Overview of Artefacts in Nuclear Cardiology

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Myocardial imaging with thallium-201 at rest and during exercise. Comparison with coronary arteriography and resting and stress electrocardiography
JL Ritchie, GB Trobaugh, GW Hamilton, KL Gould, KA Narahara, JA Murray and DL Williams
*Circulation* 1977;56;66-71

![FIGURE 3. A patient with three-vessel coronary artery disease. There is an antero-apical defect in the rest image (decreased activity in the superior aspect of the ANT view) which enlarges further following exercise (best seen as near total absence of activity in the superior-apical portion of the ANT view).](image)
ACC/AHA/ASNC Guidelines 2003 for the Clinical Use of Cardiac Radionuclide Imaging (pooled data)

![Graph showing sensitivity and specificity comparison between exercise and vasodilator]

- **Sensitivity**:
  - Exercise: 87%
  - Vasodilator: 89%
- **Specificity**:
  - Exercise: 73%
  - Vasodilator: 75%
- **Normalcy Rate**:
  - Exercise: 91%
  - Vasodilator: 90%

*Pts n. 7693*
Comparison of diagnostic performances of three different software packages in detecting coronary artery disease


<table>
<thead>
<tr>
<th>Software</th>
<th>Sensitivity</th>
<th>Specificity</th>
<th>Accuracy</th>
</tr>
</thead>
<tbody>
<tr>
<td>ECT v3</td>
<td>92.1%</td>
<td>29.0%</td>
<td>54.4%</td>
</tr>
<tr>
<td>ECT v2</td>
<td>96.5%</td>
<td>10.7%</td>
<td>45.2%</td>
</tr>
<tr>
<td>4DM v4</td>
<td>73.7%</td>
<td>63.3%</td>
<td>67.5%</td>
</tr>
<tr>
<td>QPS v3</td>
<td>95.6%</td>
<td>12.4%</td>
<td>45.9%</td>
</tr>
<tr>
<td>QPS v4</td>
<td>93.0%</td>
<td>17.2%</td>
<td>47.7%</td>
</tr>
</tbody>
</table>

**Optimally located threshold values of SSS and corresponding sensitivity, specificity and accuracy values**

<table>
<thead>
<tr>
<th>SSS</th>
<th>Sensitivity</th>
<th>Specificity</th>
<th>Accuracy</th>
</tr>
</thead>
<tbody>
<tr>
<td>≥7</td>
<td>82.5%</td>
<td>62.1%</td>
<td>70.3%</td>
</tr>
<tr>
<td>≥8</td>
<td>74.6%</td>
<td>66.9%</td>
<td>70.0%</td>
</tr>
<tr>
<td>≥9</td>
<td>69.3%</td>
<td>72.2%</td>
<td>71.0%</td>
</tr>
<tr>
<td>≥10</td>
<td>75.4%</td>
<td>56.8%</td>
<td>64.3%</td>
</tr>
<tr>
<td>≥11</td>
<td>69.3%</td>
<td>65.7%</td>
<td>67.1%</td>
</tr>
<tr>
<td>≥12</td>
<td>67.6%</td>
<td>71.0%</td>
<td>69.6%</td>
</tr>
<tr>
<td>≥4</td>
<td>73.7%</td>
<td>63.3%</td>
<td>67.5%</td>
</tr>
<tr>
<td>≥5</td>
<td>67.6%</td>
<td>76.3%</td>
<td>72.8%</td>
</tr>
<tr>
<td>≥6</td>
<td>60.6%</td>
<td>83.4%</td>
<td>74.2%</td>
</tr>
<tr>
<td>≥10</td>
<td>78.1%</td>
<td>56.2%</td>
<td>65.0%</td>
</tr>
<tr>
<td>≥11</td>
<td>70.2%</td>
<td>65.1%</td>
<td>67.1%</td>
</tr>
<tr>
<td>≥12</td>
<td>63.2%</td>
<td>72.2%</td>
<td>68.6%</td>
</tr>
<tr>
<td>≥9</td>
<td>76.3%</td>
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<td>68.9%</td>
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<tr>
<td>≥10</td>
<td>69.3%</td>
<td>71.0%</td>
<td>70.3%</td>
</tr>
<tr>
<td>≥11</td>
<td>62.3%</td>
<td>75.7%</td>
<td>70.3%</td>
</tr>
</tbody>
</table>
Artifacts in SPECT MPI
Artifacts in SPECT MPI

- Mechanical & electronical
  - Energy window
  - Detector center-of-rotation and alignment
  - Flood field non-uniformity
  - Degradation in resolution with distance from the collimator
Artifacts in SPECT MPI

• Mechanical & electronical
  – Energy window

• Biological
  – Myocardial hypertrophy
  – Left bundle branch block
  – Cardiac position with thorax
Artifacts in SPECT MPI

