https://doi.org/10.3329/jicc.v5i1. 75808

ORIGINAL ARTICLE

Lesion Characterization by ^{99m}Tc-MIBI Myocardial Perfusion Imaging (MPI) & ^{18}F-FDG Cardiac PET Following Myocardial Infarction Before Revascularization & Outcome Prediction: Initial Experience in Bangladesh

Afroza Akhter[1], Shankar Kumar Biswas[1], Shaila Sharmin[1], Sabrina Islam[1], Rubina Begum[1], Jasmine Ara Haque[1], Pijous Biswas[2], Abdul Wadud Chowdhury[3]

Abstract:

99mTc-MIBI SPECT myocardial perfusion imaging (MPI) and ^{18}F-FDG cardiac positron emission tomography (Cardiac PET) can assess the extent and severity of myocardial perfusion and metabolic defect following myocardial infarction (MI) and also able to predict the outcome before revascularization in known coronary artery disease patients. About 135 cases of known coronary artery disease patients were enrolled here for combined nuclear imaging tests, rest only ECG gated MPI and FDG cardiac PET to assess myocardial perfusion and viability status following MI prior to revascularization. In this study we want to figure out the utility of this combined protocol for myocardial lesion characterization and its role for clinical decision-making in-patient selection prior to revascularization and treatment planning. We are also intended to share the initial outcome in available follow up cases.

Key words: Myocardial perfusion imaging, FDG Cardiac PET, Coronary artery disease, Myocardial infarction, Revascularization.

J Inv Clin Cardiol 2023; 5(2): 45-52

Introduction:

Assessment of myocardial perfusion & metabolism before revascularization following myocardial infarction in known coronary artery disease is crucial because accurate detection of disease severity is the key factor for guiding management and risk stratification. There are various perfusion and metabolic radiotracer used in SPECT and PET to identify myocardial blood flow and metabolism. After myocardial infarction, perfusion and metabolic defects can be identified by combined non-invasive nuclear imaging technique such as rest only gated MPI and 18F-FDG cardiac PET. In our country for SPECT MPI, we are using 99mTc-sestamibi, a lipophilic cation which, when injected intravenously to a patient, is taken up by the myocardial cell proportional to myocardial blood flow[1]. Although there is expanded use of FDG PET CT for oncology, FDG cardiac PET is an emerging modality to assess the metabolic status of myocardium which may be affected by physiologically significant coronary artery disease. Molecular imaging technique of nuclear cardiology has led to a better understanding of the pathophysiology of ischaemic heart disease[2]. Defining the pattern of match, mismatch or reverse mismatch defect(s) in this combined protocol, it is possible to distinguish between viable from non-viable myocardium, such as hibernating /stunned myocardium from infarcted/ scarred tissue[3]. It can also predict the outcome prior to revascularization. The first FDG Cardiac PET in Bangladesh was performed at INMAS, Dhaka on May 2018. Since then, about 200 cases were done in our center, among them we have selected 135 cases who were referred for combined perfusion and metabolic viability assessment before revascularization following MI. And we are also doing case based follow up of these patients to see the initial and long-term outcome.

1. Institute of Nuclear Medicine & Allied Sciences (INMAS), DMCH campus, Dhaka, Bangladesh.
2. National Institute of Cardiovascular Diseases, Dhaka, Bangladesh.
3. Department of Cardiology, Dhaka Medical College Hospital, Dhaka, Bangladesh.

Address of Correspondence: Dr. Afroza Akhter, Assistant Professor, MBBS, FANMB, Fellow SNUH. Institute of Nuclear Medicine & Allied Sciences (INMAS), Dhaka, DMCH Campus, BAEC, Bangladesh. Phone: +8801816404873, Email: afrozainmas@gmail.com

