational study conducted during March 2018 to June 2019 in the Department of Nuclear Medicine and PET/CT, Apollo Hospitals, Chennai. It included 75 patients who have done CABG after F18-FDG PET/CT aged 25–85 years. They are chronic (>90 days) IHD patients with ejection fraction (EF) ≤40. Patients who had undergone other procedures such as cardioverter defibrillator implantation and maze procedure and were medically managed patients were excluded. A detailed clinical history and consent for both imaging was obtained. Patients were stratified into low (0–2), moderate (2–5), and high risks (>5) using EuroSCORE II calculator from website www.euroscore.org/calc.html formed by the EuroSCORE Study Group 2011.[5,6]

Myocardial single photon emission computed tomography (SPECT) imaging was performed with 8–10 mCi/296–370 Mbq of Tc-99m sesta-methoxyisobutylisonitrile (MIBI) administered intravenously at rest, following which the patients were advised to have a fatty meal to accelerate hepatic clearance of tracer. SPECT with low-dose CT (for attenuation correction) was performed 45–60 min postinjection using Siemens Symbia T6 Dual head gamma camera by Siemens healthineers, USA. The images were acquired in 32 projections per detector over 104°, 20 s per projection, with starting angle at 52° using Low energy High resolution (LEHR) collimator coupled with Electrocardiography (ECG) gating. Reconstruction was done using iterative reconstruction. Quantitative processing (5-point scale: 0 = no defect; 1 = mildly reduced; 2 = moderately reduced; 3 = severely reduced; 4 = absent activity) was done on Cedars Sinai Toolbox.

The following day, after 6 h of fasting, the patients underwent cardiac F18-FDG PET/CT. Blood glucose level was checked and glucose load and insulin were given as per the American Society of Nuclear Cardiology guidelines.[7,8] 3–5 mCi/111–185 Mbq of F18-FDG was injected intravenously. Imaging was performed 1-h postinjection on Philips Gemini TF-64 PET-CT scanner by Philips, USA with ECG gating using standard cardiac protocol. The images were reconstructed using iterative reconstruction technique. A cutoff level for FDG uptake of 50% or greater has been considered as HVM segment. Both images were loaded and analyzed in "17-segment" model for HVM segmental analysis as illustrated in Figure 1a and b. Defects in both the studies (matched) were considered scars [Figure 1a]. Perfusion defects at Tc-99m MIBI SPECT/CT study, showing F18-FDG uptake (mismatched), were regarded as HVM segment [Figure 1a]. Minimum of four HVM segments has shown overall improvement after CABG;[7,8] hence, patients were classified into two groups (Group I ≥4 segments and Group II <4 segments). Death occurring within 30 days of the cardiac surgery (cardiac and noncardiac causes) and clinical improvement status were obtained with the help of referring physician, patients, and case records.

Approval

The study was approved by our hospital ethical committee.

Statistical analysis used

Continuous variables were expressed as mean plus or minus standard deviation, if they were normally distributed. Nonnormally distributed continuous variables were represented by median (interquartile range). Categorical/qualitative variables were represented by percentage. Comparison of categorical variables was done by Chi-square test or Fisher's exact test. Comparison of paired categorical variables was done using McNemar test. Comparison of paired continuous variables was done using paired *t*-test. Comparison of independent continuous variable between the groups was done using independent sample *t*-test. Data entry was done in MS Excel Spread Sheet. Data analysis was carried out in SPSS version 25 (Statistical Package for Social Science) software for statistics by IBM company. $P < 0.05$ was considered as statistically significant. Receiver operating characteristic (ROC) curve was constructed between viability and EuroSCORE II to calculate sensitivity and specificity for cutoff for 30-day mortality prediction.

