CARDIAC WALL MOTION ANALYSIS; PARAMETRIC IMAGES

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radionuclide studies of the heart

• Ventricular wall motion (with blood pool labeling)
• Myocardial perfusion (MIBI, Tetrofosmin, TlCl)
• Myocardial glucose metabolism (FDG)
• MIBG uptake and distribution (I-123 MIBG)

What should you check after acquisition?

• Patient movement ⇒ restart acquisition
• High activity near the heart ⇒ wait, then restart acquisition
• Spatial matching of SPECT and CT ⇒ correction if necessary and possible

ECG gating

Equilibrium ECG-gated ventriculography

Pharmaceutical: \[^{99m}\text{Tc}\] in vivo labelled red blood cells (with pyrophosphate)
Phenomenon imaged: Changing blood content of the ventricles and atria during the cardiac cycle
Acquisition mode: ECG-gated, averaging some hundreds of cycles.
Quantitative parameters: Left (and right) ventricular ejection fraction
Peak filling and emptying rate
Left ventricular volume

Parametric images used:

- Phase
- Amplitude (Fourier analysis)
- Decreased wall motion
- Stroke volume

Abnormalities shown:

- Decreased EF
- Decreased peak filling and/or ejection rate of the left ventricle
- Abnormal sequence of cardiac contraction
- Decreased or paradox regional wall motion

Relative contraindication: Arrhythmia absoluta.

ECG-gated blood pool scintigraphy

Gamma cameras for cardiac imaging

Best visualized where the arcs of the detectors meet

Pharmaceutical: Equilibrium ECG-gated ventriculography
Example: Gated blood pool study

Amplitude

Phase

Hypokinesis

(Walsh-Hadamard transform)

ECG-gated RN ventriculography: normal

Gated SPECT technique

- Each projection is gated
- Differences from gated planar:
  - Wider time window (± 15%)
  - Shorter time for each projection (e.g. 30 good cycles)
  - Less images (generally 8, possibly 16) / projection
- Differences from ungated SPECT:
  - Same or a little longer time (20-40 s) / projection
  - Each time interval reconstructed separately

Results from gated SPECT:

- Reconstruction from the ED and ES bins (wide time intervals)
- EF
- Display of movement
- Wall thickening (partial volume effect!!!)

Cine display of selected slices

Most common software packages for myocardial perfusion imaging

- QGS (Quantitative Gated SPECT)
- ECT (Emory Cardiac Toolbox)
Most significant differences: QGS and ECT

<table>
<thead>
<tr>
<th>QGS</th>
<th>ECT</th>
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</thead>
<tbody>
<tr>
<td>Projection</td>
<td>Cylindrical envelope</td>
</tr>
<tr>
<td>Abnormal areas:</td>
<td>Hybrid model (semisphere+cylinder)</td>
</tr>
<tr>
<td>&lt; 50% Central surface with minimal cost</td>
<td>&lt; 30% Fixed to ED position</td>
</tr>
<tr>
<td>SD referred to neighborhood</td>
<td></td>
</tr>
<tr>
<td>Wall thickening</td>
<td>From intensities: Fourier-trf. of the time function of radial maxima</td>
</tr>
<tr>
<td>(with constant myocardial mass)</td>
<td></td>
</tr>
<tr>
<td>Validating</td>
<td>Phantom; EF: 1st pass</td>
</tr>
<tr>
<td></td>
<td>Volume, EF: MRI</td>
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<tr>
<td></td>
<td>EF: 1st pass</td>
</tr>
<tr>
<td></td>
<td>Volume, mass, EF: MR</td>
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</tbody>
</table>

Set parameters for reslicing

1. Mask for left ventricle
2. Cylindrical envelope
3. Limiting planes (apex, base)
4. Max. activity surface
5. Valve plane

Steps of processing: Emory Toolbox

1: On ungated SHA slices

- Setting threshold – search for cluster (size, symmetry) – cylindrical envelope
- Adjustments: center, radius
- With region growing
- By thresholding
- Hybrid: hemisphere + cylinder
- Searching along radius
- Iterative: new center, radial range, limit planes
- 2-part: bent at the septum

Steps of processing in the Emory Toolbox:

gated acquisition, for each time bin

- ED internal & external surface
- With 10 mm wall thickness
- Wall thickening
- Radial maxima as a function of time
- Fourier-trf., thickening: from amplitudes (reference: ED)
- Non-perfused areas
- Fixed to ED position
- Radial smoothing (2D)
- Median + linear

ECT: Validation of outlines with MRI

Reconstruction of gated study

InterView: EF estimation
Report elements 1. Defect areas

Report elements 2. Extent, severity

Report elements 3. Slice series

Report elements 4. Wall motion, wall thickening

On screen: Wall motion
- Example: hard to guess wall position

Example: reduced septal wall thickening

Example: good global EF

Methods for the estimation of EF in Emory Toolbox

Original:

Modified #1:

Modified #2:
QGS: Grades of wall motion abnormalities

Common aims of gated myocardial perfusion studies:

- Functional information without gated blood pool study (EF, regional wall motion)
- To differentiate fix defect from attenuation artifact (no perfusion, but wall thickening occurs)
- Viability around infarct area (lower perfusion, but moving wall)
- To avoid rest study (decreased perfusion during stress, but wall motion detected: active ischaemia)

Lower limits of reference range

| QGS, 8 images/cycle; Tc, post-stress |
|-----------------|-----------------|
|                  | Female | Male  |
| Left ventricular ejection fraction | 50%    | 45%   |
| End diastolic volume index (ml/m²) | 56     | 70    |
| End systolic volume index (ml/m²)  | 25     | 32    |

