Cardiac PET/MR Delineates Extensive Subendocardial Infarction Leading to Acute Coronary Syndrome

Eun-Jung Kong, M.D. Ph.D[1]; Partha Gosh, M.D.[2]

[1] Division of Cardiology, Yeungnam University Medical Center, Daegu, South Korea
[2] Siemens Healthineers, Molecular Imaging, Hoffman Estates, IL, USA

History

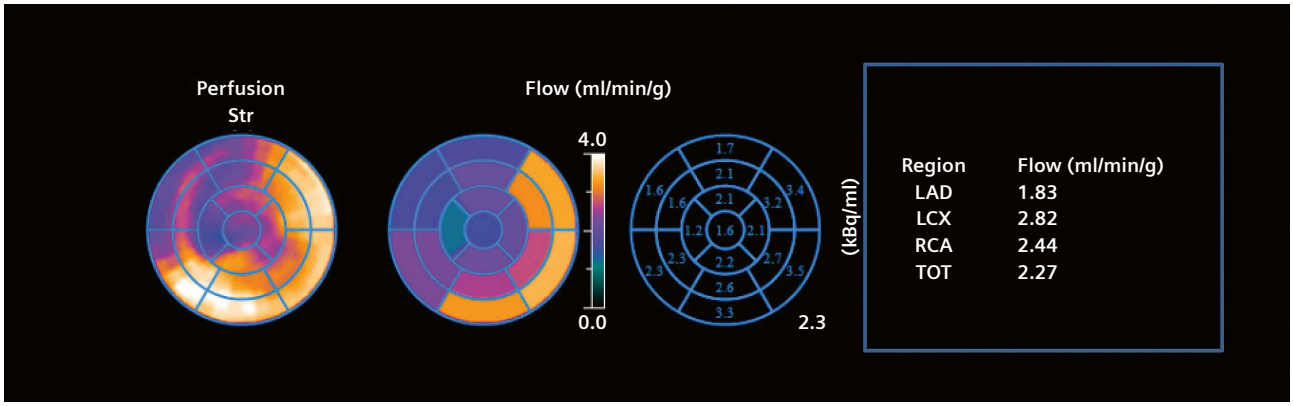
A 57-year-old man with a 20-plus-year history of diabetes and hypertension presented with severe respiratory distress accompanied by eyeball deviation and swelling of lower limbs. Paramedics arrived and delivered cardio-pulmonary resuscitation (CPR) followed by defibrillation, necessitated by ventricular fibrillation. The CPR continued during the ambulance transport to the emergency room (ER) of the Yeungnam University Hospital. In the ER, the patient showed signs of hypoxic brain damage with stiffness of limbs and was successfully resuscitated. The patient's serum troponin level was significantly elevated (0.42 ng/ml) at the time of ER admission. An echocardiography, performed following resuscitation, showed mild regional-wall-motion abnormality in the anterior septum, with suspicion of hypertrophic cardiomyopathy due to asymmetric septal thickness.

Twelve years prior, the patient underwent a coronary angiography which demonstrated an absence of any luminal stenosis.

Findings

The patient underwent an adenosine stress ^{13}N NH_3 PET/CT myocardial perfusion study, which showed a reduction of blood flow to the anterior wall and upper septum (Fig. 1). In view of the suggestion of left anterior descending (LAD) territory ischemia and the history of sudden cardiac arrest, the patient was referred for a Fludeoxyglucose F 18 injection (^{18}F FDG) cardiac PET/MR to evaluate the cause of the acute coronary syndrome.

An ^{18}F FDG PET/MR study was performed on a Biograph mMR system five days after emergency admission. The patient received a low-carbohydrate diet the day prior to imaging, followed by a 12-hour fasting period in order to suppress physiological myocardial ^{18}F FDG uptake. Thirty minutes before the ^{18}F FDG injection, the patient received an intravenous dose of unfractionated heparin (50 UI/kg body weight) to further suppress physiological myocardial ^{18}F FDG uptake. Sixty minutes after the intravenous injection of 237.5 MBq of ^{18}F FDG, a 3D listmode PET scan in was started.