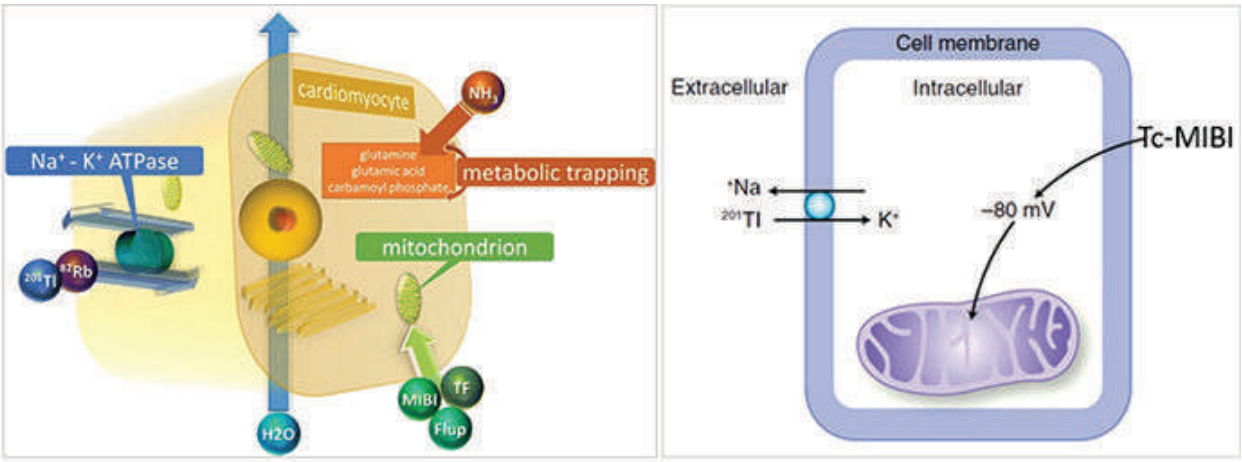

Figure 1: *Schematic representation of various radiotracers for myocardial perfusion imaging. Myocardial uptake of 99mTc-sestamibi is related to the presence of intact mitochondria (Image courtesy by Manabe, O. et al (2018). Radiopharmaceutical tracers for cardiac imaging. Journal of Nuclear Cardiology, 25(4), pp.1204–1236 (5).*

