Nuclear Cardiology

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CHU-Nancy, FRANCE.
I - A remaining need of a functional information on myocardial perfusion

II - The future:
- combining functional and anatomic information,
- new cameras and new images...
Nuclear Cardiology

I - A remaining need of a functional information on myocardial perfusion

II - The future:
- combining functional and anatomic information,
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I - A remaining need of a functional information on myocardial perfusion

Anatomical information:
- is not always enough for detecting and assessing CAD,
- coronary atherosclerosis remains frequently:
  - without ischemia,
  - uncomplicated.
Autopsy studies have determined the rates of high grade coronary atherosclerosis in patients:

(i) who were without any history of CAD
(ii) who died because of a non-cardiac cause.

What is this rate in north-american non-diabetic men of 65 years old?

1. less than 40%
2. from 40 to 60%
3. more than 60%

Prevalence of high-grade coronary atherosclerosis at autopsy by diabetes and clinical coronary disease status.
Severe coronary stenoses are not always associated with severe perfusion abnormalities.

Mechanisms:
- collaterals,
- antianginal medications.

Patient with a total occlusion of the right coronary artery, but with a normal exercise-SPECT under beta-blockers.
The most serious coronary stenoses are those associated with perfusion abnormalities.

5-year rate of major cardiac events (death or MI) as a function of the stress-$^{201}$TI and angiographic results.

- No stenosis Normal $^{201}$TI (n=101)
- Stenosis Normal $^{201}$TI (n=52)
- Stenosis Abnormal $^{201}$TI (n=105)

$^{99m}$Tc-sestamibi imaging:
- Short-axis
- Apical
- Median
- Basal
- Long-axis
- Horizontal
- Vertical
Prognostic stratification using exercise MPI

Main parameters:

✓ Exercise testing parameters (maximal work load and heart rate, positive test)
✓ Normal stress-SPECT
✓ Extent of stress defects
✓ Extent of reversible stress defects
Main parameters:

- Exercise testing parameters (maximal work load and heart rate, positive test)
- Normal stress-SPECT
- Extent of stress defects
- Extent of reversible stress defects
- Post-stress LV ejection fraction (<45%) and end-systolic volume (>70 mL)
- Reversible wall motion abnormalities

Prognostic stratification using exercise MPI

<table>
<thead>
<tr>
<th>Perfusion</th>
<th>Function</th>
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<tbody>
<tr>
<td>Exercise</td>
<td>Rest</td>
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<tr>
<td>Short-axis</td>
<td></td>
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<tr>
<td>apical</td>
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<td>median</td>
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<td>basal</td>
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<td>Long-axis</td>
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<td>horizontal</td>
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Myocardial Perfusion Tomoscintigraphy

I - A remaining need of a functional information on myocardial perfusion

II - The future:
- combining functional and anatomic information,
- new cameras and new images...
Combining functional and anatomic information

Hybrid SPECT/CT scanners
In case of normal MPI, **CT measurements of coronary calcium** might allow **subclinical atherosclerosis** to be detected.


Combining functional and anatomic information
Hybrid SPECT/CT scanners for CT coronary angiography

Gaemperli O, Eur Heart J, 2006
Gamma-cameras with semiconductors

Cadmium zinc telluride (CZT) solid-state detectors
- much higher myocardial count rate
- much higher energy resolution
- higher spatial resolution
- smaller size

GE Medical Systems

Spectrum Dynamics
Gamma-cameras with semiconductors

Camera head = 9 rotating detectors with
- large tungsten collimators,
- pixelized CZT detectors (2.5 mm).
Gamma-cameras with semiconductors

Camera head = 9 rotating detectors with
- large tungsten collimators,
- pixelized CZT detectors (2.5 mm).

‘Region-centric’ acquisition maximizing the recording time in the heart area.
Cadmium zinc telluride (CZT) solid-state detectors
- much higher myocardial count rate

Allows shortening acquisition time, up to:
- 2 min for high injected $^{99m}$Tc activities,
- 3 to 4 min for low injected $^{99m}$Tc activities and $^{201}$Tl.

Herzog BA et al. 

Semi-conductors

<table>
<thead>
<tr>
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<th>Stress</th>
<th>Rest</th>
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<tbody>
<tr>
<td>CZT</td>
<td>2 min</td>
<td>4 min</td>
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Conventional

<table>
<thead>
<tr>
<th></th>
<th>Stress</th>
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<tbody>
<tr>
<td></td>
<td>11.5 min</td>
<td>14 min</td>
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</table>

inferior wall & apical ischemia
Might also allow:

- reducing injected activities, up to
  . 100 MBq for $^{99m}$Tc tracers,
  . 50 to 75 MBq for $^{201}$Tl.