1 4DM (Invia, Ann Arbor, MI, USA) myocardial blood flow values at peak stress and stress perfusion bulls eye plot show decreased perfusion in the anterior wall, apex, and upper septum with significant reduction in myocardial blood flow values (1.83 ml/min/gm), as compared to the inferior and lateral walls, which is suggestive of the LAD territory ischemia during stress.

A two-point Dixon sequence was acquired for the purpose of PET attenuation correction. During the acquisition of listmode PET, multiple MR sequences were also acquired. Initial axial T2 HASTE, cine MRI using TrueFISP, and dark-blood T2 HASTE acquisitions were performed. Subsequently, intravenous Gadolinium (Gd) contrast was infused and a first-pass perfusion with turboFLASH sequence was performed, followed by late Gd enhancement with TrueFISP sequence in order to delineate myocardial contrast enhancement.

As depicted in Figures 2–4, the ^{18}F FDG PET/MR study shows late enhancement with Gd contrast seen with inversion recovery MR sequences limited to the subendocardium in the apex and adjacent septal and lateral walls, suggestive of subendocardial infarction. Simultaneously acquired ^{18}F FDG PET shows increased ^{18}F FDG uptake in the same subendocardial areas with the late Gd enhancement, which suggests the subendocardial hypermetabolism may be secondary to inflammation within the zone of acute myocardial infarction. The patient subsequently underwent coronary angiography.

Coronary angiography (Fig. 5) shows 80% stenosis in the proximal LAD and the origin of IM1. The stenotic lesions correlate with the distribution of the subendocardial infarct in the apex and septum, which correspond to the LAD territory.

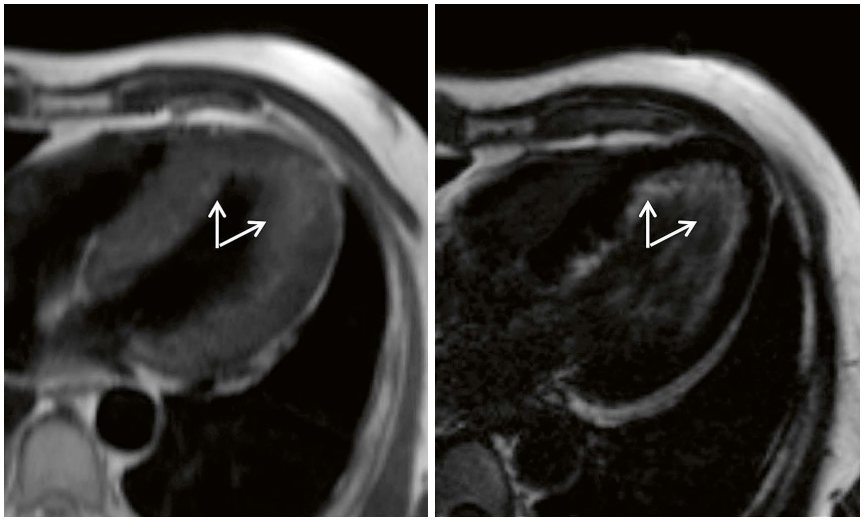
The patient underwent balloon dilatation and stenting of the LAD and IM lesions. Six days following percutaneous coronary intervention, there was slight improvement of the regional wall-motion abnormality.

Comments

This study demonstrates the value of simultaneous ^{18}F FDG PET/MR in defining the extent of acute myocardial infarction, as well as the inflammatory process characteristic of such acute myocardial injury. The extent of post-Gd late enhancement, as seen on MRI, clearly delineates the subendocardial nature of the acute myocardial infarction. The exact co-registration of ^{18}F FDG uptake with the subendocardial post-contrast enhancement on MRI reflects the degree of inflammation caused by the acute myocardial injury, which is the hallmark of the immunological response immediately following acute myocardial infarction.