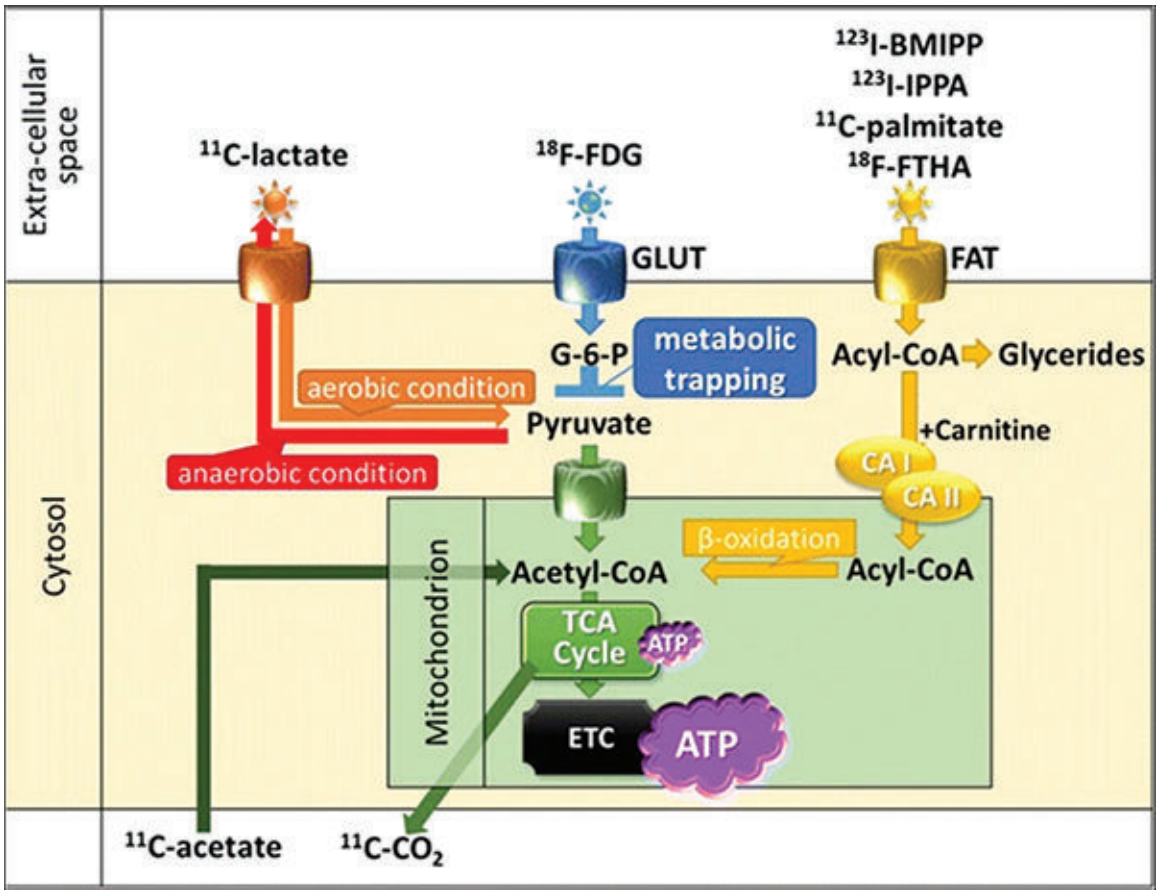

Figure 2: *Schematic representation of various myocardial metabolic tracers. 18F-FDG is a glucose analog actively transported into the cell by GLUT & phosphorylated as 18F-FDG-6-phosphate but it cannot enter glycolysis pathway. Thus, metabolic trapping of 18F-FDG in myocardium can be imaged by cardiac PET to assess myocardial viability. Image courtesy by Manabe, O. et al (2018). Radiopharmaceutical tracers for cardiac imaging. Journal of Nuclear Cardiology, 25(4), pp.1204–1236 (5)*

Materials and Methods:

Study population: In our study we have enrolled 135 patients of known coronary artery disease (M/F: 126/9, age range: 32-75 years). Clinical data from medical documentation: age, gender, weight, height, body mass index, comorbidities, clinical symptoms of heart disease, risk factors of cardiovascular disease, electrocardiography (ECG), echocardiography and coronary angiogram (CAG) findings were collected and analyzed. All patients underwent rest MPI and FDG cardiac PET imaging in combined two days protocol.

Rest MPI protocol: All patients were intravenously injected with a technetium 99m (^{99m}Tc) labeled sestamibi (8-10 mCi, adjusted to body mass index) at overnight fasting state. ECG gated SPECT MPI was performed 45-60 min after ^{99m}Tc -MIBI injection, with a dual-head Siemens Symbia-True point SPECT-CT gamma camera, using a low-energy, high-resolution collimator, a 20% window at 140 keV, 64 X 64 matrix, an orbit with 120 projections, at 3-degree steps and a 20 s per step, patient positioned in a supine position with the arms held above the head.[4]

FDG Cardiac PET Protocol: ECG gated FDG PET myocardial viability imaging was performed for all patients at overnight fasting state with oral glucose loading and intravenous insulin simultaneously. Fasting blood sugar was measured then 50 g oral glucose was administered if blood sugar level ≤150 gm/dl; amount of oral glucose was adjusted < 50 g in diabetic patient. Then blood sugar was monitored every 15 min interval up to 45-60 minutes and 18F-FDG was injected intravenously. ECG gated PET images were obtained 60 to 90 min after 18F-FDG injection using PHILIPS Ingenuity TF PET/CT system. The duration of PET acquisition was 15 min following a low-dose CT scan for attenuation correction.

Myocardial perfusion and metabolic defects were analyzed by MPI and PET derived data using 17 segment model. Finally, MPI and PET fusion imaging was done by Corridor4DM application software.

Results:

In our study most of the patents were in 51-60 years of age group (40%). Coronary angiogram data were available in 119 cases, majority had triple vessel disease (63%), 19% had double vessel disease and 18% had single vessel disease. MPI-PET study characterized the lesions in 5 points scoring system according to severity of myocardial perfusion and metabolic defect in 17 segment model (score 0: normal perfusion-metabolism, score 1-3 as mild, moderate and severe defect and score 4 as absent perfusion-metabolism). MPI-Cardiac PET fusion imaging characterized the