Results

Seventy-five patients with LV dysfunction had undergone CABG after F18-FDG PET/CT myocardial viability study. 42 patients had 4 or more HVM segments. Thirty-three patients had less than four HVM segments. The general characteristics of the study population are shown in Table 1. Distribution of HVM segments among the survivors and survivors are shown in Figure 2a and b. Mortality was found higher in patients with less than four HVM segments compared with patients with four or more HVM segments. Pearson's Chi-square test showed statistically significant association between 30-day mortality and viability, with significant $P = 0.020$. Observed mortality in

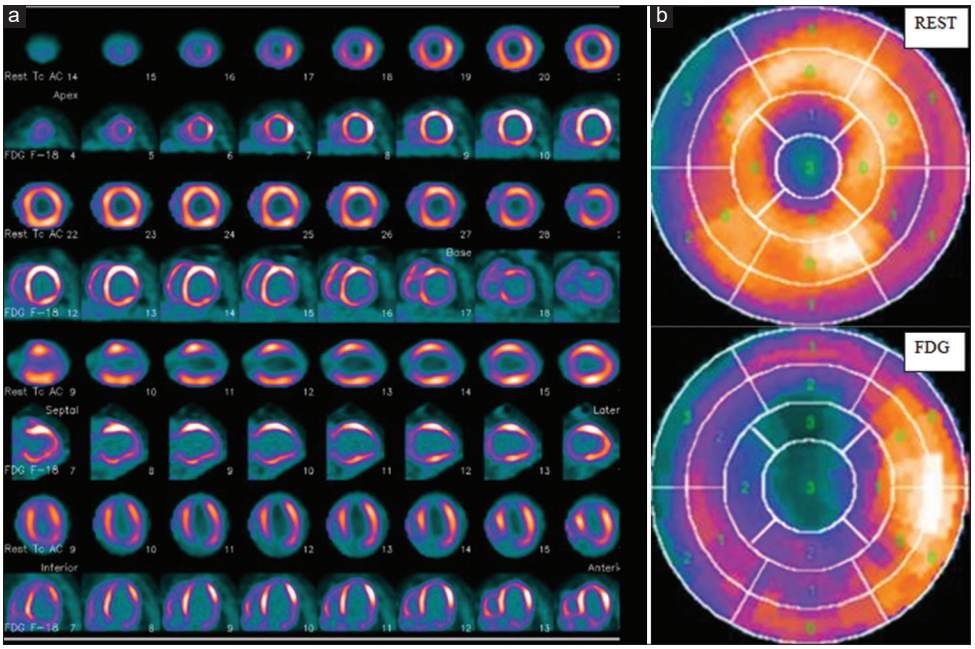

Figure 1: (a) Fluorine 18-fluorodeoxyglucose positron emission tomography/computed tomography and Tc-99m sesta-methoxyisobutylisonitrile myocardial viability study sectional images. (b) 17 segmental analysis showing hibernating viable myocardial segments in part of apical and mid anterior, part of anteroseptum and small part of inferolateral segments of left ventricular myocardium-4 segments. Apex and the remaining adjoining segments show scarred myocardium

Table 1: Overall characteristic of study population

Factor	Percentage (%)
Gender (male/female)	59/16
Age (mean)	56.99
Preoperative NYHA	
Class I	1 (1)
Class II	32 (43)
Class III	42 (56)
EuroSCORE II risk group	
Low risk (0-2)	30 (40.0)
Moderate risk (2-5)	37 (49)
High risk (>5)	8 (11)
Diabetes	45 (60)
Hypertension	50 (66)
Dyslipidemia	25 (33)
COPD	10 (13)
No comorbidities	15 (20)
Previous history of CAD	75 (100)
Smoking	30 (40)

NYHA: New York Heart Association for Heart Failure symptoms, COPD: Chronic obstructive pulmonary disease, CAD: Coronary artery disease

EuroSCORE II risk groups is shown in Table 2. Fisher's exact test showed that there was no significant association between 30-day mortality and EuroSCORE II (P = 0.6). On comparing observed mortality among EuroSCORE II with HVM segments as shown in Figure 3, two patients were low risk by the EuroSCORE II but had only <4 HVM segments. Hence, EuroSCORE II underestimated risks in patients with <4 HVM segments. ROC curve for viability and EuroSCORE II in predicting 30-day mortality showed that the sensitivity and specificity cutoff of ≤4 hibernating viable segments in identifying nonsurvivors is 85% and 40% area under curve (AUC = 0.7). EuroSCORE II failed to differentiate between survivors and nonsurvivors (AUC = 0.4). It is shown in Figure 4. Observed mortality in <4 HVM segments group is 5 times higher than the mean EuroSCORE II predicted mortality score. EuroSCORE II underestimated theperioperative risk in patients with <4 HVM segments, that is 5 times higher risk was observed in patients with less than four HVM segments, as shown in Table 3.