• Mechanical & electronical
  – Energy window

• Biological
  – Myocardial hypertrophy
  – Left bundle branch block

• Technical artifacts
  Selection or cardiac axes
  Selection of apex and base for polar maps
Artifacts in SPECT MPI

- **Mechanical & electronical**
  - Energy window

- **Biological**
  - Myocardial hypertrophy
  - Left bundle branch block

- **Technical artifacts**
  - Selection or cardiac axes

- **Patient-related artifacts**
  - Soft-tissue attenuation
  - Superimposed abdominal visceral activity
  - Motion artifacts
Breast attenuation

• Most commonly encountered attenuation artifact in cardiac SPECT
• Extremely variable in appearance
• Consider the position and configuration of the breasts with patients in supine position
Breast attenuation

- Women of average body habitus: anterior, anteroseptal, anterolateral walls
- Women with large, pendulous breasts: lateral attenuation artifacts
- Elderly women with very large, pendulous breasts: lateral abdominal wall
- Not necessarily directly proportional to breast size, but may vary considerably according to the position, configuration, and density of the breast.
Breast attenuation: what not to do?

• A binder to flatten the breasts: decrease the thickness of the breast but a considerable degree of uncertainty the exact position of the breast

• Brassiere:
  – position the breast anteriorly, increase the amount of soft tissue attenuation
  – SPECT: brassiere off

• Breast implants
Breast attenuation: What to do?

- Tc-99m sestamibi breast-attenuation artifacts less marked
- Gated SPECT
  - Artifacts: normal wall motion and thickening
  - Infarcts: hypokinetic, decreased wall thickening
- Transmission image
Diaphragmatic attenuation

- Diaphragm, right ventricle (lesser degree) => decrease count density in inferior wall of left ventricle
- Diaphragmatic elevation: obesity, pleural or pulmonary parenchymal disease, atelectasia, loss of lung volume, diaphragmatic paralysis, gastric dilation.
Supine vs. Prone

supine

prone

supine

prone
Gated-SPECT and Fixed Defects

- 98/102 (96%) pts with fixed PD and clinical MI: WMA
- 78 pts with fixed PD and no clinical MI:
  - 18 (23%) WMA: possible silent MI
  - 60 (77%) NO WMA:
    - 48% women and anterior PD
    - 43% men and inferior PD

False positive rate: from 14% to 3%

Attenuation causes quantitative errors as well as distortions in the projection profiles that are propagated into the reconstructed images. Knowledge of the attenuating distribution is required for attenuation correction. Solid lines depict true profile; dotted lines depict attenuated profile.
Attenuation Map

A CT image is a measure of attenuation profiles in different angular projections.

The reconstructed image is a two-dimensional map of linear attenuation correction $\mu(x,y)$ of the X radiation.
Relationships between linear attenuation coefficients as a function of photon energy for different body tissues.
CONTROVERSIES IN NUCLEAR CARDIOLOGY

• SPECT attenuation correction: An essential tool to realize nuclear cardiology’s manifest destiny
  – E.V. Garcia (J Nucl Cardiol 2007;14:16-24.)

<table>
<thead>
<tr>
<th>Years</th>
<th>Pazienti</th>
<th>Sensitivity %</th>
<th>Specificity %</th>
<th>Normalcy %</th>
</tr>
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<tbody>
<tr>
<td>1996 - 2006</td>
<td>1327</td>
<td>86</td>
<td>57</td>
<td>75</td>
</tr>
<tr>
<td></td>
<td></td>
<td>86</td>
<td>77</td>
<td>92</td>
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</table>

AC markedly improves diagnostic accuracy over no AC regardless of:
✓ clinical site,
✓ radionuclide used,
✓ camera manufacturer,
✓ whether quantitative versus qualitative techniques are used,
✓ whether an obese versus a non obese population is studied
✓ whether exercise or pharmacologic stress is used
Clinical value of attenuation correction in stress-only Tc-99m sestamibi SPECT imaging

The value of attenuation correction by hybrid SPECT/CT imaging on infarct size quantification in male patients with previous inferior myocardial infarct

Raffaele Mario Tarquinio Giubbini\textsuperscript{a,b}, Sara Gabanelli\textsuperscript{a}, Silvia Lucchini\textsuperscript{b},

\textit{Nucl Med Commun. 2011 Nov;32(11):1026-32}

56 Consecutive pts with inferior MI

<table>
<thead>
<tr>
<th></th>
<th>ATN uncorrected</th>
<th>ATN corrected</th>
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<tbody>
<tr>
<td>SSS</td>
<td>14.02±7.9</td>
<td>9.4±7.1</td>
</tr>
<tr>
<td></td>
<td>P&lt;0.001</td>
<td></td>
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<tr>
<td>SRS</td>
<td>9.5±7</td>
<td>5.6±6.1</td>
</tr>
<tr>
<td></td>
<td>P&lt;0.001</td>
<td></td>
</tr>
<tr>
<td>SDS</td>
<td>4.5±3.2</td>
<td>3.8±2.8</td>
</tr>
<tr>
<td></td>
<td>P=n.s.</td>
<td></td>
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</table>
A new source of errors:

