Strength and Weaknesses of Myocardial Viability Imaging with SPECT, PET and CMR

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Case 1

- 68 yrs old diabetic patient with exertional dyspnea who was referred for evaluation of ischemic heart disease by means of TI-201 SPECT perfusion imaging.
TI-201 SPECT Perfusion Imaging
What would be your diagnosis?

1. Transmural infarction
2. Non-transmural infarction
3. Ischemia
4. Ischemia and non-transmural infarction
5. Uncertain
6. Further diagnostic work-up necessary
CT-Scan

**EF = 29%**

*Akinesia antero-apical*

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Image Fusion of 64 slice-CT and FDG-PET
Diagnosis

- **Apico-septal**: Reduced perfusion and no viability (transmural infarction).

- **Antero-apical**: Reduced perfusion but viable myocardium (although reduced) indicative of hibernating myocardium (and most-likely non-transmural infarction).
**Reversible Contractile Dysfunction**

- Normal blood flow
  
  or
  
- Normal glucose utilization
  
  or
  
- Reduced blood flow combined with enhanced glucose utilization

  = “mismatch”

**Irreversible Contractile Dysfunction**

- Severely reduced blood flow
  
  or
  
- Severely reduced glucose utilization
  
  or
  
- Reduced blood flow combined with reduced glucose utilization

  = “match”
N-13 ammonia PET-perfusion images

Glucose metabolism by FDG-PET

Normal
= "Match"
(Scar Tissue)

Irreversible dysfunction
= "Mismatch"
(Hibernation)

Reversible dysfunction

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Higher Sensitivity of FDG-PET in the Detection of Viable Myocardium than TI-201 SPECT Perfusion Imaging

(Brunken R. Circulation 1992;86:1357)

In patients with ischemic cardiomyopathy and LVEF < 30%
TI-201 SPECT redistribution images may underestimate viability
- Impaired sarcolemma function
- Severe hypoperfusion may limit TI-201 delivery
- Attenuation of low energy photons of TI-201 in dilated ventricles

(Akinboboye O. Am J Cardiol 1999;83:1271)
Amount of Viability and LVEF Improvement

\[ y = 4.6 + 1.07x \]
\[ r = 0.65 \quad p < 0.001 \]
Survival by Viability and Treatment

With PET Mismatch

- CABG
- Medical

Without PET Mismatch

- CABG
- Medical

Patients at Risk

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\[ p = 0.007 \]

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Summary

Myocardial Blood Flow and Glucose Metabolism Imaging

- Identifies Patients at high Risk for Cardiac Events
- Predicts Post-revascularization Improvement in:
  - Global Left Ventricular Function
  - Congestive Heart Failure related Symptoms
  - Long-term Survival
Case 2

- 71 year old patient with severe heart failure and dyspnea who was referred for evaluation of ischemic heart disease by means of 99Tc- SPECT perfusion imaging.
3D Display of Tc-SPECT

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What would be your diagnosis?

1. Transmural infarction
2. Non-transmural infarction
3. Ischemia
4. Ischemia and non-transmural infarction
5. Uncertain
6. Further diagnostic work-up necessary
Display of FDG-PET/CT Images
What would be your diagnosis?

Antero-basal: Transmural infarction

Antero-apical: viable

Inferior: mildly reduced viability

1) Agree
2) Disagree
Pitfall!

- Glucose utilization in normal myocardium is suppressed by high circulating free fatty acids (FFA) and low insulin-levels.
- The current study was performed WITHOUT glucose loading and insulin.

⇒ The absence of FDG-uptake in the antero-basal wall (while perfusion was normal) reflects regional FFA utilization preventing the FDG-uptake.
Glucose Loading Protocol for Cardiac FDG-PET Viability Study

Measurement of plasma glucose

- **< 6 mmol/l**
  - 25g dextrose i.v.

- **6-12.5 mmol/l**
  - 13g dextrose i.v.

