The Integral Role of Metabolic and Perfusion Imaging in Assessment of Myocardial Scar: Comparison between 18F-FDG PET and 99Tc-Sestamibi

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Abstract

The Purpose: Viable myocardium has the potential to recover in function after intervention, whereas scarred tissue will not recover even after revascularization. Nuclear imaging techniques using either PET or SPECT have played a major role in this field. In this study, myocardium viability assessed by 99Tc MIBI, and 18 F-FDG, with identification of scar by each imaging modality.

Methods: Comparative cross section study, 31 patients were included in our study and all were assessed by TC-99m MIBI myocardium scan and F18 FDG myocardial scan.

Results: By using paired t sample test to detect the presence of difference in assessment of the scarred segments between TC 99 MIBI scan and FDG PET there was statistically difference between both of them.

Conclusion: Perfusion imaging by Tc 99m MIBI alone is not a ideal method to define myocardial viability compared to metabolic imaging by F18 FDG. So the combined imaging by Tc-99m MIBI myocardial perfusion SPECT and 18 F-FDG myocardial metabolic PET should be used widely in clinical practice.

Key Words: Cardiac viability – Hibernation – FDG PET – Perfusion MIBI scan.

Introduction

DESPITE recent developments in therapeutic options, heart failure due to coronary artery disease (CAD) continues to be one of the leading causes of morbidity and mortality in many countries, including Egypt. It is well known that dysfunctional but viable myocardium has the potential to recover after restoration of myocardial blood flow by either coronary arterial bypass grafting (CABG) or percutaneous coronary intervention (PCI), whereas scarred tissue will not recover even after revascularization [1].

Therefore, substantial efforts have been made to differentiate such potentially reversible and hence viable myocardium from scar [2].

Nuclear imaging techniques using either PET or SPECT have played a major role in this field [3]. Each technique has advantages and disadvantages, identification of viable dysfunctional myocardium falsely as scar is a concern as this can adversely influence treatment decisions [4].

Technetium-99m-labeled methoxy-isobutyl-isonitrile (Tc99m-MIBI) has emerged as an excellent perfusion marker for myocardial imaging to evaluate (CAD). Myocardial MIBI uptake is based on diffusion of the tracer into the myocyte and intracellular retention. Its uptake therefore is affected by coronary blood flow and thus delivery of the tracer to the myocyte and also by cell membrane integrity however, the relationship between the amount of regional myocardial Tc-MIBI uptake and myocardial viability as assessed by metabolic PET imaging need further evaluation [5].

18 F-FDG PET provides a biological signal on cellular viability, and is considered to be one of the most accurate noninvasive techniques to identify viable tissue, as supported by a number of studies using PET [6].

In this study, a group of patients referred for viability assessment underwent testing with two imaging modalities, Tc 99m-MIBI, and newly introduced...
in Egypt F18-FDG, with a particular emphasis on the identification of scar by each imaging modality.

**Material and Methods**

51 patients of this study were referred to our nuclear medicine department in Misr Radiology center (MRC) for nuclear myocardial perfusion assessment over a 6 month period (from December 2012 to May 2013). Among the 51 patient referred to our department and agree to perform the study, 20 patients who were normal or had reversible ischemia on Tc 99m MIBI scan were excluded from the study and the 31 patients with suggestive non viable myocardium were included in our study and completed F18 FDG PET scan.

The demographic distribution of the study group was: 22 (71%) men, and 9 (29%) women. The mean age was 43; (age range, 21-66 years).

The perfusion of the myocardium were assessed by Tc 99m-MIBI scanning; one -day protocol (rest/stress scans) was used; The rest phase was done at 45-60min after intravenous administration of 8-12 mCi of the tracer; The stress phase was on the same day, stress test used was exercise in 21 patients and dipyridamole in 10 patients, exercise stress test (Tradmill) Exercise endpoints were 85% or more of the maximum predicted heart rate, symptoms of severe angina, or 2-mm ST-segment depression on ECG and written inform consent was obtained, 20mCi of 99mTc-MIBI was intravenously injected at peak exercise with stress continuing for another minute. Gated SPECT myocardial imaging acquisition started 30min later. Gated SPECT myocardial imaging data were acquired in the supine position with a dual-head SPECT gamma camera (Philips, Bright view) equipped with a general purpose low-energy collimator. Sixty four projection images over a 180-non-circular orbit were acquired. Time per projection was 15s, matrix size 64x64, zoom 1.45, and gating eight frames per cardiac cycle.