Discussion

Revascularization with reduced mortality and morbidity in patients with LV dysfunction patients depends on extent of HVM segments. Our study compared EuroSCORE II mortality prediction with observed mortality in HVM segments by F18-FDG PET/CT for risk stratification. Maruskova *et al.*,[9] in their study of predicting perioperative mortality using myocardial viability by delayed contrast magnetic resonance imaging and LV dyssynchrony in high-risk patients evaluated with EuroSCORE, concluded that viability and cardiac dyssynchrony are independent predictors of 30-day mortality, and they observed that most of the survivors had more than five HVM segments. Predicted and observed mortality of EuroSCORE was comparable in the viable group, whereas in the nonviable group, the observed mortality of EuroSCORE was much higher than predictive value. Our study also observed similar finding, but we used EuroSCORE II. The

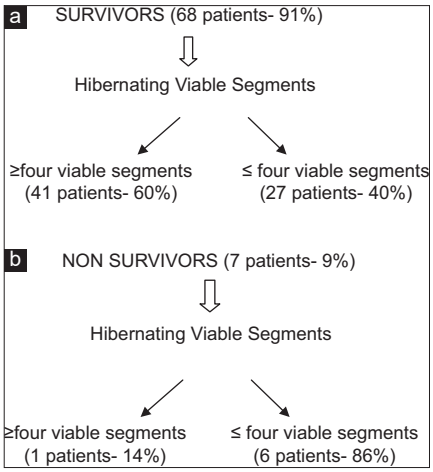

Figure 2: (a) Hibernating viable myocardial segments pattern in survivors. Among the survivors 60% had more than 4 hibernating viable myocardial segments. (b) Observed mortality with hibernating myocardial viable segment. Among the nonsurvivors, 14% had less than 4 hibernating viable myocardial segments

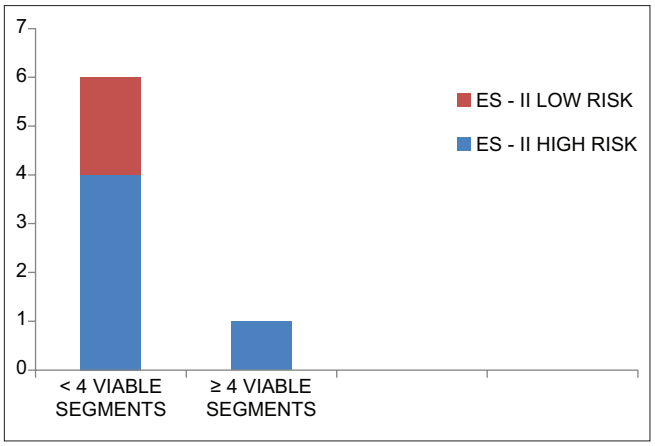

Figure 3: Bar diagram showing observed mortality distribution in comparison with ES II risk groups and hibernating viable myocardial segment groups. It shows 5 patients were ES II high risk and 2 patients were low risk. 6 patients had <4 hibernating viable myocardial segments and only one patient had >4 hibernating viable myocardial segments. ES: EuroSCORE

Table 2: Mortality distribution among EuroSCORE II groups

EuroSCORE II - low risk (30 patients)		EuroSCORE II - moderate and high (45 patients)	
Survivors (%)	Nonsurvivors (%)	Survivors (%)	Nonsurvivors (%)
28 (93)	2 (7)	40 (89)	5 (11)

