Emerging role of PET in nuclear cardiology

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PET principles

511 keV gamma

$e^+ - e^-$

180°
PET/CT Cyclotron Unit UNAM

Cyclotron
Radiopharmacy
PET Camera
PET

CT

Perfusion

Anatomic evaluation of coronary atherosclerosis

Diagnosis

Prognosis

Follow-up
Complementary Role of CT and myocardial perfusion imaging

CT
- Anatomic evaluation of atherosclerosis
- Detection
- Stadification
- Ischemia localization
- Treatment follow-up

Myocardial perfusion
- Functional evaluation of atherosclerosis

Endothelial damage
- Asymptomatic
- Chronic ischemia
- ACS

Atherosclerosis
- Atherotrombosis
- Myocardial damage
- C.H.F.

Endothelial dysfunction
PET/CT applications in Cardiology

- Myocardial perfusion
- Coronary Angiotomography
- Cardiac function
- Oxidative metabolism
- Myocardial viability
- Coronary blood flow quantification
- Endothelial dysfunction
- Plaque inflammation
PET/CT applications in Cardiology

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Myocardial Perfusion
Possitron emitting Tracers

- $^{82}$Rubidium
- $^{15}$O-Water
- $^{11}$C-Acetate
- $^{13}$N-Ammonia

Ammonia PET
PET/CT applications in Cardiology

- Myocardial perfusion
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- Plaque inflammation
Calcified Plaque

Non-Calcified Plaque
Advanced characterization of the coronary plaque: the value of PET
PET/CT applications in Cardiology

- Myocardial perfusion
- Coronary Angiotomography
- Hybrid imaging
- Cardiac function
- Oxidative metabolism
- Myocardial viability
- Coronary blood flow quantification
- Plaque inflammation
29 patients with the suspicion of CAD were studied with PET

Coronary Anatomy and Stenosis were evaluated with CT

Stenosis: any reduction in the lumen diameter; it was considered as significative when the reduction was bigger than 50%
Results

<table>
<thead>
<tr>
<th></th>
<th>+ Coronary CT</th>
<th>- Coronary CT</th>
</tr>
</thead>
<tbody>
<tr>
<td>+ PET</td>
<td>23</td>
<td>2</td>
</tr>
<tr>
<td>- PET</td>
<td>1</td>
<td>3</td>
</tr>
</tbody>
</table>

Sensitivity 95.8%  Specificity 60%

PPV 92%  NPV 75%

Accuracy 90%  p < 0.001
Results

CT  
\[ n = 29 \]

- Normal  
  \[ n = 5 \]
  - PET Ischemia  
    \[ n = 2 \]

- Esthenosis  
  \[ n = 24 (100\%) \]
  - Significative  
    \[ n = 15 (62.5\%) \]
    - PET Ischemia  
      \[ n = 15 (100\%) \]
    - Normal PET  
      \[ n = 0 (0\%) \]

  - Non-significative  
    \[ n = 9 (37.5\%) \]
    - PET Ischemia  
      \[ n = 8 (88\%) \]
    - Normal PET  
      \[ n = 1 (11\%) \]
### Results

**Significant stenosis (>50%)**
- Mild ischemia: 5
- Moderate ischemia: 1
- **Severe ischemia**: 9

**Non-significant stenosis (<50%)**
- Non-ischemic: 1
- Mild ischemia: 4
- Moderate ischemia: 4
- **Severe ischemia**: 0

\[ n = 15 \quad \text{and} \quad n = 9 \]

**Correlation between coronary stenosis and the severity of ischemia**
Normal CT
n=9

Normal PET/SPECT
n=6

Abnormal PET/SPECT
n=3

Normal Angiography
n=9

Non-obstructive CT
n=16

Normal PET/SPECT
n=6

Abnormal PET/SPECT
n=10

Non-obstructive angiography
n=16

Obstructive CT
n=33

Normal PET/SPECT
n=14

Non-obstructive angiography
n=3

Obstructive Angiography
n=11

Non-obstructive angiography
n=3

Obstructive Angiography
n=16

Obstructive PET/SPECT
n=19

JACC 2006;48(12):2508-14
Why don’t they always match?

- The coronary stenosis percentage is just one of the factors that interact in coronary resistance; it is not sufficient to determine the plaque’s hemodynamic significance.
  - It is difficult to estimate the stenosis degree in “soft” or very calcified plaques
- Balanced ischemia
- Non-Coronal causes of myocardial lesions
  - Coronary Anomalies
  - Ectasia
  - Coronary Aneurysms
- There may be coronary lesions without ischemia
- There may be ischemia without coronary lesions

Dorbala et al. JACC 2006: 48:2515-17
Di carli et al. J Nucl Cardiol 2006;13:139-44
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LVEF 62%

LVEF 23%
Stress LVEF 73%

Rest LVEF 69%

NORMAL
Gated PET

Stress NH3: 04/08/2006
EF = 70% (R0)
EDV = 60 ml
ESV = 18 ml
SV = 42 ml
Mass = 88 gm

Estimated % Thickening:
- > 40%
- 25% => 40
- 10% => 25
- 0% => 10
- -10% => 0%
- < -10%

Rest NH3: 04/08/2006
EF = 65% (R0)
EDV = 54 ml
ESV = 19 ml
SV = 35 ml
Mass = 88 gm
Gated PET

Stress NH3: 08/04/2006
EF = 53% (RO)
EDV = 66 ml
ESV = 41 ml
SV = 47 ml
Mass = 129 gm
gates in cine: 8

Rest NH3: 08/04/2006
EF = 54% (RO)
EDV = 63 ml
ESV = 38 ml
SV = 45 ml
Mass = 129 gm
LVEF Rest-Stress
Non-ischemic

64.6 ± 7.5%
70 ± 7.1%
n = 5, p < 0.001

Alexánderson E. Presentado en ICNC 8, Praga 2007
LVEF Rest-Stress Ischemic

56.9 ± 5%

n = 12, p < 0.001

Alexánderson E. Presentado en ICNC 8, Praga 2007
$\Delta$ LVEF and Magnitude of affected myocardium

Results PET Rb$^{82}$

Disease extension with Angiography

Dorbala et al. J Nucl Med 2007;48
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Myocardial blood flow quantification

- Early detection of coronary artery disease
- Precise diagnosis of ischemia
- Physiological impact of stenosis

Determination of myocardial blood flow.