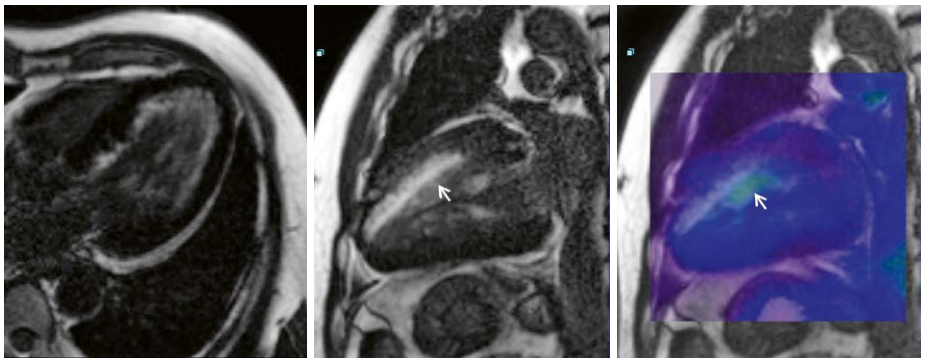
Myocardial infarction is often associated with adverse myocardial remodeling and development of heart failure in many patients. The immune system plays a key role in the repair and subsequent myocardial-scar formation. Shortly after acute myocardial infarction, neutrophils and monocytes invade the ischemic myocardium and cause the removal of dead cells as well as the breakdown of the extracellular matrix. Thereafter, anti-inflammatory cytokines are produced that stop the inflammatory processes and cause the transition to the proliferative phase. The final, so-called maturation, phase is thought to be responsible for a stable scar formation [1].

Exaggerated inflammatory response may result in the expansion of infarct and impaired infarct healing. Excessive cellular infiltration after myocardial infarction by neutrophils and monocytes may cause exaggerated degradation of the extracellular matrix and support infarct expansion, left ventricular dilatation, aneurysm formation,



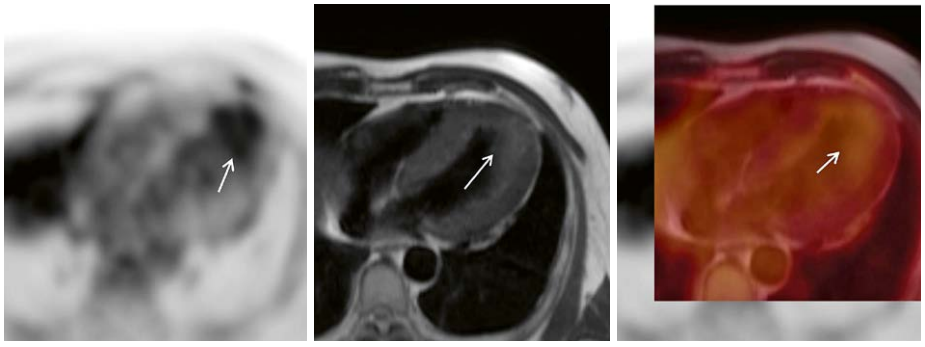
T2 HASTE Late Gd enhancement (TrueFISP)

2 Axial T2 HASTE and post-Gd TrueFISP show mild hyperintensity in the subendocardium in the apical region and the adjacent lateral wall and septum, which corresponds to the regions of contrast enhancement in the post-Gd sequence (arrows). These regions reflect patchy subendocardial infarction, which is illustrated by the Gadolinium enhancement. The myocardium appears slightly hypertrophied and the late Gd enhancent (TrueFISP) sequence clearly delineates the absence of myocardial signal characteristic of normal myocardium separate from the subendocardial contrast enhancement, which highlights the non-transmural nature of the infarction.