Table 3: Compare EuroSCORE II mean predicted and observed mortality among the viability groups

	≥4 hibernating viable segments	<4 hibernating viable segments
Mean EuroSCORE II predicted mortality	2.66	2.77
Observed mortality	2.4	18.2
Mortality risk change by assessment of viability	No change	↑557
P	0.4736	0.00001

↑ = increased

observed mortality was high in patients with less than four myocardial segments which is five times more than the predicted mortality of EuroSCORE II. EuroSCORE II underestimated risks in patients with less than 4 viable segments. Pillai *et al*.[10] in their study compared the predictive accuracy of EuroSCORE II with three other risk stratification scoring systems (Parsonnet, System-97, and Cleveland). They concluded that EuroSCORE II was not suitable for Indian population. In their study, mortality was comparable in low- and moderate-risk groups, but predictive accuracy was low in high-risk group. In our study, EuroSCORE II has underestimated mortality in all three risk groups. ROC curve, constructed between EuroSCORE II and HVM segments, demonstrated that viability stands as a good predictor of mortality (area under the curve [AUC] = 0.7) while EuroSCORE II lost its predictive accuracy in differentiating between survivors and non survivors (AUC = 0.4). This is because EuroSCORE II low-risk group had nonsurvivors who had less than 4 viable segments. If viability is added, predictive accuracy of the EuroSCORE II would have been improved. Our study is in close agreement with Maruskova *et al*.,[9] where <5 HVM segments were an independent predictor of 30-day mortality (AUC = 0.7). Nashef *et al*.,[5,6] in their study on update of EuroSCORE in European population with additional risk factors (EuroSCORE II), concluded that EuroSCORE II was well calibrated with additional risk factors and good discrimination ability. It had 0.809 as area under receiver operative curve. However, in our study, EuroSCORE II underestimated risks, that is five times more in the less than four hibernating viable segments group than the EuroSCORE II predicted mortality. One of the reasons for the difference in results among the Indian population study could be that the number of subjects and population-based characters is different from place to place. EuroSCORE II is formed based on the European population; hence, acceptance depends on similar population characteristics.

Perioperative mortality depends on multiple variables such as age, sex, heart failure symptom group, LVEF, LV end diastolic pressure, history of chronic obstructive pulmonary disease, hypertension, diabetes, stroke, myocardial dyssynchrony, viability, ventricular remodeling, and intraoperative surgical skills and anesthesia. Among the above mentioned factors, the extent of HVM segments plays an important role in mortality prediction, especially in LV dysfunction patients.[11-14] In our study, we have observed mortality is high in patients with less than four HVM segments. Hence, for preoperative risk assessment, HVM segments can be considered along with cardiac risk scoring systems. Including myocardial viability in

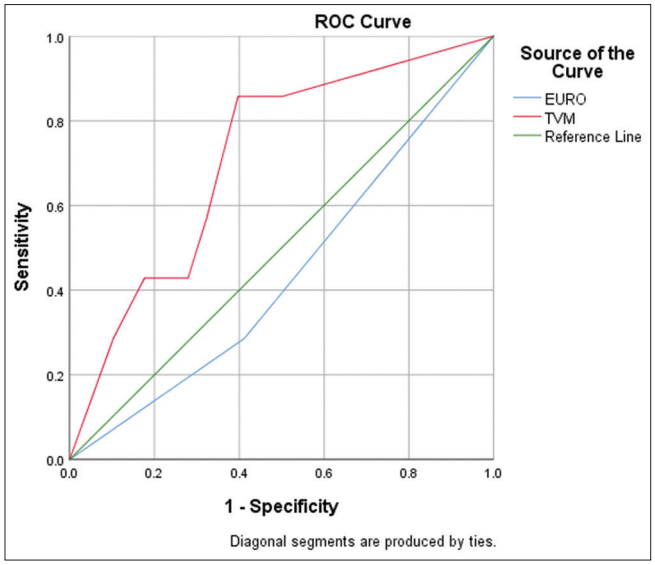

Figure 4: ROC curve for EuroSCORE II and viability showing high sensitivity for HVM segments. EURO: EuroSCORE, ROC: Receiver operating characteristic, TVM: Total viable myocardium

preoperative risk scoring systems can be considered for better risk stratification.