The reconstructed data were projected as myocardial tomographic slices in the short axis, vertical-long axis, and horizontal long axis views. Gated SPECT myocardial imaging data were then processed and analyzed using software Quantitative Gated SPECT (QGS, QPS Cedars-Sinai Medical Center, Los Angeles, CA). The left ventricular EDV, ESV, and EF were also determined.

The presence of perfusion defects was classified the defects as reversible (including partially reversible) or fixed (irreversible). To determine the presence, location and severity of any perfusion abnormalities, SPECT images were assessed in the following manner: The left ventricle was divided into 20 segments, and each segment was assigned a score using a five-point scoring system (0, normal; 1, mildly reduced; 2, moderately reduced; 3, severely reduced; and 4, absent uptake). The sums of segment scores at stress (SSS), scores at rest summed rest score (SRS) and differences between the stress and rest scores summed difference score (SDS) were calculated.

On the same week 18 F-FDG PET scanning was organized to all the 31 patients. Subjects were fasted for at least 6 hours. A hyperinsulinaemic euglycaemic clamp was performed to standardize metabolic conditions and to maximize myocardial 18F-FDG uptake. The average glucose infusion rate during the equilibrium phase of the clamp was 4.2+-1.7mg/kg/min. At least 80 minutes after commencement of insulin (during clamp steady state), F18-FDG (185 MBq) was injected and scanning performed 30 minutes after injection of isotope. For all patients, this level was below the activity for peak 3D noise equivalent counting rate for the Philips Ingenuity PET/CT 128 slices. All datasets were corrected for attenuation and reconstructed iteratively (4 iterations; 8 ordered subsets; gauss filter; Nyquist frequency 6.0; 128 matrix; zoom of 2; offset c=3cm, y=5cm). Random and scatter correction was used as implemented by the manufacturer. PET analysis Quantitative, semiquantitative, and visual image analysis was performed. Sinogram files of the gated data (2D-G, 3D-10, and 3D-5) were summed and reconstructed. Results were analyzed using a 20-segment polar map. The activity concentration (Bq/mL) was determined for each segment.

Visual analysis was based on a 3-point rating scale: 1= Viable, 2= Nontransmural scar, 3= Transmural scar. Further clinical information and angiography results were considered for visual analysis.

Images were compared to determine agreement between areas of scar identified by each technique. 18 F-FDG PET and Tc99m MIBI can show 4 patterns of blood flow and metabolism in myocardial segments: Normal; mildly reduced (matched pattern consistent with subendocardial scarring); severely reduced (matched pattern consistent with transmural scarring); or, uniquely, mismatched (reduced flow with preserved metabolism), which indicates viable myocardium capable of contractile recovery.

All images were interpreted by experienced consultant in nuclear medicine.
Statistical calculations:

Data analysis using SPSS Version 17. Numerical values are presented as mean+/–standard deviation. Comparisons between group means were carried out by paired t-test p-value 0.05 was considered statistically significant.

Results

During the time of the study, 31 patients were included in our study, and all were assessed by TC-99m-MIBI gated SPECT myocardium scan and F18 FDG-PET scan.

By assessment of the risk factors for the study group, 16 (51.6%) patients had diabetes mellitus (DM), 11 (35.5%) patients had hypertension, and 8 (25.8%) patients were well known and had documentation for myocardial infarction.

Single vessel diseases (SVD) was reported in 7 (22.5%) patients and 24 (77.5%) patients had multi-vessels disease (MVD), Fig. (1).

All the 31 patients had fixed perfusion defects on both the rests and stress phases of TC-99m-MIBI myocardium perfusion Gated SPECT study, based on 20 segments polar map analysis, 9 (29%) patients had the same numbers of scarred segments on F 18-FDG scan (completely matched). The over-estimation of scar by Tc-99m-MIBI were identified in 15 (48.6%) patients as deduced from higher number of segments were identified as scar by MIBI than by F18-FDG but those patients still had scarring on both imaging modalities. The diagnosis changed completely in 7 (22.4%) patients who were positive for scarring on Tc-99m-MIBI and entirely negative in F18-FDG scan and those patients could be considered as false positive, Fig. (2).

The mean and standard deviation for the total number of scarred segments as assessed by Tc-99m MIBI and F18-FDG-PET scan are mentioned in Table (1).

By using paired t sample test to detect the presence of difference in assessment of the scarred segments between TC-99-MIBI scan and F18-FDG-PET, there was statistically significant difference between both modalities ($t=5.950$, $p=0.00$).

Table (1): Mean & SD for scarred segments by Tc-99m MIBI and F18-FDG-PET.

