Cardiac Molecular Imaging

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Disclosures

β None
Objectives

• Discuss various radiotracers used for MPI
• Understand pitfalls of different tracers
• Discuss and distinguish various sources of image artifact
• Review practices used to minimize image artifact
• Review Stress protocols
• Discuss Rb82 for PET cardiac
• Discuss PYP for Amyloidosis
Leading Causes of Death

By AMERICAN HEART ASSOCIATION NEWS

Heart disease continues to kill more Americans than any other cause, followed by stroke at No. 5, according to 2015 federal data.

<table>
<thead>
<tr>
<th>Cause</th>
<th>Total Deaths</th>
<th>Share of Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heart disease</td>
<td>633,842</td>
<td>23.4%</td>
</tr>
<tr>
<td>Cancer</td>
<td>595,930</td>
<td>22%</td>
</tr>
<tr>
<td>Chronic lower respiratory diseases</td>
<td>155,041</td>
<td>5.7%</td>
</tr>
<tr>
<td>Accidents</td>
<td>146,571</td>
<td>5.4%</td>
</tr>
<tr>
<td>Stroke</td>
<td>140,323</td>
<td>5.2%</td>
</tr>
<tr>
<td>Alzheimer’s disease</td>
<td>110,561</td>
<td>4.1%</td>
</tr>
<tr>
<td>Diabetes</td>
<td>79,535</td>
<td>2.9%</td>
</tr>
<tr>
<td>Flu, pneumonia</td>
<td>57,062</td>
<td>2.1%</td>
</tr>
<tr>
<td>Kidney disease</td>
<td>49,959</td>
<td>1.8%</td>
</tr>
<tr>
<td>Suicide</td>
<td>44,193</td>
<td>1.6%</td>
</tr>
</tbody>
</table>

Source: Centers for Disease Control and Prevention
Published Dec. 8, 2016
Why We Image

- Diagnosing cardiovascular disease
- Establishing prognosis
- Assessing the effectiveness of therapy
- Evaluating viability
Why not CTA?

A. shows significant lesion in the LAD (Curved multiplanar)
B. severe positive arterial remodeling of a mixed plaque (cross-sectional view)
C. Severe discrete stenosis in LAD (Volume- rendering)
D. Significant stenosis in same area (Conventional angio)
MPI Pitfalls

FIGURE 1.

Causes of, and potential corrections for, MPI artifacts and pitfalls may be related to the patient, the equipment, or the technologist, often with overlap among these categories. LBBB = left bundle branch block; GI = gastrointestinal.
Radiotracers
Radiotracers

ßThallium
ßTc99m Sestamibi
ßTc99m Tetrofosmin
Thallium

1971

88 X-ray photons at 70 to 80 keV and approximately 12 gamma photons at 135 and 167 keV for each 100 disintegrations.

Half life of 72.1 hours (physical)

Normal distribution:

- Myocardium
- Skeletal muscle
- GI tract
- Liver
- Kidneys
Thallium

- Potassium analog
  - poisonous to mammalian species in a dose of approximately 20 mg/kg.

- Typically has less diaphragmatic uptake

- Limited image quality
  - 4 mCi associated with a relatively high absorbed dose.
Thallium

Viability

Dual-isotope stress test
**TI201 Viability**

**βHibernating Myocardium**
- Wall motion abnormality at rest which improves during redistribution

**β3mCi-4mCi TI201 IV**
- 10 min post inj, 4 hour post inj, possible 24 hour post inj

**βPt prep**
- Fasting until redistribution
Hibernating Myocardium Presentation on Images

Rest images: Several areas of reduced resting blood flow
Redistribution: Substantial redistribution, indicating myocardial viability

Routine stress/rest imaging would have given misleading information about viability because there are some of the irreversible defects
Tc99m Sestamibi & Viability

Does not redistribute

Uptake: Blood flow

Weaknesses for viability due to impairment of blood flow

– Uptake at rest correlates more strongly with 201Tl redistribution activity, than with initial uptake of 201Tl.

Study showed: Tc-99m sestamibi underestimates viable myocardium in patients with chronic CAD and LV dysfunction
Tc99m Sestamibi

FDA Approval in 1991

- Originally inferior to thallium for the determination of regional myocardial perfusion
- “Reduced contrast”
- Lipophilic cationic complexes cross the cell membrane by passive diffusion and localize in the mitochondria, binding to intramitochondrial proteins.

6 hour half life

- Lower effective dose
- More dose = more counts = better quality images
- Detects inducible myocardial ischemia & determining whether LV function is normal
Tc99m Tetrofosmin (Myoview)

Photon energy: 140 keV

Half life: 6 hours

Excretion: renal (40%) Feces (26%) 66% of total dose excreted in first 48 hours

Clears more rapidly from liver (vs. sestamibi)
Common Artifacts with Tc99m
Tc99m Artifacts: GI Uptake
Tc99m Artifacts: Breast Attenuation
Tc99m Artifacts: Infiltration & Malignancy

Lymph Node

Infiltration w/ lymph node uptake
General Artifact: Motion
General Artifact: Motion Correction
Gated Rest & Stress Images

βGating:

– Simultaneous assessment of perfusion, function, and viability
– Small dose of tracer = fuzzy images
  – Gating rest & stress will help accommodate for low count rate
– More accurate LV function
  – LVF may decrease w/ stress
Stress Protocols
**Stress Protocols**