Summary: states of the myocardium

Wall thickening after infarct

Diagnostic value of gated SPECT


- 10 336 rest/stress SPECT studies surveyed (with gated stress)
- mean 29 months follow-up
- Lost patients; rejected if revasc. within 60 days – 8767 remained
- Independent nuclear medical predictors of cardiac death:
  - Abnormal stress perf. ($SSS\geq4$ points): $1.46^*$
  - Decreased EF (<45%): $2.71^*$
  - Wall motion abnormality ($SWMS\geq5$ points): $1.78^*$
- The only independent nuclear medical predictor of non-fatal infarct is $SSS\geq4$ ($2.1^*$)
Value of perfusion scintigraphy with preserved EF (>45%)

Independent nuclear medical predictor of cardiac death:
- Wall motion abnormality (SWMS ≥ 5): 1.69*

Independent NM predictor of non-fatal infarct:
- Reversible perf. defect (SDS ≥ 2): 2.02*

Annual frequency of cardiac events with EF>45%:
- Normal perfusion AND wall motion: 0.9%
- Abnormal perfusion OR wall motion: 2.5%
- Abnormal perfusion AND wall motion: 4.2%

Critical points
- Fix perfusion defect with preserved wall thickening: attenuation artifact or viable subendocardial infarct?
- Normal perfusion and decreased wall thickening: stunning?

Interpretation of wall thickening (WT) without infarct (20 patients, 400 segments)

<table>
<thead>
<tr>
<th>Condition</th>
<th>Frequency</th>
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<tbody>
<tr>
<td>9% Severe fixed perfusion defect</td>
<td>71%</td>
</tr>
<tr>
<td>29% Severely decreased WT</td>
<td>??</td>
</tr>
<tr>
<td>61% Normal perfusion</td>
<td>7%</td>
</tr>
<tr>
<td>93% Normal WT</td>
<td></td>
</tr>
<tr>
<td>20% Insignificant fixed perfusion defect</td>
<td>2.02*</td>
</tr>
<tr>
<td>10% Reversible defect</td>
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Image fusion: myocardial perfusion and CTA

Dynamics of norepinephrine and MIBG

- a) Norepinephrine (NE) is stored in synaptic vesicles at sympathetic nerve endings and is released via exocytosis due to nerve excitation. Most of the released NE returns to the nerve ending via the re-absorption mechanism designated as uptake-1. A fraction of the released NE becomes bound to the receptors, while the remaining part is released into the blood by spillover. The NE is ultimately inactivated by COMT and MAO.
- b) MIBG is also incorporated into nerve endings via uptake-1, and released via the excitation of nerves, in a manner similar to NE. MIBG, however, is neither bound to the receptors nor degraded by enzymes. Owing to these characteristics, most of the MIBG is reabsorbed via uptake-1, and retained in the nerve ending for many hours.

Method of calculating the H/M ratio and washout rate on MIBG planar images

Evaluation of risk areas in acute coronary syndrome

One case of unstable angina in which MIBG was of diagnostic value. Female, aged 62 years. The patient was admitted to the hospital owing to a diagnosis of unstable angina, but no significant findings were obtained on 201TlCl myocardial perfusion SPECT at rest. MIBG showed decreased accumulation in the infero-posterior wall. On the delayed image, increased washout was observed at the same site, and the abnormal findings became more marked. On coronary angiography performed later, advanced stenosis was recognised in the proximal part of the right coronary artery.

Predictive value of MIBG heart/mediastinum ratio (HMR) in heart failure

Major cardiac event rates over 2 years in relation to left ventricular ejection fraction (LVEF) and 123I-mIBG heart mediastinal ratio HMR in patients who had New York Heart Association class II-IV heart failure. Major cardiac events included cardiac death, cardiac transplant, and potentially fatal arrhythmias (implantable cardioverter defibrillator discharge). (Adapted from Agostini O., Verberne HJ, Bunchert W, et al. 123I-mIBG myocardial imaging for assessment of risk for a major cardiac event in heart failure patients: insights from a retrospective European multicenter study. Eur J Nucl Med Mol Imaging 2008;35:542)
Significance of mIBG HMR in heart failure

- 90 patients with moderate or severe heart failure,
- EF < 45%

<table>
<thead>
<tr>
<th>HMR</th>
<th>6 mo survival</th>
<th>12 mo survival</th>
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<tbody>
<tr>
<td>&lt; 1.2</td>
<td>60%</td>
<td>40%</td>
</tr>
<tr>
<td>≥ 1.2</td>
<td>100%</td>
<td>100%</td>
</tr>
</tbody>
</table>

Merlet & al.

Cardiac death is better predicted by mIBG than New York Heart Association (NYHA) score, age, earlier myocardial infarct (MI), or left ventricular ejection fraction. Nakata & al., 400 beteg

Predictive value of mIBG washout rate in heart failure

- 79 patients with heart failure,
- EF < 40%

- washout ≥ 27% 35% deaths in 52 months
- washout < 27% 0% deaths in 52 months

Ogita & al.

Usefulness of MIBG in hypertrophic cardiomyopathy

Prediction of the therapeutic effects of β-blockers by MIBG myocardial scintigraphy (quoted from [59]). In 53 patients with dilated cardiomyopathy who received β-blocker therapy continuously for 6 months or longer, MIBG myocardial scintigraphy was performed twice, before and 6–12 months after the start of the treatment. The improvement in the washout rate after treatment was the strongest predictor of prognosis. No cardiac events occurred in the group of patients showing an improvement in washout rate by 10% or more following β-blocker therapy. Table 1 shows the relationship of various clinical characteristics to washout rate improvement by β-blocker therapy. Lower values of the extent score and higher values of the washout rate on the early image were predictive of washout rate improvement by β-blocker therapy and were thus also predictive of a favourable long-term prognosis.