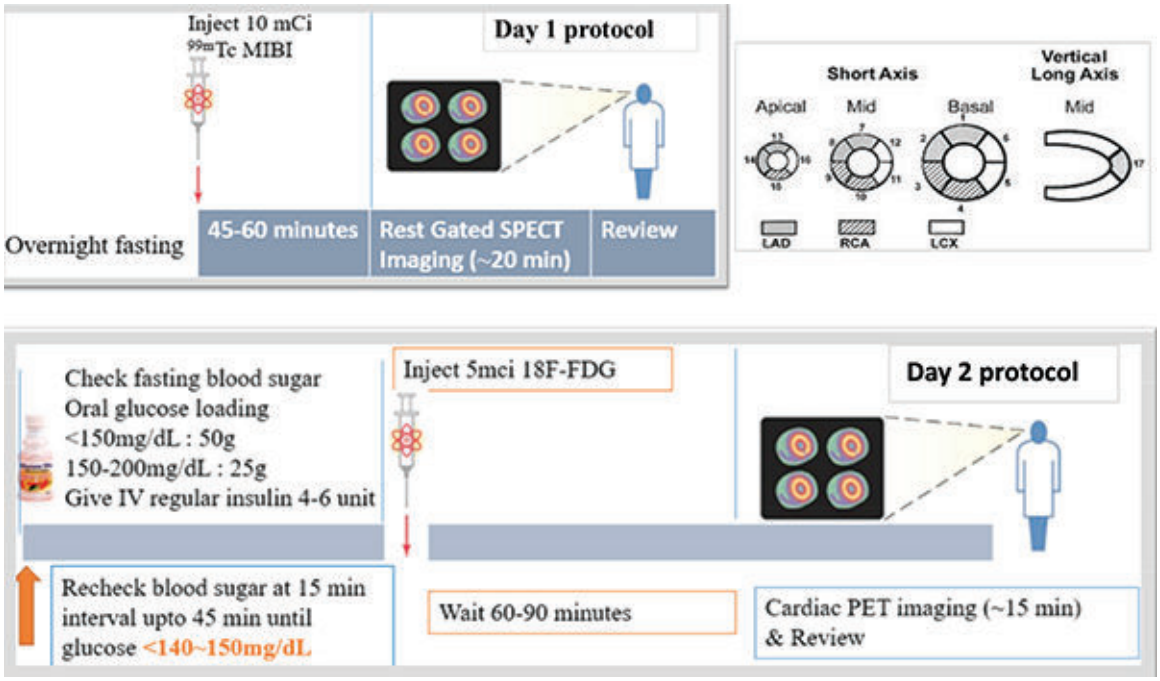

Figure 3: *Rest MPI and FDG Cardiac PET combined protocol and 17 segment model for image interpretation.*

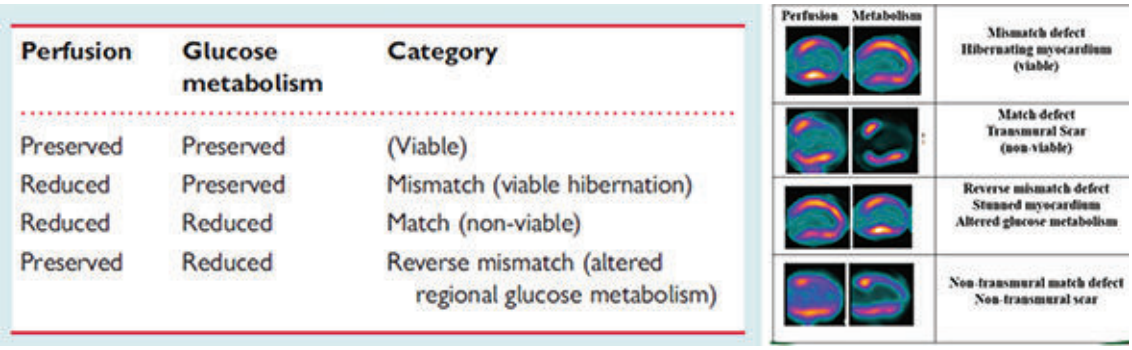

Figure 4: *(a) Simplified classification system for pattern of myocardial perfusion and metabolism (Courtesy by European Heart Journal (2010) 31, 2984–2995 doi:10.1093/eurheartj/ehq361) (6). (b) Radiotracer uptake patterns in myocardial lesion characterization (vertical long axis view).*

lesions in 4 groups along the three major coronary artery territories: severe match defect (absent perfusion-metabolism in infarcted/ scarred myocardium), mismatch defect (reduced/absent perfusion-preserved metabolism in hibernating myocardium), reverse mismatch defect (preserved perfusion-reduced metabolism in stunned myocardium) and mild to moderate match defect (reduced perfusion-reduced metabolism in hibernating myocardium).