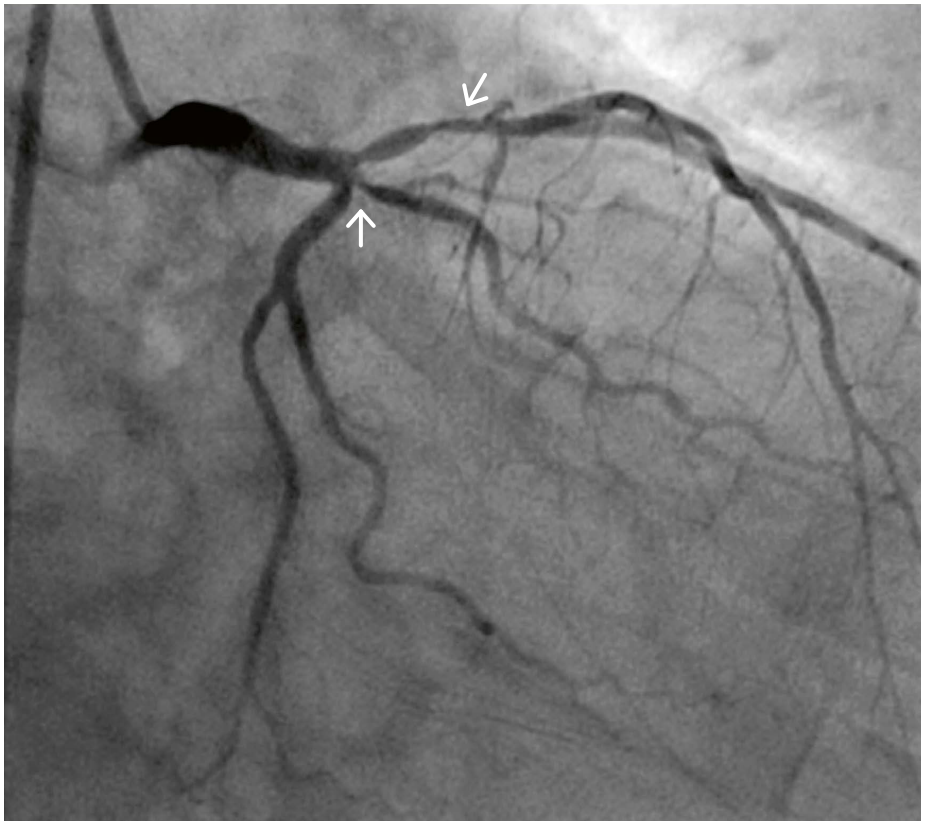
LGE TrueFISP Tra | LGE TrueFISP Sag | ^{18}F FDG PET/MR fusion

3 Two-chamber and four-chamber views through the left ventricle of the post-Gd TrueFISP sequence (late Gd enhancement also known as LGE) show the subendocardial contrast enhancement with increased ^{18}F FDG uptake in part of the subendocardium (arrows), reflecting inflammation induced by acute myocardial injury corresponding to the subendocardial infarction in the fused PET/MR images.



^{18}F FDG PET | T2 HASTE Tra | ^{18}F FDG PET/MR fusion

4 Four-chamber views of ^{18}F FDG PET, T2 HASTE, and fused PET/MR showing increased ^{18}F FDG uptake in the apical, septal, and adjacent lateral wall subendocardium (arrows), co-registering with the mild hyperintensity in the same myocardial region seen on the HASTE images, which reflects subendocardial inflammation secondary to acute myocardial infarction limited to the subendocardium.



5 Coronary angiography shows 80% tubular eccentric stenosis in the proximal LAD as well as 80% discrete stenosis at the origin of the IM1 (arrows).

pLAD: Tubular eccentric stenosis 80% (arrow)
IM: Discrete eccentric stenosis 80% (arrow)
dRCA: Diffuse eccentric stenosis 30%

or even ventricular rupture [1]. This makes the immune system a potential therapeutic target for the prevention of heart failure after myocardial infarction.