Conclusions

F18-FDG PET/CT for viability assessment along with EuroSCORE II in preoperative risk assessment for CABG in patients with LV dysfunction provided better risk stratification.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

References

1. Koene RJ, Kealhofer JV, Adabag S, Vakil K, Florea VG. Effect of coronary artery bypass graft surgery on left ventricular systolic function. J Thorac Dis 2017;9:262-70.
2. Lehtinen M, Schildt J, Ahonen A, Nikkinen P, Lauerma K, Sinisalo J, *et al.* Combining FDG-PET and 99mTc-SPECT to predict functional outcome after coronary artery bypass surgery. Eur Heart J Cardiovasc Imaging 2015;16:1023-30.
3. Granton J, Cheng D. Risk stratification models for cardiac surgery. Semin Cardiothorac Vasc Anesth 2008;12:167-74.
4. Nilsson J, Algotsson L, Höglund P, Lührs C, Brandt J. Comparison of 19 pre-operative risk stratification models in open-heart surgery. Eur Heart J 2006;27:867-74.
5. Nashef SA, Roques F, Michel P, Gauducheau E, Lemeshow S, Salamon R. European system for cardiac operative risk evaluation (EuroSCORE). Eur J Cardiothorac Surg 1999;16:9-13.
6. Nashef SA, Roques F, Sharples LD, Nilsson J, Smith C, Goldstone AR, *et al.* EuroSCORE II. Eur J Cardiothorac Surg 2012;41:734-44.
7. Srivatsava MK, Indirani M, Sathyamurthy I, Sengottuvelu G, Jain AS, Shelley S. Role of PET-CT in the assessment of myocardial viability in patients with left ventricular dysfunction. Indian Heart J 2016;68:693-9.
8. Dilsizian V, Bacharach SL, Beanlands RS, Bergmann SR, Delbeke D, Dorbala S, *et al.* ASNC imaging guidelines/SNMMI procedure standard for positron emission tomography (PET) nuclear cardiology procedures. J Nucl Cardiol 2016;23:1187-226.
9. Maruskova M, Gregor P, Bartunek J, Tintera J, Penicka M. Myocardial viability and cardiac dyssynchrony as strong predictors of perioperative mortality in high-risk patients with ischemic cardiomyopathy having coronary artery bypass surgery. J Thorac Cardiovasc Surg 2009;138:62-8.
10. Pillai BS, Baloria KA, Selot N. Validation of the European system for cardiac operative risk evaluation-II model in an urban Indian population and comparison with three other risk scoring systems. Ann Card Anaesth 2015;18:335-42.
11. Chareonthaitawee P, Gersh BJ, Araoz PA, Gibbons RJ. Revascularization in severe left ventricular dysfunction: The role of viability testing. J Am Coll Cardiol 2005;46:567-74.
12. Beanlands RS, Ruddy TD, deKemp RA, Iwanochko RM, Coates G, Freeman M, *et al.* Positron emission tomography and recovery following revascularization (PARR-1): The importance of scar and the development of a prediction rule for the degree of recovery of left ventricular function. J Am Coll Cardiol 2002;40:1735-43.
13. Bouabdallaoui N, Stevens SR, Doenst T, Petrie MC, Al-Attar N, Ali IS, *et al.* Society of thoracic surgeons risk score and EuroSCORE-2 appropriately assess 30-day postoperative mortality in the STICH trial and a contemporary cohort of patients with left ventricular dysfunction undergoing surgical revascularization. Circ Heart Fail 2018;11:e005531.
14. Di Carli MF, Davidson M, Little R, Khanna S, Mody FV, Brunken RC, *et al.* Value of metabolic imaging with positron emission tomography for evaluating prognosis in patients with coronary artery disease and left ventricular dysfunction. Am J Cardiol 1994;73:527-33.