Gamma-cameras with semiconductors

Cadmium zinc telluride (CZT) solid-state detectors

- much higher myocardial count rate (‘centric’ acquisition)

Clinical validation studies in progress
Might also allow:
- reducing injected activities, up to 100 MBq for $^{99m}$Tc tracers, 50 to 75 MBq for $^{201}$Tl.
- or maximizing spatial and/or temporal resolutions

Cadmium zinc telluride (CZT) solid-state detectors
- much higher myocardial count rate (‘centric’ acquisition)

Clinical validation studies in progress

Sestamibi (400 MBq)
4 min recording time
16 frames / cycle
Voxels of 30 mm$^3$
Gamma-cameras with semiconductors

Cadmium zinc telluride (CZT) solid-state detectors
- much higher myocardial count rate,
- much higher energy resolution

Dual energy recording

✓ 3-7 mCi of $^{99m}$Tc tracer and 1.5-2.5 mCi of $^{201}$Tl,
✓ limited irradiation exposure (10-15 mSv)
✓ only 1 positioning scan
✓ scatter correction (20-30% $^{99m}$Tc scatter in $^{201}$Tl peak)
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$^{99m}$Tc tracer or $^{201}$Tl
$^{99m}$Tc tracer or $^{201}$Tl

Stress (6 to 20 min)
Camera recording (12-15 min)

Inferior MI
Simultaneous rest-Tl/stress-Tc recording with CZT

Yes, this is definitly a reversible defect!
Gamma-cameras with semiconductors

Cadmium zinc telluride (CZT) solid-state detectors
- much higher myocardial count rate,
- much higher energy resolution

Dual energy recording with other tracers:

Exemple of dual $^{201}$TI/$^{123}$I-MIBG in severe diabetes

![Image of dual energy recording with $^{201}$TI and $^{123}$I-MIBG in severe diabetes]
Étude de la viabilité myocardique avec le $^{18}$F-FDG

Encore considérée comme la référence, en particulier :
- pour la détection du myocarde hibernant,
- en cas de dysfonction VG sévère.

Mismatch

<table>
<thead>
<tr>
<th>Grand-axe</th>
<th>Petit-axe</th>
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<tr>
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<td><img src="image4" alt="Image" /></td>
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Match

<table>
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<tr>
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<td><img src="image8" alt="Image" /></td>
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Necrotic areas exhibit a dramatic decrease in metabolic activity decrease in FDG uptake

2-months after coronary occlusion in rats
Maskali F. J Nucl Cardiol 2005

Injection before sacrifice of
- $^{111}$In-DTPA
- $^{99m}$Tc-Sestamibi
- $^{18}$F-FDG

Sirius red
Collagen fibrosis

LV
RV
Central necrosis
Border zone
Remote myocardium

$^{18}$F-FDG

$\mu$-imager
Necrotic areas exhibit a dramatic decrease in myocardial perfusion (decrease in Sestamibi uptake)

Injection before sacrifice of

- $^{111}$In-DTPA
- $^{99m}$Tc-Sestamibi
- $^{18}$F-FDG

$^{99m}$Tc-Sestamibi

2-months after coronary occlusion in rats
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Étude de la viabilité myocardique avec le $^{18}$F-FDG

Amélioration de la qualité d’images :
- nouvelles caméras TEP
- prémédication par acide nicotinique (↓ AG circulants),

FDG-TEP + Acipimox
Homme avec IDM apical
Étude de la viabilité myocardique avec le $^{18}$F-FDG

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- prémédication par acide nicotinique ($↓$ AG circulants),

Prémédication par acide nicotinique (Acipimox) chez le rat.
*Poussier S. Eur J Nucl Med 2010*
New PET tracers for myocardial perfusion imaging

Nekolla SG, and coll. Evaluation of the Novel Myocardial Perfusion PET Tracer $^{18}$F-BMS-747158-02 Comparison to $^{13}$N-Ammonia and Validation With Microspheres in a Pig Model. Circulation 2009;119: 2333-42

New cationic lipophylic tracers, labeled with $^{18}$F:
- high rates of myocardial extraction (>90%) and retention
- better « flow tracer » than current SPECT and PET tracers,
- very high image quality,
Remodeling

Sinusas A. Yale University School of Medicine

New tracers developed for cardiologic and oncologic indications

Imaging of matrix metalloproteinase (MMP) activity in a mouse heart infarct.

*Sinusas A. Yale University School of Medicine*
Molecular Imaging

New tracers developed for cardiologic and oncologic indications

Remodeling

Angiogenesis

Imaging of αvβ3 integrin expression using \(^{18}\text{F-galacto-RGD}\) in a rat heart infarct
- for characterisation of angiogenesis in vivo
- for monitoring therapeutic effects.