Cardiac Imaging with Nuclear Medicine

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Outline

- Patient presentation
- Why use nuclear medicine?
- The physics, equipment, and radiotracers
- Stress testing
- Patient outcome
Patient H.S.

- 38 YOM presenting to ED with chest pain
- Substernal chest pain, radiating to back and left arm, with SOB
- PMHx: HIV, Hyperlipidemia
- Meds: Anti-retrovirals
- SocHx: 1 pack/d
- PE: BP 120/70. HR 76. Otherwise wnl.
Patient HS - Presenting CXR

- Read as normal.

BIDMC PACS
Patient H.S.

• What to do next?
Why Use Nuclear Medicine?

• Indicates areas of myocardium with
  – Hypoperfusion
  – Ischemia
  – Viability
  – Dysfunction
Cardiac Parameters Measured

- Perfusion
- Myocardial viability
  - Time course
- Ejection fraction (EF)
# Use of Nuclear Medical Imaging

- **Indication varies with clinical situation**

<table>
<thead>
<tr>
<th>Situation</th>
<th>Indication</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acute myocardial infarction</td>
<td>Diagnose “culprit” artery, area at risk, final extent of infarction, ejection fraction (EF)</td>
</tr>
<tr>
<td>Unstable angina</td>
<td>Diagnose “culprit” artery</td>
</tr>
<tr>
<td>Chronic ischemic heart disease</td>
<td>EF</td>
</tr>
<tr>
<td>Improvement with PTCA</td>
<td>Perfusion, EF</td>
</tr>
</tbody>
</table>
Testing Modalities

• Planar
  – Oldest modality
  – No 3-D reconstruction

• SPECT
  – Standard of care
  – Rest and stress imaging

• PET
  – Less widely used, more experimental
  – Higher cost
The Physics

Radioactive Body

Collimator (Pb)
Detector Crystal (NaI)
Photomultiplier Tubes (PMTs)
Localization Circuit

Computer and Display

PMT array

A PMT

http://www.physics.ubc.ca/~mirg/home/tutorial/hardware.html
The Equipment

Planar

GE 300

SPECT

Siemens ECAM
http://www.siemensmedical.com

PET

GE Advance
http://www.nationalpetscan.com/images/scanner.jpg
SPECT Reconstruction

- Planar images from multiple axes
- Reconstruct 3-D
- Similar to CT reconstruction

Cine courtesy of Dr. Donohoe

http://info.med.yale.edu/intmed/cardio/imaging/techniques/spect_camera/graphics/spect_camera.gif
Gating for Ejection Fraction

- Gate the acquisition using the ECG
- Calculate the EF by the end systolic and end diastolic volumes

\[
EF = \frac{LVEDV - LVESV}{LVEDV}
\]

Patient with dilated CM

EF = 13%

Cine courtesy of Dr. Donohoe
Cardiac Imaging Radiotracers

• Gamma Camera (Planar / SPECT)
  – Thallium-201
  – Technetium-99m labeled Sestamibi
  – Technetium-99m labeled Tetrofosmin

• PET
  – Fluorine-18 labeled Fluorodeoxyglucose
  – Rubidium-82
  – Nitrogen-13 labeled ammonia
Thallium-201

- Tl-201
  - Photon emitter (70-80 keV)
  - Half-life: 64 hours
- Na-K ATPase actively pulls Tl into cells
- Distribution immediately after injection vs. delayed uptake (redistribution)
- Wash out + active transport in = redistribution
- Good for imaging perfusion, viability
Technetium-99m Sestamibi

- **Tc-99m**
  - Photon emitter (140 keV)
  - Half-life: 6 hours
- Lipophilic cationic complex
- Uptake proportional to blood flow
- Much slower clearance than Tl-201: need 2 injections for stress and rest images
- Better resolution than Tl-201
- Better uptake but more expensive than Tetrofosmin
Stress Test

- Exercise preferred
  - Bruce Protocol
  - Target: 85% max HR
- Otherwise pharmacologic
- Inject radionuclide at peak stress
- Do rest imaging before or after

Bruce Protocol

<table>
<thead>
<tr>
<th>Stage</th>
<th>Time (mins)</th>
<th>Speed (mph)</th>
<th>Gradient</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>3</td>
<td>1.7</td>
<td>10%</td>
</tr>
<tr>
<td>II</td>
<td>3</td>
<td>2.5</td>
<td>12%</td>
</tr>
<tr>
<td>III</td>
<td>3</td>
<td>3.4</td>
<td>14%</td>
</tr>
<tr>
<td>IV</td>
<td>3</td>
<td>4.2</td>
<td>16%</td>
</tr>
<tr>
<td>V</td>
<td>3</td>
<td>5.0</td>
<td>18%</td>
</tr>
<tr>
<td>Etc...</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Okay, I’ll inject the radiotracer.

