PET imaging techniques in cardiology

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PET-CT in Nuclear Cardiology

- Myocardial perfusion imaging
  - $^{82}$Rb
  - $^{13}$N Ammonia
  - $^{18}$F-Flupiridaz

- Myocardial metabolism imaging
  - $^{18}$FDG
    - Viability imaging
    - Ischemia imaging
Potential clinical applications of PET MBF quantification

• Impaired MFR in early atherosclerosis
  – Hypertension
  – Hyperlipidemia
  – Diabetes
  – smoking

• Impaired MFR in coronary stenosis and advanced coronary atherosclerosis
  – Evaluation of functional significance of intermediate coronary lesions
  – Detection/delineation of multivessel coronary disease
  – Track disease progression/regression

• Impaired MFR in nonatheroclerotic microvascular disease
  – Syndrome X
  – Cardiomyopathies HCM, DCM, AS, Hypertensive heart disease
• PET successful in MBF and CFR estimation
  – $^{15}$O-labeled water
  – $^{13}$NH$_3$
  – $^{82}$Rb
  Resting MBF in healthy adults ranges from 0.59 - 2.05 mL/min/gm (average 0.98+- 0.23) and hyperemic flow 1.85-5.99 (av. 3.77+- 0.85) : Chareonthaitawee et al Cardiovasc Res 2001
  Women have higher resting MBF
  Spatial heterogeneity of MBF
  CFR< 2.5 is considered abnormal
Dynamic PET perfusion protocol

Adenosine inj

\( ^{13} \text{N-amermonia} \)
Stress injection

\( ^{13} \text{N-amermonia} \)
Rest injection

Beta-Blocker iv
Metoprolol 5-15 mg

CT scout
(5 sec)

CAC
(10-40 sec)

LMR stress
(6 mm)

Gated stress
(12 min)

LMR rest
(6 min)

Gated rest
(12 min)

CTAC
10-40 sec

Dynamic acquisition
for
- MBF (ml/min/g)

Static acquisition
for
- Perfusion
- Venticulography

Dynamic frames:
12 x 10 sec
3 x 20 sec
6 x 30 sec

Static frames:
12 x 16 sec
3 x 20 sec
6 x 30 sec

LFR: List Mode Reconstruction
CTAC: CT-based Attenuation Correction
CAC: Coronary Artery Calcium scan
CTA: CT Angiography
MBF: myocardial blood flow
Advantage of PET over SPECT
LAD TERRITORY: Anterior wall is well perfused. MBF at stress: 2.67 ml/gm/min (Normal range >2ml)

RCA and LCX TERRITORY: Lateral wall and inferior walls are well perfused and there is no evidence of ischemia or infarcts in these territories. RCA: MBF at stress: 2.65 ml/gm/min (Normal range >2ml) LCX: MBF at stress: 3.1 ml/gm/min (Normal range >2ml)

COMMENTS:
• No evidence of inducible ischemia in the myocardial territories.
• Normal myocardial blood flow response to adenosine vasodilator stress.

<table>
<thead>
<tr>
<th></th>
<th>QMP (ml/g/min)</th>
<th>Stress</th>
<th>mean</th>
<th>std dev.</th>
</tr>
</thead>
<tbody>
<tr>
<td>LAD</td>
<td></td>
<td>mean</td>
<td>2.67</td>
<td>0.37</td>
</tr>
<tr>
<td></td>
<td></td>
<td>std dev.</td>
<td>0.37</td>
<td></td>
</tr>
<tr>
<td>LCX</td>
<td></td>
<td>mean</td>
<td>3.10</td>
<td>0.22</td>
</tr>
<tr>
<td></td>
<td></td>
<td>std dev.</td>
<td>0.22</td>
<td></td>
</tr>
<tr>
<td>RCA</td>
<td></td>
<td>mean</td>
<td>2.65</td>
<td>0.36</td>
</tr>
<tr>
<td></td>
<td></td>
<td>std dev.</td>
<td>0.36</td>
<td></td>
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<tr>
<td>Global</td>
<td></td>
<td>mean</td>
<td>2.78</td>
<td>0.39</td>
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<tr>
<td></td>
<td></td>
<td>std dev.</td>
<td>0.39</td>
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</table>
The above findings indicate:
1) Inducible ischemia in LAD territory
2) Inducible ischemia in Left Circumflex territory
3) Inducible ischemia in LAD and Circumflex
4) Triple vessel disease
Answer