- **>12.5 mmol/l**
  - Insuline s.c.*

Measurement of plasma glucose

- **< 8 mmol/l**
  - 5-10 mCi FDG Injection i.v.
  - 30-45 min
  - PET Acquisition

- **>8 mmol/l**
  - Insuline s.c.*
  - (20min)

*Humalog Dosis Plasma glucose

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Selective Angiography of the Left Coronary Artery
Selective Angiography of the Right Coronary Artery
Visual Case 3

Interpretation

1) Infarction: antero-septal and infero-septal

2) Uncertain

3) Further diagnostic work-up

FDG-PET

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« Mismatch » between FDG and perfusion antero-lateral
Interpretation

• Perfusion is normal in the (antero)-septal and infero-septal wall

⇒ viable!

• How would we explain the absence of FDG in the (antero-) septal wall despite glucose load and insulin application?

⇒ « mismatch » or hibernating myocardium in the antero-lateral wall with « high » FDG uptake!

⇒ CAVE: In the non-hibernating myocardium FDG-uptake is relatively less which may be misinterpreted as myocardial infarction
Pre-Angioplasty

Post-Angioplasty

3 days
7 weeks

Perfusion FDG-PET

(Courtesy of HR Schelbert)
84 year old patient with severe heart failure (LVEF: 27%) and dyspnea who was referred for viability evaluation. The patient had suffered previous antero-septal myocardial infarction in 2007 with rescue PTCA and stent employment of the proximal LAD.
MRI Delayed Enhancement Imaging of Gadolinium

Long- Axis: vertical

Long- Axis: horizontal

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MRI Delayed Enhancement Imaging of Gadolinium

Short-Axis: base

Short-Axis: mid-ventricular

Short-Axis: apical

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What would be your diagnosis?

Anterior wall: > 50% necrosis
Septal wall: > 75% necrosis

1) Agree
2) Disagree
Radiology report based on a visual analysis of the delayed enhancement images

Anterior wall: > 50% necrosis

Septal wall: > 75% necrosis
Timing of delayed enhancement image acquisition with MRI

Protocol: Scout-acquisition

Several images with « time inversion recovery sequence (TI) » between 200-300ms

TI sequence will be chosen according to the « null » equilibration of the myocardium

Acquisition of delayed-enhancement images with proper TI sequence (≈10-15 min after gadolinium injection)

CAVE: if equilibration with TI sequence is not perfect an OVERESTIMATION of the delayed enhancement and, thus, necrosis may result!
Short-Axis: mid-ventricular
Vertical Long-Axis
MRI  FDG-PET

Horizontal Long-Axis

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What would be your diagnosis?

Anterior wall: viable

Septal wall: preserved viability though mildly diminished

1) agree
2) disagree

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FDG-PET is probably more accurate in the evaluation of myocardial viability in the «intermediate» range than CMR.

- Investigations by
Reserve Slides

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Polar Map Analysis of Myocardial Viability

Munich Heart Software

FDG uptake was normalized to the top 5% of resting perfusion activity; “Mismatch”: $\geq 15\%$ difference between FDG uptake and resting perfusion

Viability: Mismatch $>5.2\%$ of LV

(Courtesy of XL Zhang and H. Schelbert)
Identification of Viable and Nonviable Myocardial Regions by Polar Map (Munich Heart Software)

Regions with a difference of ≥ 15% between FDG and $^{13}$NH$_3$ uptake were defined as viable while regions with a difference of <15% were defined as nonviable (Courtesy of XL Zhang and H. Schelbert)
Algorithm to stratify patients with ischemic cardiomyopathy for treatment options

FEVG < 30%

Viability ≥ 20-25%

Sufficient Coronary Anatomy

PCI and/or CABG

No Viability

Insufficient Coronary Anatomy

Transplantation

Aggressive Medical Treatment

No Improvement
Spectrum of Contractile Dysfunction

- **Normal**:
  - Flow Reserve: 3.0 - 4.0
  - Rest MBF: Normal
  - Contractile Function: Normal

- **Repetitive Stunning**:
  - Flow Reserve: < 1.5
  - Rest MBF: Normal
  - Contractile Function: NS

- **Hibernation**:
  - Flow Reserve: NS
  - Rest MBF: NS
  - Contractile Function: NS

- **Scar Tissue**:
  - Flow Reserve: NS
  - Rest MBF: NS
  - Contractile Function: NS

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