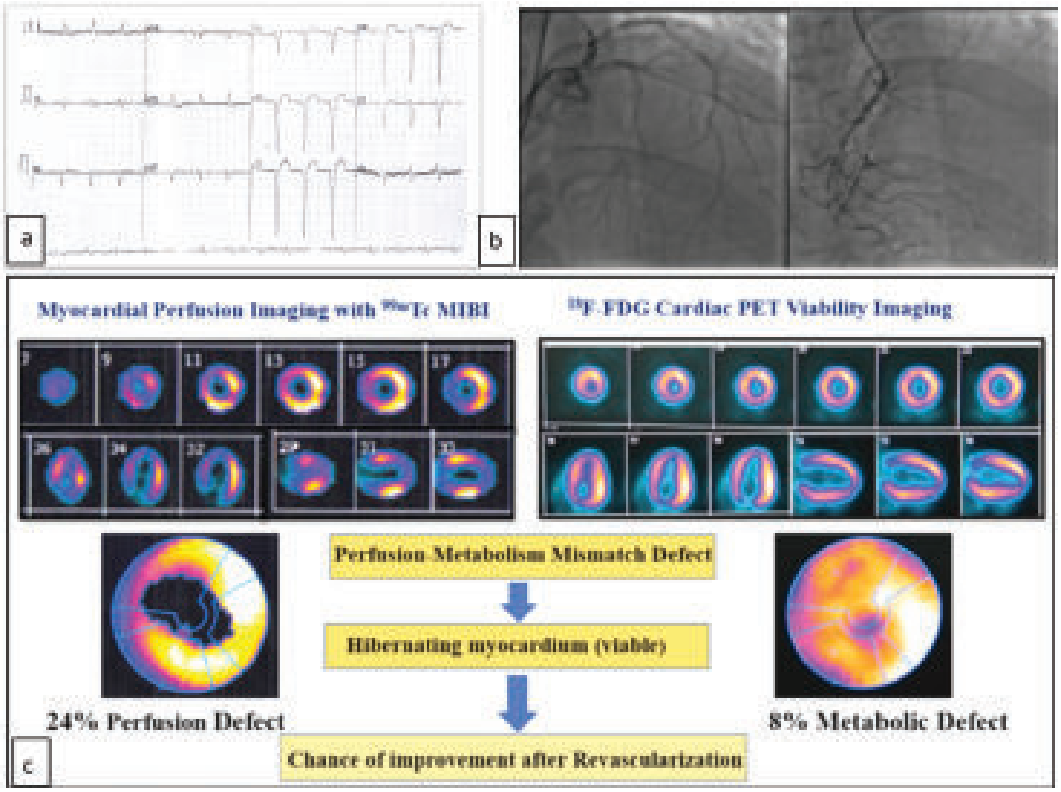

Figure 5 (case 1): *A 56 years old male was presented with acute anterior MI with LVF with HTN, DM and dyslipidemia. On ECG (a) pathological Q wave in lead V1-V4 with ST elevation. (b) CAG revealed triple vessel disease involving left main and LAD, LCX and RCA territory. (c) Combined rest MPI and FDG cardiac PET revealed mismatch defect in the apex, apical to mid anterior & anteroseptal wall, apical lateral wall and basal inferior and inferoseptal wall (24% perfusion and only 8% metabolic defect) with LVEF 30%. This patient underwent CABG with 3 grafts in LIMA to LAD & RSVG to OM & distal RCA. He showed significant clinical improvement (LVEF 45-50% on follow up echocardiogram) on 3 months onward.*

Positive outcome was predicted for mismatch defect having hibernating myocardium and also for stunned myocardium having altered glucose metabolism due to acute/recent coronary event. Negative outcome was predicted for severe match defects in corresponding coronary artery territory. Other parameters like LV global systolic function (ejection fraction%), cavity dilatation, wall thickness and wall motion abnormality derived from 3 D volumetric data of ECG gated MPI and cardiac PET were also account for overall impression to predict the outcome of individual patient. Initially we have collected follow up data in 30 cases, among them 3 patients had died before intervention due to comorbid condition, 10 underwent CABG, 4 had PCI and rest 13 were on medical treatment. Pre and post intervention follow up echocardiogram showed significant functional improvement of LV ejection fraction in mismatch defects group after surgical intervention whereas reverse mismatch group showed slow functional recovery.

