Radionuclide Imaging Techniques

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Radionuclide Imaging Techniques

Perfusion
- Radionuclide SPECT imaging
- Positron emission tomography (PET)

Function
- Radionuclide ventriculography
- Gated-ECG SPECT

Sympathetic innervation
- MIBG (Meta Iodo Benzyl Guanidine)

Myocardial metabolism
- F-18 fluorodeoxyglucose (^{18}FDG)
- I-123-labelled modified fatty acids
Radionuclide MPS - Principles

- Perfusion tracer
- Gamma camera
- Cardiac stress
- Image reconstruction and interpretation
The Gamma Camera

- Gamma rays are emitted from the radiopharmaceutical injected into the patient

- Gamma rays pass through a collimator and strike a sodium iodide crystal, a scintillator which emits light when struck by gamma rays

- Photomultiplier tubes convert the light to an electrical signal which is used to produce the image
Gamma Camera

- Patient
- Positioning and summing circuits
- NaI (Tl) detector
- Collimator
- Photomultiplier tubes
- Lead shielding
- X coordinate pulse
- Y coordinate pulse
- Z Pulse
- Energy window
- Unblank pulse
- Discriminator
- ADC
- Processor
- VDU
Modern gamma cameras have 1-2 heads which permit SPECT image acquisition.
Theory of Back Projection

Imaging a point source

Only photons \perp to camera face are detected
Raw Cardiac SPECT Data

- Heart within FOV

- Sources of artefact
  - motion & upward creep
  - attenuation by soft tissue or objects
  - hot activity next to heart
  - low counts

- Pathology
  - LV dilatation/TID
  - RV dilatation/hypertrophy
  - lung uptake
  - other significant tracer uptake outside heart
  - pattern of myocardial uptake

Cine raw data
Realignment

Planar image

Transaxial slice

Transaxial slice
Colour Scale

Cool colour scale

Grey scale

SA

HLA

VLA
Image Display - Snake
Image Display - Triangulation
• 9, 17- or 20-segment models

• 9-segment model most useful clinically
## Image Interpretation - Severity of Defect

<table>
<thead>
<tr>
<th>Severity</th>
<th>Percentage Uptake</th>
<th>Score</th>
<th>Cool Colour</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal</td>
<td>70-100%</td>
<td>4</td>
<td>Orange to White</td>
</tr>
<tr>
<td>Mildly reduced</td>
<td>50-69%</td>
<td>3</td>
<td>Purple</td>
</tr>
<tr>
<td>Moderately reduced</td>
<td>30-49%</td>
<td>2</td>
<td>Blue</td>
</tr>
<tr>
<td>Severely reduced</td>
<td>10-29%</td>
<td>1</td>
<td>Green</td>
</tr>
<tr>
<td>Absent</td>
<td>0-9%</td>
<td>0</td>
<td>Black</td>
</tr>
</tbody>
</table>
Vascular Distribution

Vascular territories

VLA

HLA

SA
67-year old female ex-smoker with atypical chest pain.

- homogeneous
- septum-to-lateral wall ratio <1
- septum slightly shorter than lateral wall
<table>
<thead>
<tr>
<th>State</th>
<th>Pattern of tracer uptake</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal</td>
<td>• Normal uptake in stress and rest images</td>
</tr>
<tr>
<td>Infarction</td>
<td>• Reduced uptake in stress images</td>
</tr>
<tr>
<td></td>
<td>• No change in uptake in rest images</td>
</tr>
<tr>
<td>Ischaemia</td>
<td>• Reduced uptake in stress images</td>
</tr>
<tr>
<td></td>
<td>• Normal uptake in rest images</td>
</tr>
</tbody>
</table>
Quantification

Anterior

Septum

Inferior

Polar plot

3D display
Bull’s Eye Plot

Stress Extent (%)

Rest Extent (%)

Reversibility Extent (%)

ANTERIOR

SEPTUM

LATERAL

INFERIOR

Vascular territories
Imaging protocols

**Thallium**
- Stress - redistribution
- Stress - redistribution - reinjection
- Stress - reinjection
- Stress - reinjection - 24 hour imaging
- Rest
- Rest - redistribution

**Technetium**
- Two day
- One day, stress - rest
- One day, rest - stress

**Dual isotope**
- Rest thallium - stress technetium

**Adjuncts**
- Nitrate
- Fatty meal
Thallium protocols

**Stress / Redistribution**

Injection

Stress

0 min 5-10 min

Stress SPECT

4 hr

Rest SPECT

**Stress / Redistribution / Reinjection**

Injection

Stress

0 min 5-10 min

Stress SPECT

4 hr

Redistribution SPECT

15 min-1 hr

Reinjection SPECT
Technetium protocols

• **Two-day Protocol**
  
  ✓ To avoid effect of residual activity from first injection
  
  ✓ Ideal protocol for obese patients

• **One-day Protocol**
  
  ✓ Convenient
  
  ✓ 3 - 5 times larger dose given on second occasion
One-day Technetium protocols

Rest / Stress

Injection

Rest SPECT

0 min 1 hr 4 hr

Injection

Stress

Stress ECG-gated SPECT

45 min-1 hr

Stress / Rest

Injection

Stress

Stress SPECT

0 min 45 min-1 hr

Injection

Rest ECG-gated SPECT

2-4 hrs 45 min-1 hr
Sources of artefact

- LBBB
- Breast
- Creep
- Reconstruction
- Diaphragm
- Motion
- Low count
Ways of overcoming the effects of attenuation:
- using Tc-99m-labelled tracers
- breast binding
- prone imaging
- evaluation of cine raw data
- evaluation of ECG-gated SPECT
- reading “around” attenuation artefacts
- use of attenuation correction (AC)
Attenuation Correction

Stress Tc-99m-tetrofosmin images

- Improved artefact recognition
- ↑ specificity
- Increased reader confidence
Radionuclide ventriculography

- Labelling of autologous erythrocytes with technetium-99m
- ECG gating is used to acquire 16 to 32 frames through the cardiac cycle
- Imaging of first-pass of tracer through heart and/or after blood-pool equilibrium
- First-pass good for RV function and L $\to$ R shunting
- Equilibrium good for LV function, systolic and diastolic
Quantification

- Manual drawn ROI or automatic edge detection of blood pool at ED and ES
- Background correction
- Time-activity curve at each frame in the cardiac cycle is generated
- LVEF = background corrected difference in ES and ED counts / ED counts x 100%

Normal EF = 50 - 70%
Variation < 5%
Quantification

Phase

Timing of peak contraction
Detection of delayed contraction
LV and RV same phase
Atria with opposite phase to ventricles

Amplitude

Magnitude of contraction throughout cardiac cycle
Smaller amplitude in atria than ventricles
Greatest amplitude at LV apex
Stress MUGA

EF = 54  EF = 52  EF = 46  EF = 43
HR = 70  HR = 80  HR = 100  HR = 100
LD = 70  LD = 80  LD = 100  LD = 100