<table>
<thead>
<tr>
<th></th>
<th>Mean</th>
<th>Std. Deviation</th>
</tr>
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<tbody>
<tr>
<td>Tc-99m-MIBI</td>
<td>7.2258</td>
<td>3.56567</td>
</tr>
<tr>
<td>FDG-PET</td>
<td>4.9677</td>
<td>3.85991</td>
</tr>
</tbody>
</table>

Table (2): Comparison of scar burden between the tow modalities.

<table>
<thead>
<tr>
<th></th>
<th>Paired differences</th>
<th>Confidence 95% interval of the difference</th>
<th>Sig (2-tailed)</th>
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<tbody>
<tr>
<td>Mean</td>
<td>Std. Deviation</td>
<td>Lower Upper</td>
<td></td>
</tr>
<tr>
<td>MIBI</td>
<td>2.25806</td>
<td>1.48303 3.03310 5.950 0.00</td>
<td></td>
</tr>
<tr>
<td>PET</td>
<td>2.11294</td>
<td></td>
<td></td>
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Fig. (3): A 63 year old diabetic male patient presented with history of myocardial infarction. Tc-99m-MIBI myocardium perfusion Gated SPECT study (A) showed fixed perfusion defect affecting the inferior wall yet, FDG PET (B) exhibited metabolic activity at the inferior wall denoting viable myocardial tissue therein.

Fig. (4): A 49 year old male patient presented with history of recurrent chest pain, Tc-99m-MIBI myocardium perfusion Gated SPECT (A) study showed fixed perfusion defect affecting the cardiac apex, apical segments of the anterior, inferior as well as the entire septal wall, PET scan (B) exhibited normal FDG uptake all over the myocardium including except for the apex denoting viable myocardium at the aforementioned sites with scarred non viable tissue at the apex.

Discussion

Patients with previous myocardial infarction (MI) have a marked propensity for cardiovascular morbidity and mortality is evident. Therefore, identification and management of such patients are very important not only for decreasing the mortality but also for improving the quality of life [7]. There is therefore a clinical need to identify the patients most likely to benefit from revascularization.

For clinical use in perfusion assessment, technetium based tracers are often preferred as these tracers result in lower radiation exposure to the patient and a reduction in soft tissue attenuation. However, we have found that MIBI overestimates areas of myocardial scar tissue [8].

Schinkel et al., demonstrated that 18-F-FDG uptake is present in hibernating myocardium and is a good predictor of functional recovery after revascularization, as has since been confirmed by other studies [9].

In current clinical practice, a combination of 18-F-FDG PET and a perfusion study is usually applied to determine viability [10].

In this study, Tc-99m-MIBI appeared to overestimate scar, the diagnosis change completely from scared to viable myocardium on FDG-PET scan in 22.4% of the study group and was considered as false positive and subsequently the management will differ greatly, the rest of this overestimation often in the inferior LV segments, as a result of diaphragmatic attenuation yet patients, differences were also found in the imaging of the lateral wall and apex suggesting that this cannot completely explain these results.

These findings would bring into question the use of Tc-99m-MIBI which would seem to be scarred, are in fact viable by FDG-PET. The over-reporting of scar by MIBI is unlikely to be explained solely by changes in perfusion at rest as it is known that hibernating myocardium has preserved blood flow.
at rest. Reduced uptake/enhanced washout of technetium based tracers has been reported and it has been postulated that repetitive ischaemia might contribute to this [11]. Based on these results, it may be prudent to consider alternatives to technetium MIBI in the assessment of myocardial viability.

Preserved myocardial metabolic activity using FDG is often regarded as the gold standard to assess viability [12]. This study suggests that there is clinically significant difference between FDG imaging and MIBI for viability assessment.

Several studies have shown that Tc-99m-MIBI myocardial perfusion SPECT combined with 18F-FDG myocardial metabolic PET are comparable with 13 N-ammonia perfusion PET and FDG metabolic PET in evaluation of myocardial viability [13].

The results obtained in this study using two common imaging techniques in a group of patients, suggests that technetium MIBI should not be used to define myocardial viability where more accurate methods exist. The use of FDG-PET and our data suggest that there is practical difference between these two modalities.

Conclusion:

Perfusion imaging by Tc-99m-MIBI alone is not an ideal method to define myocardial viability compared to metabolic imaging by F18-FDG. So, the combined imaging by Tc-99m-MIBI myocardial perfusion SPECT and 18F-FDG myocardial metabolic PET should be used widely in clinical practice.

References


