Myocardial blood flow PET evaluation and quantification

Dr. Erick Alexánderson Rosas
Clinical case

62 year old female patient with a history of DM2 and chronic systemic hypertension

She complains of progressive shortness of breath associated with diaforesis and a feeling of “chest pressure”

She went to the ER of the ICNICH due to the presence of typical chest pain
Clinical case

- With these findings she was sent for an invasive angiography
Clinical case

- A PCI was performed and a stent was placed in the LAD artery (responsible vessel)

- The result was successful with a final TIMI flow III, TMP III
Clinical case

- A Nuclear Medicine Myocardial perfusion test was performed to evaluate the remaining territories (RCA and Cx)
<table>
<thead>
<tr>
<th>Vascular territory</th>
<th>Rest</th>
<th>Stress</th>
<th>CFR</th>
</tr>
</thead>
<tbody>
<tr>
<td>LAD</td>
<td>0.78 ml/min/gr</td>
<td>1.93 ml/min/gr</td>
<td>2.48</td>
</tr>
<tr>
<td>RCA</td>
<td>1.08 ml/min/gr</td>
<td>1.93 ml/min/gr</td>
<td>1.78</td>
</tr>
<tr>
<td>Cx</td>
<td>1.14 ml/min/gr</td>
<td>2.16 ml/min/gr</td>
<td>1.98</td>
</tr>
</tbody>
</table>
SPECT

- Flow heterogeneity to see the defect
- Homogenous decrease:
  - Three vessel disease, Left main
- Microvascular disease

Beanlands et al. J Am Coll Cardiol 2009 54: 157-159
### SPECT

<table>
<thead>
<tr>
<th>Author, year (reference)</th>
<th>Number of pts</th>
<th>Tracer</th>
<th>Stress</th>
<th>Sensitivity%</th>
<th>Specificity%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Iskandrian, 1989 (4)</td>
<td>193</td>
<td>Thalium 201</td>
<td>Physical</td>
<td>86</td>
<td>62</td>
</tr>
<tr>
<td>Maddahi, 1989 (5)</td>
<td>110</td>
<td>Thalium 201</td>
<td>Physical</td>
<td>95</td>
<td>56</td>
</tr>
<tr>
<td>Mahmarian, 1990 (6)</td>
<td>296</td>
<td>Thalium 201</td>
<td>Physical</td>
<td>87</td>
<td>87</td>
</tr>
<tr>
<td>Cramer, 1994 (11)</td>
<td>38</td>
<td>Thalium 201</td>
<td>Dipiridamol</td>
<td>90</td>
<td>71</td>
</tr>
<tr>
<td>Kapur, 2002 (14)</td>
<td>2560</td>
<td>MIBI</td>
<td>Adenosine</td>
<td>91</td>
<td>87</td>
</tr>
</tbody>
</table>

**SENSITIVITY:** 90 %  
**SPECIFICITY:** 73%
SIMULTANEOUS RECOGNITION OF CORONARY DISEASE IN 2 OR MORE TERRITORIES

n = 1600

Alexánderson Arch Inst Cardiol Mex 2000. 70:234-40
### PET

<table>
<thead>
<tr>
<th>Reference</th>
<th>Number of pts</th>
<th>Women</th>
<th>History of CAD</th>
<th>Tracer</th>
<th>Sensitivity</th>
<th>Specificity</th>
<th>PPV</th>
<th>NPV</th>
<th>Accuracy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sampson et al</td>
<td>102</td>
<td>0.42</td>
<td>0</td>
<td>$^{82}$Rb</td>
<td>0.93</td>
<td>0.83</td>
<td>0.80</td>
<td>0.94</td>
<td>0.87</td>
</tr>
<tr>
<td>Go et al</td>
<td>202</td>
<td>NR</td>
<td>0.47</td>
<td>$^{82}$Rb</td>
<td>0.93</td>
<td>0.78</td>
<td>0.93</td>
<td>0.80</td>
<td>0.90</td>
</tr>
<tr>
<td>Tamaki et al</td>
<td>51</td>
<td>NR</td>
<td>0.75</td>
<td>$^{13}$NH</td>
<td>0.98</td>
<td>1</td>
<td>1</td>
<td>0.75</td>
<td>0.98</td>
</tr>
<tr>
<td>Gould et al</td>
<td>31</td>
<td>NR</td>
<td>NR</td>
<td>$^{82}$Rb/$^{13}$NH</td>
<td>0.95</td>
<td>1</td>
<td>1</td>
<td>0.90</td>
<td>0.97</td>
</tr>
</tbody>
</table>

- Sensitivity 95%
- Specificity 89%
- PPV (94%)
- NPV (84%)

SPECT V.S. PET

SPECT

PET
Coronary circulation

Smooth muscle cell

Arteriole

Capilar
Ohm’s Law: \( F = \frac{\Delta P}{R} \)

Poiseuille’s Law: \( F = \frac{\text{MC}}{r^4} = \frac{\Delta P + \text{Diameter}}{8nL} \)
Radiotracers

- Methods: PET
  - Ammonia
  - Oxygen
  - Rubidium
  - Acetate

Unidad PET/CT Ciclotrón UNAM

Courtesy of Turku PET Centre

Courtesy of B&WH Harvard

Unidad PET/CT Ciclotrón UNAM
Radiotracers used in myocardial blood flow evaluation