- **One- day protocol**
  - Rest images followed by stress with 1:10 ratio (mibi)

- **Two- day protocol (high BMI)**
  - Stress image on day one
  - Rest image to rule out artifact and ischemia
    - Max dose (~30 mCi tc99m) on both days

- **Treadmill**
  - Bruce protocol
  - Modified Bruce protocol

- **Chemical**
  - Dobutamine
  - Adenosine
  - Regadenoson
Stress Protocols- Treadmill

βFunctional Tolerance

– Aides in distinguishing artifact and ischemia

βBruce Protocol

– 3 min stages
– 85% of max HR
  – 1-2 min walk after injection
Treadmill Contraindications

- **Physical Limitations**

- **EKG changes & LBBB**
  - Do not raise HR!
  - Possible reversible septal defect due to the erroneous blood flow from the block if the HR is increased.

- **CAD Medications**
  - Beta Blockers
  - Calcium channel blockers

- **Post treadmill stress imaging: 15 minutes**
  - Cardiac creep – post stress images too quickly
  - Expanded lugs draw heart downward
Stress Protocols- Vasodilator – Lexiscan

- Adenosine A2A receptor agonist
  - low affinity for receptors that are responsible for the major side effects of adenosine and dipyridamole
    - A1, A2B, and A3
- Patient Prep:
  - NPO 4 HR
  - No caffeine products 12 hr
  - Hold Beta and calcium channel blockers 24 hours
- IV dose of 0.4 mg (10 sec), followed by saline flush followed by radio tracer 10-20 seconds after flush.
Lexiscan Considerations

• GI Artifact
  • Have pt eat fatty meal to increase liver & gallbladder clearance

βBronchospastic airway disease
  – bronchodilator should be immediately available

βSeizures
  – Ativan or patient’s medication

150 mg of IV aminophylline can be injected at least 3–4 minutes after the radiotracer injection
WHY NOT BOTH?
Processed Images
Images

**Polar Maps**

- 2D display of 3D distribution of radiotracer activity in the left ventricle
- Review of MP information for the whole LV in a single image

Normalize to the region of myocardium that has the highest counts

- Relative imaging (no absolute values)
  - Normalization to test patients
Black out map

–The degree of hypoperfusion can be expressed locally as a percentage of the total defect belonging to a given region or segment.
Summed Stress Score

Summed Stress Score: 0
Summed Rest Score: 3
Summed Difference Score: -3
PET Cardiac
PET For Cardiac

Powerful, versatile non-invasive diagnostic tool with utility in the identification of high-risk plaques, myocardial perfusion defects, and viable myocardial tissue

– Assess function and viability
General PET for Cardiac Pro’s

• **Image Quality**
  - high myocardial counts
  - high spatial and contrast resolution
  - high signal-to-noise ratio
  - accurate and reliable correction for the effects of tissue attenuation and scatter.

• **Exposure**
  - complete rest-stress scan routinely exposes patients to less than 5 mSv and as little as 1 mSv effective dose using 3D imaging protocols

• **Time & Throughput**
  - A complete rest/stress study can be acquired in less than one hour if rubidium-82 is used
82-Rubidium

β Decay product of Strontium 82

β Half-life 76s
  – Primarily pharmaceutical stressing

β Exposure
  – Staff Exposure: WB Effective dose 0.4 uSv (RB82) 3.3 uSv (MIBI)
  – Patients: 80mrem (Rb82) 1500 mrem (mibi)
**82-Rubidium Protocol**

1. Topogram
2. CT
3. Inject 25-30mCi Rb82 (~2min uptake)
4. 6 min Acquisition
5. 2\textsuperscript{nd} CT (optional)
6. Chemical stress w/ 25-30 mCi Rb82 (~2min uptake)
7. 6 min Acquisition
82-Rubidium

- Detection of obstructive CAD:
  - sensitivity 90%
  - specificity 88%
- Provides an accurate assessment of the absolute MBF and CFR
- Viability
  - Also potassium analog
  - Optimized to cope with the high count levels during first-pass
  - List mode can help reconstruct relative & absolute BF
- Simultaneous examination of anatomy with hybrid systems
RB82 for Viability
82-Rubidium Considerations

Cost
- Growing re-imbursement

Isotope availability
- In-house generator
  - Two IV’s
Imaging Cardiac Amyloidosis
Cardiac Amyloidosis

Autosomal dominant disease caused by a mutation in the transthyretin (TTR) gene that results in misfolded TTR proteins accumulating as amyloid fibrils
PYP Images

1 hour delayed imaging

Ratio of >1.5 at 1 hour
Positive

9, 11
PYP for Cardiac Amyloidosis Considerations

βRenal Failure

- May have persistent blood pool

βBone artifact

- SPECT/CT
Conclusion

• PET imaging
  • Better for patient and staff
  • Increasing reimbursement
  • Generator needed

• NM Imaging
  • Great for patients with known disease
  • Various tracers
  • Many road blocks
    • Artifacts

• Stress Testing
  • Treadmill V. Chemical V. Combination

• PYP Imaging for ATTR Cardiac Amyloidosis
Thank you!
References & Resources


References & Resources