1) Inducible ischemia in LAD territory
2) Inducible ischemia in Left Circumflex territory
3) Inducible ischemia in LAD and circumflex
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Question:
The above findings indicate:
1) Inducible ischemia in distal anterior wall, apex and apical septum, (LAD territory)
2) Inducible ischemia in LAD and circumflex territories
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  2) Inducible ischemia in LAD and circumflex territories
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Viability assessment

• Myocardium under aerobic conditions uses fatty acids as metabolic fuel
• Under ischemic conditions glucose becomes the preferred substrate
• Viable myocardium retains metabolic activity, scarred tissue does not
• Perfusion- metabolism mismatch is hallmark of viability (Rubidium-FDG, ammonia-FDG, Tc-MIBI/Tetrofosmin-FDG)
Outcome after Revascularization: Improvement of Prognosis

Meta-analysis: reviewing 24 studies including 3,088 patients evaluated for viability with non-invasive testing (11 with FDG):

Improved survival in patients with viable myocardium and revascularization

## Patterns of Perfusion and Metabolism

<table>
<thead>
<tr>
<th>PATTERN</th>
<th>DIAGNOSIS</th>
<th>PERFUSION</th>
<th>METABOLISM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal or Normal</td>
<td>Normal</td>
<td>Normal</td>
<td>Normal</td>
</tr>
<tr>
<td>Mismatch</td>
<td>Hibernation</td>
<td>Reduced</td>
<td>Normal or Increased</td>
</tr>
<tr>
<td>Match</td>
<td>Transmural scar</td>
<td>Severely reduced</td>
<td>Severely reduced</td>
</tr>
<tr>
<td>Match</td>
<td>Nontransmural scar</td>
<td>Mildly reduced</td>
<td>Mildly reduced</td>
</tr>
<tr>
<td>Reversed Mismatch</td>
<td>Normal Stunning LBBB</td>
<td>Normal</td>
<td>Reduced</td>
</tr>
</tbody>
</table>

Highest metabolism can be seen in normal or ischemic myocardium! Perfusion images are necessary to judge most normal myocardium.
**Guidelines:** The potential for a post-revascularization improvement of LVEF by at least 5% or more EF units is high if the mismatch affects 20% of the LV myocardium (~ 4 ischemic viable segments).

Case 3

- 55/F Diabetic, hypertensive, obese
- h/o old anterior wall myocardial infarct, CKD
- Symptoms of cardiac failure
- ECHO: LVEF= 10-15%
- H/o PTCA in 2012, stent to LAD and LCX
- Sent for viability assessment
Question:

The following statements are true:
1) There is no evidence of viable myocardium
2) An FDG PET study is necessary for confirming viability
3) No further viability testing is necessary
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1) There is no evidence of viable myocardium

2) An FDG PET study is necessary for confirming viability

3) No further viability testing is necessary
Case 4

• 58/m with no risk factors and coronary artery disease
• Angiography showing occlusion of RCA and minor plaques in LAD and LCX
• ECHO LVEF= 45%
• Now had one episode of retrosternal discomfort
• Underwent rest-stress adenosine MPI and FDG viability PET
Question:
The images show:
1) Large infarct in mid and basal inferior wall and inferolateral wall with no inducible ischemia or viable myocardium in infarct zone
2) Same as above, but cannot comment on viability. FDG PET is needed
3) There is inducible ischemia and viability in infarct zone
Answer

• Question:
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  1) Large infarct in mid and basal inferior wall and inferolateral wall with no inducible ischemia or viable myocardium in infarct zone
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  3) There is inducible ischemia and viability in infarct zone
Basis for stress FDG imaging

- Normally perfused, non ischemic myocardium metabolises primarily fatty acids
- Underperfused, ischemic myocardium metabolises glucose
- Fasting suppresses glucose metabolism in normally perfused myocardium (but has no effect on anaerobic glucose metabolism in ischemic myocardium)
- Catecholamines released during exercise further suppress glucose metabolism in normal myocardium, but do not alter anaerobic glucose metabolism in ischemic myocardium
TRIPLE VESSEL DISEASE

• 59 year old male
• Hypertensive, non-diabetic
• Chronic stable angina
• No previous infarcts
• Coronary angiography shows –
  – LAD – mid 50% followed by 80% stenosis.
  – LCx – non-dominant, discrete 70% stenosis
  – RCA – dominant, 80% proximal stenosis
    – PDA – 90% stenosis
Rest perfusion

Stress perfusion

Stress PET