I’m starting to get tired.

## Pharmacologic Stress Test

<table>
<thead>
<tr>
<th>Agent</th>
<th>Dipyridamole</th>
<th>Adenosine</th>
<th>Dobutamine</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mechanism</td>
<td>Blocks adenoside reuptake, causing coronary vasodilation</td>
<td>Adenosine receptor A2a causes coronary vasodilation</td>
<td>Stimulates A1, B1, B2 receptors, increasing O2 demand and secondary vasodilation</td>
</tr>
<tr>
<td>Hemodynamics</td>
<td>Incr. HR, Incr. BP</td>
<td>Incr. HR, Decr. BP</td>
<td>Incr. HR</td>
</tr>
<tr>
<td>Side Effects</td>
<td>Minor</td>
<td>Flushing, nausea, heart block</td>
<td>Chest pain, NSVT, MI</td>
</tr>
<tr>
<td>Contraindications</td>
<td>Bronchospasm, AV block, sick sinus syndrome</td>
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<td>Recent coronary syndrome, hemodynamic / electrophysiologic instability</td>
</tr>
</tbody>
</table>

From Up to Date: www.utdol.com/application/image.asp?file=card_pix/compar6.gif
Stress Test - Patient Perspective

- No caffeine or theophylline-containing medications (adenosine antagonists)
- No beta-blockers or nitrates unless assessing improvement with medication
  - less effect with dipyridamole or adenosine
- Avoid sildenafil (Viagra) in case nitroglycerine (NTG) is needed
Back to our patient...
Patient H.S. - MIBI Stress Test

- Performed to identify “culprit” lesion
- Resting images obtained first with Tl-201
- 9.5 minutes on Bruce Protocol
- Attained 82% target HR
- Experienced angina and stopped due to pain
- Tc-99m Sestamibi injected at peak stress
Patient H.S. - Initial Scan

- Single vessel proximal LAD disease
- Large reversible anterior, apical, septal perfusion defect
- EF = 53%

Cine and patient images courtesy of Dr. Donohoe
Diagram: http://www.physics.ubc.ca/~mirg/home/tutorial/pics/heart.jpg
Patient H.S. - Treatment

• Interventional cardiology
  – Proximal LAD
    • Atherectomy
    • PTCA
    • Stenting
  – First diagonal branch
    • PTCA

• Resolution of symptoms, discharged.
Patient H.S. - Recurrence

- 3 months s/p intervention: recurrence of chest pain
  - Refused admission; left AMA.
  - Discharged on Plavix and Diltiazem.
- Agreed to repeat MIBI stress test one month later.
  - 15 minutes on a Bruce Protocol
  - Attained 92% target HR
Patient H.S. - s/p Stenting

- Mild reversible defect distal anterior wall and apex
- Possible partial in-stent restenosis

Cine and patient images courtesy of Dr. Donohoe
http://www.physics.ubc.ca/~mirg/home/tutorial/pics/heart.jpg
Patient H.S. - Cardiac Function

- Ejection Fraction?

$EF = 70\%$

Thus, good cardiac function

Cine courtesy of Dr. Donohoe
Conclusions

• Nuclear medicine images physiology
• SPECT imaging with Tl-201 and Tc-99m Sestamibi can
  – Localize pathology
  – Indicate severity of disease
References

• www.physics.ubc.ca/~mirg/home/tutorial/hardware.html (SLIDE 10)
• www.kfshrc.edu.sa/radiology/assets/images/nuc4.jpg (SLIDE 11)
• www.siemensmedical.com (SLIDE 11)
• www.nationalpetscan.com/images/scanner.jpg (SLIDE 11)
• info.med.yale.edu/intmed/cardio/imaging/techniques/spect_camera/graphics/spect_camera.gif (SLIDE 12)
• www.cardiocontrol-us.com/images/products/stress2.jpg (SLIDE 17)
• Up to Date: www.utdol.com/application/image.asp?file=card_pix/compar6.gif (SLIDE 18)
• http://www.contusalud.com/website/images/270400/chest_pain.jpg (SLIDE 20)
• www.physics.ubc.ca/~mirg/home/tutorial/pics/heart.jpg (SLIDES 22 and 25)
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