- 17 healthy controls
- 13 patients with CAD previously diagnosed with PCI.
- 13N-Ammonia myocardial perfusion imaging
- Quantification of coronary blood flow.
- Comparison with cardiac catheterism.
Coronary flow quantification

Improves the diagnosis of CAD.
Relationship between coronary flow and coronary stenosis

Coronary stenosis percentage

Stress coronary flow

Less than 50%  50% to 70%  70% to 90%  90% to 100%
Relationship between coronary stenosis and coronary vasodilation reserve

![Graph showing the relationship between coronary stenosis percentage and coronary vasodilation reserve.](image-url)
Myocardial blood flow quantification

• Detection of endothelial dysfunction
  – DM: ↓ CFR
  – Systemic Hypertension: ↓ EDVI
  – Anti-phospholipid syndrome: ↓ EDVI
  – Normal perfusion

• Patients’ follow-up

• Vascular disease might be ruled-out
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Ammonia  18-FDG

Discordant  Concordant
The goal of viability imaging

• Identify patients with a bad cardiac function in which revascularization might improve:
  – Left ventricular function
  – Symptoms
  – Survival
PET viability Criteria

Ammonia 18-FDG

DISCORDANT

CONCORDANT

Circulation 1983; 67: 766-78
Diagnostic accuracy of viability tests evaluated with PET

Modificado de Bax et al. Curr Probl Cardiol 2001
18FDG 13N Ammonia

Viability
Long-term prognosis of patients with left ventricular dysfunction and viability evaluated with PET and received therapy

Di Carli et al. JTCVS 1998
Risk of suffering a MACE in patients with evidence of viability demonstrated with PET treated with revascularization or medical therapy

n = 634 patients
Relative risk and CI 95%

Di Carli. J Nucl Cardiol 2002
Mortality rate in patients with or without viability treated with revascularization or medical therapy

Allman et al. JACC 2002
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- Plaque inflammation
Evidence of FDG uptake in the carotid arteries.

Atherosclerotic plaque inflammation

<table>
<thead>
<tr>
<th>Factor</th>
<th>Strong uptake (SUV ≥ 2.7), N = 11</th>
<th>Weak uptake (SUV 1.2 to 2.3), N = 2</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Female</td>
<td>3</td>
<td>1</td>
<td>1.0</td>
</tr>
<tr>
<td>Age, mean ± S.D.</td>
<td>66.2 ± 102</td>
<td>66.5 ± 16.2</td>
<td>0.9</td>
</tr>
<tr>
<td>Hypertension</td>
<td>8</td>
<td>1</td>
<td>1.0</td>
</tr>
<tr>
<td>Diabetes</td>
<td>2</td>
<td>1</td>
<td>0.4</td>
</tr>
<tr>
<td>Hyperlipidemia</td>
<td>6</td>
<td>2</td>
<td>0.4</td>
</tr>
<tr>
<td>Good outcome Rankin 0–2</td>
<td>4</td>
<td>1</td>
<td>0.7</td>
</tr>
<tr>
<td>Stenosis</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Moderate 50–69%</td>
<td>3</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Significant 70–89%</td>
<td>5</td>
<td>0</td>
<td>0.052</td>
</tr>
<tr>
<td>Severe ≥90%</td>
<td>3</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Presence of primary endpoint</td>
<td>8</td>
<td>0</td>
<td>0.3</td>
</tr>
</tbody>
</table>
Atherosclerotic plaque inflammation

Evidence of FDG uptake in the aorta
PET/CT applications in Cardiology

- Myocardial perfusion
- Coronary Angiography
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- Endothelial dysfunction
- Myocardial viability
- Plaque inflammation
- Molecular imaging
Molecular Imaging

- 11C Palmitato
- IPPA
- BMIPP
- 201Tl+
- 82Rb+
- Misonidazole
- [O₂]
- 11C-CGP-12177
- 18FDG
- Glucosa
- Glucógeno
- Glucosa-6-P
- Glucólisis
- Piruvato
- Lactato
- 11C-Acetato
- 13C-HED
- 18F Dopamina
- 18F NE
- Adenosina
- ATP
- AGL
- ATP
- ADP
- K+
- Na+
- AGL-CoA
- Depósitos de lípidos
- β oxidación
- Krebs
- Fosforilación oxidativa
- 15O₂
- 11C-Homocisteína
CONCLUSIONS

- Innovative
- Non-invasive.
- Anatomic and functional information of the heart (coronary and cardiac anatomy, calcification and characterisation of the plaque, myocardial perfusion and ventricular function)
- Still pending to determine the diagnostic and prognostic value of this imaging technique
  - Which patients obtain a benefit with both techniques?
  - Is there a testing sequence?
  - Is there an improvement in the patient management?
- The big radiation dose and the costs make of the PET/CT an inappropriate technique for check-ups
- The combination of perfusion imaging and CT is the best available method to predict cardiovascular outcomes.