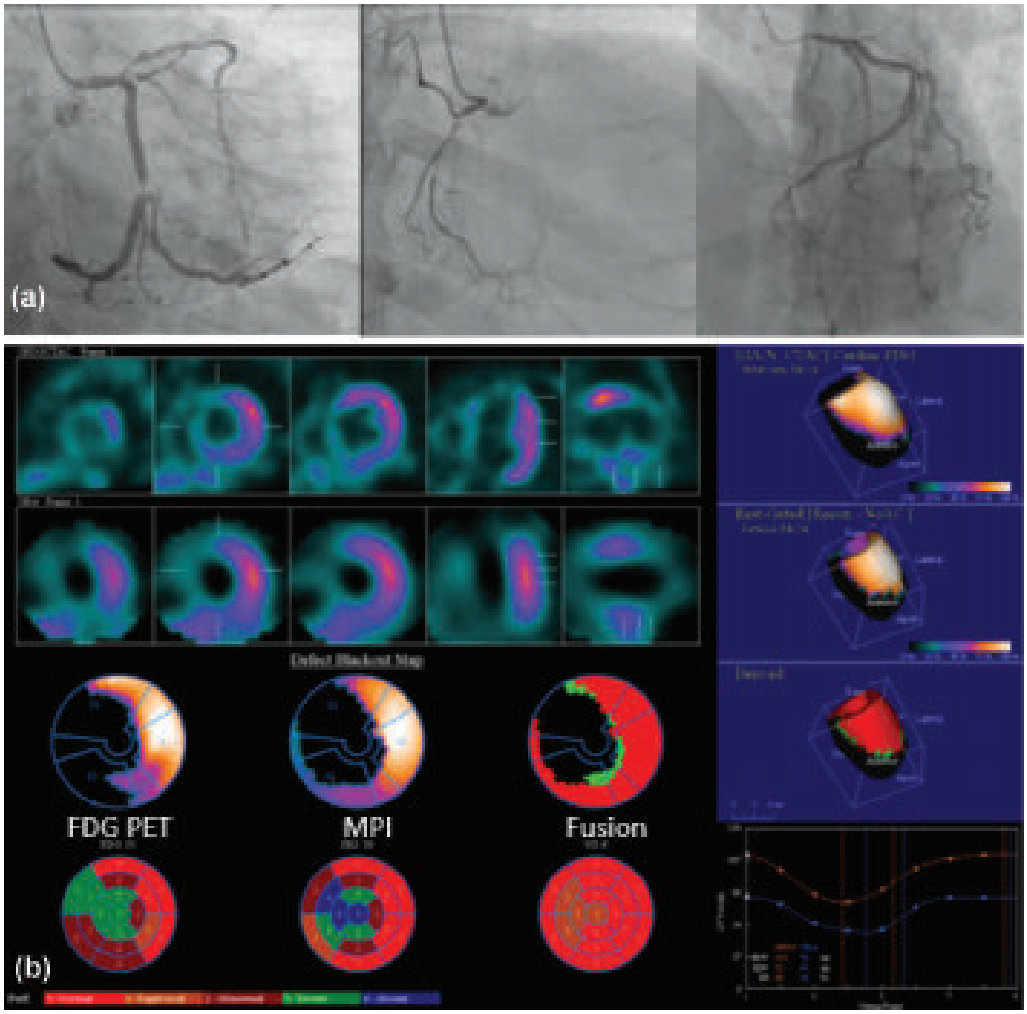

Figure 6 (case 2): *A 53 years old male was presented with post MI angina due to old anterior MI having ICM on echocardiogram with 30% LVEF. CAG (image a) revealed triple vessel disease; LAD: 90% ostio-proximal and 80% distal stenosis, LCX: 95% bifurcating lesion involving principal OM and 95% stenosis in proximal RCA. MPI and Cardiac PET fusion imaging (image b) showed large area of perfusion & metabolism severe match defect in the apex, anterior and anteroseptal wall along the LAD territory and inferior and inferoseptal wall along the RCA territory-signify large infarct with peri-infarct ischemia. Small area of reverse mismatch (stunned myocardium) in basal inferior wall. Approximately 48% perfusion & 52% metabolic abnormality in LV myocardium in fusion image. There was dilated LV cavity, global hypokinesia and severely reduced LV global systolic function (LVEF: 32%). So, this case was not suitable for revascularization and patient underwent medical management.*

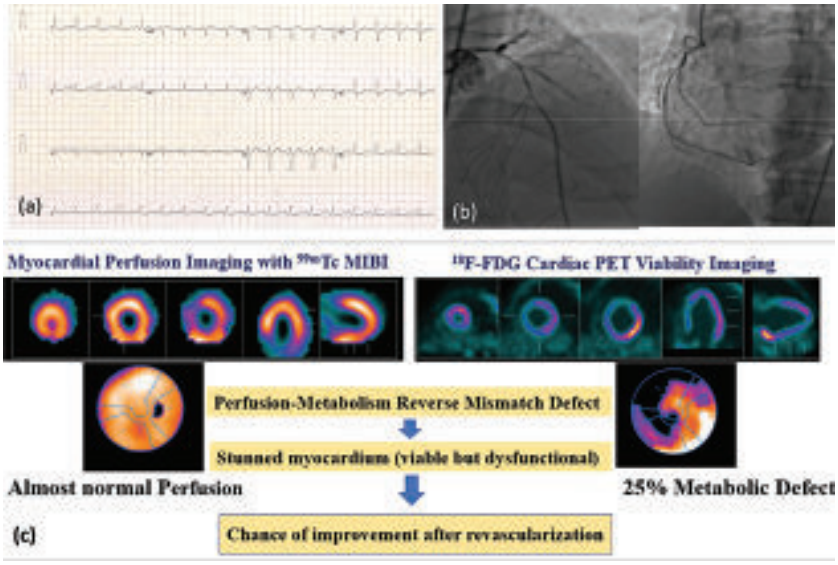

Figure 7 (case 3): *A 55 years old male was presented with ICM with (b) severe left main and TVD with DM and HTN. ECG showed sinus tachycardia with nonspecific ST changes (a). (c) Rest MPI revealed almost normal perfusion might be due to balanced ischemia however FDG PET revealed about 25% metabolic abnormality involving anteroseptal and inferoseptal wall along the LAD and RCA territories. Volumetric data also revealed dilated LV cavity, global hypokinesia& severely reduced LV global systolic function (LVEF 25-30%). This myocardial defect is defined as reverse mismatch defect (stunned myocardium) and might be suitable for revascularization as perfusion is maintained.*