- O-15-water
- N-13-ammonia
- Rb-82
Dynamic study

- 11 C - Acetate
Coronary blood flow quantification with PET
Time-Activity Curves

Input TACs

BP
LAD
LCX
RCA

[Graph of time-activity curves with different lines representing BP, LAD, LCX, and RCA]
13N-Ammonia Myocardial perfusion Protocol

- PET protocol + Gating + MBF quantification
- Dynamic study

13N-ammonia 30 mCi

- Rest Perfusion
- Adenosine
- Stress Perfusion

Total time: <1 hr
Two compartments model for $^{13}$N-Ammonia

- Freely diffused $^{13}$N-Ammonia
  - $V$(ml/g)
  - $CF$ (ml/min/g)

- Metabolically trapped $^{13}$N-Ammonia
  - $K1$ (ml/min/g)
  - $K2$ (1/min)

$Smith\ et\ al,\ J\ Nucl\ Med\ 1988;29:288-94$
Validation of coronary blood flow quantification with PET

Kuhle et al, Circulation 1992;86:1004-17
Normal Vasodilation

Pharmacologic Vasodilation

Cold Pressor Test Exercise

Flow → shear stress

Endothelial cells → NO* → Vascular smooth muscle cells

Dilation → Diminished dilation → Diminished dilation to constriction

α-adrenergic receptors
Coronary blood flow

$[^{13}N]$-ammonia PET

REST

CPT

STRESS

<table>
<thead>
<tr>
<th>Extent</th>
<th>Severity</th>
<th>Flow</th>
</tr>
</thead>
<tbody>
<tr>
<td>LAD</td>
<td>77.71</td>
<td>0.187</td>
</tr>
<tr>
<td>LCX</td>
<td>34.65</td>
<td>0.502</td>
</tr>
<tr>
<td>RCA</td>
<td>20.55</td>
<td>0.416</td>
</tr>
<tr>
<td>LV</td>
<td>47.85</td>
<td>0.459</td>
</tr>
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<tr>
<td>LAD</td>
<td>80.26</td>
<td>0.211</td>
</tr>
<tr>
<td>LCX</td>
<td>24.66</td>
<td>0.790</td>
</tr>
<tr>
<td>RCA</td>
<td>25.90</td>
<td>0.908</td>
</tr>
<tr>
<td>LV</td>
<td>49.63</td>
<td>0.849</td>
</tr>
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EDVI ≥ 1.5

CFR ≥ 3.0

Alexánderson E. Arch Cardiol Mex. 2005
Myocardial blood flow absolute quantification: Clinical applications

- Diagnosis
  - Multivascular disease
  - Microvascular disease
- Evaluation of the cardiovascular risk
- Evaluation of endothelial function
- Patient’s treatment and follow-up
Myocardial blood flow absolute quantification: Clinical applications

- Diagnosis
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  - Microvascular disease
- Evaluation of the cardiovascular risk
- Evaluation of endothelial function
- Patient’s treatment and follow-up
Coronary flow quantification

Improves the diagnosis of myocardial ischemia.

Unidad PET-Ciclotrón, UNAM, México
Diagnosis of Multivascular Coronary Disease

- Myocardial flow relative distribution imaging
  - Trivascular coronary disease
  - Left main disease or equivalents
  - Balanced ischemia
Clinical case

Stress	Rest

Stress	Rest

Stress	Rest
Clinical case

Stress

Rest

Stress

Rest

CFR

1.04

0.86

1.07

1.04

0.58

0.62

1.46

1.67

0.64

1.67
Mean percentage of abnormal sectors in patients with trivascular disease

Myocardial blood flow absolute quantification: Clinical applications

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Diagnosis of microvascular disease

- Heart transplant
- Dilated myocardiopathy
CFR in patients with a heart transplant

MACE-free survival

Months

CFR > 2.3

CFR < 2.3

p = 0.006

Rodrigues et al. Int J Cardiol 2005;201:103
Diagnosis of microvascular disease

- *Heart transplant*

- *Dilated cardiomyopathy*
Coronary flow reserve in patients with Idiopathic dilated cardiomyopathy


$p < 0.05$
Myocardial blood flow absolute quantification: Clinical applications

- Diagnosis
  - Multivascular disease
  - Microvascular disease
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- Evaluation of endothelial function
- Patient’s treatment and follow-up
Added value of CFR as a predictor of adverse events in patients with a normal perfusion study

Herzog et al. JACC 2009;2:150-6
Coronary flow in the evaluation of cardiovascular risk

Herzog et al. JACC 2009;2:150-6
CFR as a risk marker for future CAD

Myocardial blood flow absolute quantification: Clinical applications

- Diagnosis
  - Multivascular disease
  - Microvascular disease
- Evaluation of the cardiovascular risk
- Evaluation of endothelial function
- Patient’s treatment and follow-up
CONCLUSIONS

Coronary flow quantification:

- A relative distribution myocardial flow image has limited diagnostic value.
- Non-coronary cardiovascular disease with microvascular dysfunction.
- Coronary risk evaluation
- Monitoring of the efficacy of risk reduction strategies
- New F-18-bound perfusion agent