Studies show that the intensity of ^{18}F FDG uptake in an infarcted myocardium – within a few days after acute injury – have significant correlation with the size of infarction, MRI measures of the left ventricular ejection fraction, and regional wall-motion abnormalities [2]. An increased accumulation of monocytes and macrophages within the infarcted myocardium leads to higher glucose metabolism reflected by a higher ^{18}F FDG uptake. This has led to the hypothesis that performing a ^{18}F FDG PET, soon after acute myocardial infarction, can be used to assess the extent of inflammation and act as a prognostic indicator. In order for ^{18}F FDG uptake to reflect myocardial inflammation, the normal uptake exhibited by a cardiac muscle must be suppressed by fasting, a high-fat diet, or injecting heparin prior to the PET scan. These measures help switch the nonischemically injured heart's metabolism from predominate glucose consumption towards fatty acid oxidation. Consequently, ^{18}F FDG is mainly absorbed by activated inflammatory cells in the post-ischemic myocardium after infarction. In this study fasting and intravenous heparin were used based on a protocol developed to image inflammation in coronary arteries and sarcoidosis.

Post-ischemic, viable cardiomyocytes upregulate the expression of glucose transporters on their surface and thus result in an increase in ^{18}F FDG uptake within viable myocytes during acute ischemia. However, the presence of post–Gd enhancement in the myocardium is strongly reflective of myocardial infarction and any ^{18}F FDG uptake within infarcted tissue is deemed to reflect post-injury inflammation, caused by leukocyte infiltration and edema [2]. In a simultaneous PET/MR study evaluating ^{18}F FDG uptake within the myocardium following acute infarction, SUV_{mean} in the infarct area was associated with deterioration of left-ventricular function, independent of the infarct size [3]. This suggests that the level of inflammatory response within infarcted myocardium has a direct correlation to a long-term outcome, including infarct-related remodeling and a resultant wall-motion impairment and ventricular dilatation. ^{18}F FDG PET, as a measure of inflammation extent and intensity, may serve as a biomarker for post-infarct inflammation and as a prognostic indicator for infarctrelated remodeling and ventricular functional outcome.

Conclusion

^{18}F FDG PET/MR shows increased uptake of ^{18}F FDG in subendocardial infarction, an observation that was also confirmed by the presence of late post-Gd contrast enhancement on MR. Both of these observations reflect inflammation within the myocardium after acute ischemic injury in a patient with aborted sudden cardiac death with evidence of LAD and IM1 stenosis.

Biograph mMR examination protocol

PET	
Injected dose	237.5 MBq ^{18}F FDG
Scan delay	60 minutes
Scan acquisition	Simulation listmode
MR	
Sequences	2-point Dixon
	T2 HASTE
	Dynamic Gd perfusion
	Late Gd enhancement

Contact

Eun-Jung Kong, M.D., Ph.D.
Division of Cardiology
Department of Internal Medicine
Yeungnam University Medical Center
317-1 Daemyeong 5(o)-dong, Nam-gu
Daegu
South Korea
kongej@yu.ac.kr

References

1 Rischpler C. Acute myocardial infarction. Q J Nucl Med Mol Imaging. 2016;60(3):236-251.
2 Wollenweber T, Roentgen P, Schafer A, et al. Characterizing the inflammatory tissue response to acute myocardial infarction by clinical multimodality noninvasive imaging. Circ Cardiovasc Imaging. 2014;7(5):811-818.
3 Rischpler C, Dirschinger RJ, Mekolla SG, et al. Prospective Evaluation of 18F-Fluorodeoxyglucose Uptake in Postischemic Myocardium by Simultaneous Positron Emission Tomography/Magnetic Resonance Imaging as a Prognostic Marker of Functional Outcome. Circ Cardiovasc Imaging. 2016;9(4):e004316. doi:10.1161/CIRCIMAGING.115.004316.