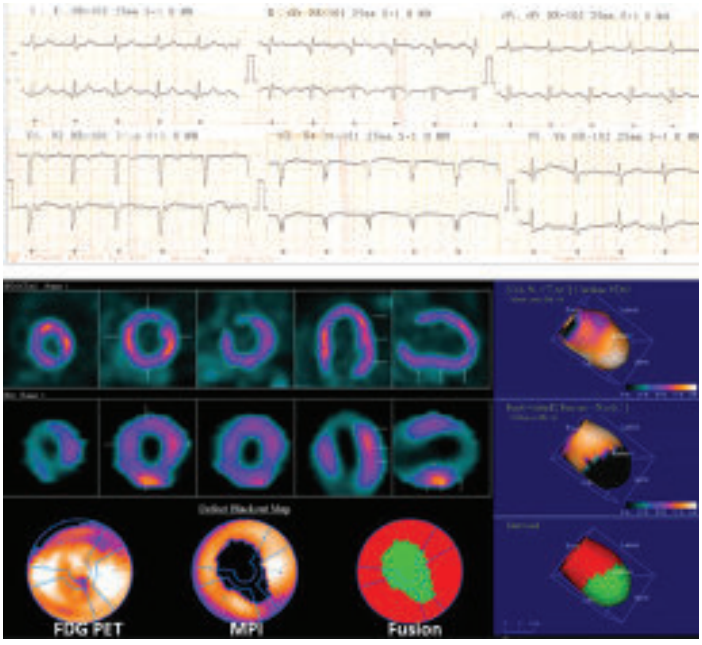

Figure 8 (case 4): *A 52 years male patient having old anteroseptal and inferior MI with critical TVD, DM, dyslipidemia and severe LV systolic dysfunction on echocardiogram (LVEF:33%). MPI and PET fusion imaging revealed large area of perfusion-metabolism mismatch defect in the triple vessel territory involving apex, apical to mid anterior, anteroseptal and inferolateral wall signify hibernating / viable myocardium & good chance of improvement after revascularization. Small area of perfusion-metabolism mild reverse mismatch defect (stunned myocardium) in basal anterior wall- suggesting dysfunctional viable myocardium. Patient underwent CABG and significant clinical improvement was seen in subsequent follow up.*

Discussion:

Dysfunctional but viable myocardium can exist as hibernating state or as stunned myocardium.

Myocardial stunning was firstly described by Braunwald and Kloner as "prolonged, post-ischemic ventricular dysfunction that occurs after brief periods of nonlethal ischemia"[7]. Meanwhile, hibernating myocardium was first described as the result of repetitive and long-lasting ischemia due to significant coronary artery stenosis and severely limited coronary flow reserve[8-10]. If the myocardium is in the hibernation stage, the contractility may recover spontaneously when the blood flow is re-established[11]. Several imaging techniques such as dobutamine stress or myocardial contrast echocardiography, SPECT MPI, 18F-FDG PET, cardiovascular magnetic resonance (CMR) with late gadolinium enhancement (LGE), and computed tomography (CT) can assess viable myocardium. SPECT MPI with 99mTc-labeled sestamibi demonstrates the myocardial uptake and retention of sestamibi, which are dependent on perfusion, cell membrane integrity, and mitochondrial function. SPECT MPI is the frequently used imaging technique for the detection of coronary artery disease (CAD) and demonstrates excellent sensitivity in the diagnosis of hemodynamically significant coronary artery stenosis. As ischemic myocardium shifted to glucose metabolism instead of fatty acid metabolism for their energy production, FGD Cardiac PET estimates the cellular function of the heart.

In our study we have compared myocardial perfusion and 18F-FDG images in corridor4DM software using 17 segment polar map; MPI-PET fusion imaging precisely distinguished viable myocardium from a fibrotic scar by the visual and quantitative analysis of radiotracer uptake pattern in LV segments. Additional ECG gated 3D volumetric data provided the information of LV global systolic function (LVEF%), end systolic and end diastolic volume, LV cavity dilatation, wall motion status and wall thickness abnormality. MPI and PET derived data revealed PET derived LVEF is more comparable with echocardiographic LVEF% than MPI. Here we have discussed 4 different clinical scenarios from our study group.