• Misregistration of Emission and Transmission Scans
Motion artifacts: Upward creep
Patient’s motion
uncorr. Stasis MDC MOCO
# EXPERIMENTAL EVALUATION

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
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<tbody>
<tr>
<td>Pixel size</td>
<td>4.5 mm</td>
</tr>
<tr>
<td>range</td>
<td>180°</td>
</tr>
<tr>
<td>step</td>
<td>3°</td>
</tr>
<tr>
<td>collimator</td>
<td>cast HR</td>
</tr>
<tr>
<td>BPF</td>
<td>Butt. 0.35 - 5</td>
</tr>
<tr>
<td>Max count density (wall)</td>
<td>95 counts</td>
</tr>
<tr>
<td>LV wall Volume</td>
<td>110 cc</td>
</tr>
<tr>
<td>External source Volume</td>
<td>150 cc</td>
</tr>
<tr>
<td>Source-myocardial wall distance</td>
<td>30 - 50 mm</td>
</tr>
<tr>
<td>Uptake ratio</td>
<td></td>
</tr>
<tr>
<td>LV wall</td>
<td>1 0</td>
</tr>
<tr>
<td></td>
<td>1 1</td>
</tr>
<tr>
<td></td>
<td>1 2</td>
</tr>
<tr>
<td></td>
<td>1 4</td>
</tr>
</tbody>
</table>
Results:

Ratio 1 : 1

Ratio 1 : 2

Ratio 1 : 4
A practical message for technologists

repeated acquisition is useful when

(1) the intensity of the extra-cardiac uptake is equal to or higher than the cardiac uptake when there is no separation between the extra-cardiac uptake and the inferior cardiac wall

(2) when the intensity of the extra-cardiac uptake is higher than the cardiac uptake when there is a separation between the extra-cardiac uptake and the inferior wall of less than one cardiac wall.

Minimize superimposed abdominal visceral activity

• Prefer exercise studies: maximal exercise
• Dipyridamole/adenosine TI-201 and Tc-99m sestamibi studies: add dynamic, submaximal exercise (walking, biking)
  – Exercise is performed immediately after the infusion of dipyridamole, and radiotracer is injected during exercise, at least 1 minute before its cessation.
• Tc-99m sestamibi: repeat after 60 min, fat meal after injection, 2 glasses of water before imaging
Model selection
Standardized Myocardial Segmentation and Nomenclature for Tomographic Imaging of the Heart

A Statement for Healthcare Professionals From the Cardiac Imaging Committee of the Council on Clinical Cardiology of the American Heart Association

American Heart Association Writing Group on Myocardial Segmentation and Registration for Cardiac Imaging:

Manuel D. Cerqueira, MD; Neil J. Weissman, MD; Vasken Dilsizian, MD; Alice K. Jacobs, MD; Sanjiv Kaul, MD; Warren K. Laskey, MD; Dudley J. Pennell, MD; John A. Rumberger, MD; Thomas Ryan, MD; Mario S. Verani, MD†

Left Ventricular Segmentation

1. basal anterior
2. basal anteroseptal
3. basal inferoseptal
4. basal inferior
5. basal inferolateral
6. basal anterolateral
7. mid anterior
8. mid anteroseptal
9. mid inferoseptal
10. mid inferior
11. mid inferolateral
12. mid anterolateral
13. apical anterior
14. apical septal
15. apical inferior
16. apical lateral
17. apex

M.Cerqueira et al Circulation 2002:105; 539-542
Standardized nomenclature and anatomic basis for regional tomographic analysis of the heart.

Short axis

<table>
<thead>
<tr>
<th>Autopsy</th>
<th>17 segm.</th>
<th>20 segm.</th>
</tr>
</thead>
<tbody>
<tr>
<td>42%</td>
<td>35%</td>
<td>30%</td>
</tr>
<tr>
<td>36%</td>
<td>35%</td>
<td>30%</td>
</tr>
<tr>
<td>21%</td>
<td>30%</td>
<td>40%</td>
</tr>
</tbody>
</table>
Gating Artefacts
Small hearts
Synchronization
LV time-volume curve
Wrong volume curve

Gated on T wave
Value of gated-SPECT in the analysis of regional wall motion of the interventricular septum after coronary artery by-pass grafting

What is needed?

• Adequate technology
• Application specialists aware of technical and physiopathological issues
• A quick quality control on MPI SPECT and SPECT/CT
• Availability of software packages for artefacts correction

If not successful; repeat acquisition!
Fox hunt?

When you are in deep trouble look straight ahead, keep your mouth shut and say nothing!