Management decisions in patients with ischemic cardiomyopathy are complex and require evaluation of other factors such as the anatomic substrate, patient comorbidities, and risk[12]. As post-surgery follow up MPI or cardiac PET was not performed in our study, we have compared our prediction with follow up echocardiogram data and clinical status of individual patient who underwent revascularization.

Conclusion:

Though it's a very initial experience in the field of nuclear cardiology Bangladesh, this combined protocol, rest only gated 99mTc-MIBI SPECT MPI and 18F-FDG Cardiac PET can identify the patients who may be benefited the most from revascularization. It can also help in clinical decision-making in complicated cases where there is minimal or absent viability to avoid unnecessary procedures and risk and thus minimize cardiac event-related mortality and morbidity.

Acknowledgment:

All stuffs of Nuclear Cardiology Division, INMAS, Dhaka.

Conflict of interest: Authors declare no conflict of interest.

References:

1. Rizk, T.H. and Nagalli, S. (2020). Technetium (99mTc) Sestamibi. [online] PubMed. Available at: https://www.ncbi.nlm.nih.gov/books/NBK553148/.
2. Ghosh, N., Rimoldi, O.E., Beanlands, R.S.B. and Camici, P.G. (2010). Assessment of myocardial ischaemia and viability: role of positron emission tomography. *European Heart Journal*, 31(24), pp.2984–2995. doi: https://doi.org/10.1093/eurheartj/ehq361.
3. Garcia, M.J., Kwong, R.Y., Scherrer-Crosbie, M., Taub, C.C., Blankstein, R., Lima, J., Bonow, R.O., Eshtehardi, P. and Bois, J.P. (2020). State of the Art: Imaging for Myocardial Viability: A Scientific Statement From the American Heart Association. *Circulation: Cardiovascular Imaging*, 13(7). doi: https://doi.org/10.1161/hci.0000000000000053.
4. Henzlova, M.J., Duvall, W.L., Einstein, A.J., Travin, M.I. and Verberne, H.J. (2016). ASNC imaging guidelines for SPECT nuclear cardiology procedures: Stress, protocols, and tracers. *Journal of Nuclear Cardiology*, 23(3), pp.606–639. doi: https://doi.org/10.1007/s12350-015-0387-x.
5. Manabe, O., Kikuchi, T., Scholte, A.J.H.A., El Mahdiui, M., Nishii, R., Zhang, M.-R., Suzuki, E. and Yoshinaga, K. (2018). Radiopharmaceutical tracers for cardiac imaging. *Journal of Nuclear Cardiology*, [online] 25(4), pp.1204–1236. Available at: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6133155/ [Accessed 8 May 2020].
6. Ghosh, N., Rimoldi, O.E., Beanlands, R.S.B. and Camici, P.G. (2010). Assessment of myocardial ischaemia and viability: role of positron emission tomography. *European Heart Journal*, 31(24), pp.2984–2995.
7. Braunwald, E.; Kloner, R.A. The stunned myocardium: Prolonged, postischemic ventricular dysfunction. Circulation 1982, 66, 1146–1149. [CrossRef]

8. Diamond, G.A.; Forrester, J.S.; deLuz, P.L.;Wyatt, H.L.; Swan, H.J. Post-extrasystolic potentiation of ischemic myocardium by atrial stimulation. Am. Heart J. 1978, 95, 204–209. [CrossRef]

9. Rahimtoola, S.H. The hibernating myocardium. Am. Heart J. 1989, 117, 211–221. [CrossRef]

10. Wijns, W.; Vatner, S.F.; Camici, P.G. Hibernating myocardium. N. Engl. J. Med. 1998, 339, 173–181. [CrossRef] [PubMed]

11. Braunwald, E.; Rutherford, J.D. Reversible ischemic left ventricular dysfunction: Evidence for the “hibernating myocardium”. J. Am. Coll. Cardiol. 1986, 8, 1467–1470. [CrossRef]

12. Garcia, M.J., Kwong, R.Y., Scherrer-Crosbie, M., Taub, C.C., Blankstein, R., Lima, J., Bonow, R.O., Eshtehardi, P. and Bois, J.P. (2020). State of the Art: Imaging for Myocardial Viability: A Scientific Statement From the American Heart Association. *Circulation: Cardiovascular Imaging*, 13(7).