Multiple Gated Acquisition (MUGA) Scanning

Dmitry Beyder  MPA, CNMT
Nuclear Medicine, Radiology
Barnes-Jewish Hospital / Washington University
St. Louis, MO
Disclaimers/Relationships

- Standard of care research studies
- None - financial
The Heart Muscle
Heart Disease

According to Centers for Disease Control and Prevention 2015

- # of deaths = 610k/yr
  = 1 in every 4 deaths
- Cause of death: # 1
Nuclear Cardiology

• Myocardial Perfusion Imaging
  – Coronary Artery Disease (CAD)

• Ventricular Function (MUGA)
  – Left & Right Ventricle Ejection Fraction
Nuclear Cardiology

- Myocardial Perfusion Imaging
  - Coronary Artery Disease (CAD)

- Ventricular Function (*MUGA*)
  - Left & Right Ventricle Ejection Fraction
Outline

• Where it Came From
  – Clinical necessity
  – Technology development

• Current Techniques
  – First-pass planar
  – Rest & Stress planar equilibrium
  – SPECT

• Problems and Controversies
Clinical Relevance
~ 50 years ago

• Ventricle Evaluation w/out Cardiac Catheterization
  – Clinical Applications
    • Myocardial infarction *ischemic CAD*
    • Cardiomyopathy *non-ischemic CAD*
  – Data Obtained
    • Left Ventricle Ejection Fraction (LVEF)
    • Wall motion abnormality

Strauss, H.W., Zaret B.L., Hurley, P.J., Natarajan, T.K. and Pitt, B.
Johns Hopkins University School of Medicine
Building the Software

• Frame-mode acquisition
  – Pre-set framing time

• 8-bit Minicomputer Software
  – 4 letter name → MUGA
    Multiple Gated Acquisition

Johns Hopkins University School of Medicine
Frame-Mode Data Acquisition
Recording Data

• First-Pass
  – Video tape
  – Sound ECG

• Equilibrium Radionuclide Angiography
  – 28 segments per heart beat
  – 200,000 counts/segment

Ashburn, W.L.
University of California, San Diego
Calculating Data

LVEF

• **1** Region of Interest
  – Identified over left ventricle
  – End-diastolic

\[
\text{LVEF} = \frac{\text{maximum counts} - \text{minimum counts}}{\text{maximum counts} - \text{background}}
\]


Johns Hopkins University School of Medicine
“...it is not unreasonable to expect that the noninvasive radioactive tracer techniques for measuring ventricular function may in many instances supplant contrast ventricular angiography and serve as primary means of evaluating patients with suspected ventricular dysfunction.”

Evolution

• Technology
  – Memory availability
  – Buffer for arrhythmia filtering
  – Edge detection

• Radiopharmaceutical labeling
  – Human Serum Albumin vs. Red Blood Cells (RBC)
Current Techniques

1. First Pass
2. Rest Planar Equilibrium
3. Stress Planar Equilibrium
4. SPECT
First-Pass Purpose

- Right Ventricle Ejection Fraction (RVEF)
- Left to Right Shunt
- Ventricular Volume
First-Pass Technique

• Radiopharmaceutical
  – Bolus injection
  – 20- 25 mCi of $^{99m}$Tc - Labeled Red Blood Cells
  – Multiple injections option

• Imaging
  5-10 cardiac cycles, 30-60 seconds
  – RVEF ~ 30 degree RAO
  – List mode
  – Gated
First-Pass
Dynamic
First-Pass
Gated Acquisition

Time Activity Curve

End diastolic
End systolic

Injection
Time
Activity
First-Pass Gated Cine
First-Pass Results
Rest Equilibrium

Purpose

- Left Ventricular Performance
  - Quantitative
    - Ejection Fraction
  - Qualitative
    - Size
    - Configuration
    - Wall motion
Rest Equilibrium Injection Technique

- $^{99m}$TcO$_4$- labeled Red Blood Cells (in vitro) - 20 to 30 mCi

- Different Methods of Administration
  - labeling efficiency
    - in vitro $\sim$ 97%
    - modified in vivo $\sim$ 90%
    - in vivo $\sim$ 75%
Rest Imaging Technique

• Imaging 2 to 6 million counts, 5-10 minutes
  – LVEF best septal view, ~ 42 to 45 degree LAO
  – Qualitative anterior & left lateral views

  – Gating
    • ECG R-wave trigger begins recording data
      – 16 or 32 segments per heart beat
    • Arrhythmia filtering
      – 90% R-R Interval acceptance
      – 60% Allowable variance
Rest Imaging – left ventricle

- Aorta
- Left Ventricle
- Interventricular Septum
- Right Ventricle
Rest Technique

- Imaging 2–6 million counts, 5-10 minutes
  - LVEF best septal view, ~ 45 degree LAO
  - Qualitative anterior & left lateral views

- Gating
  - ECG R-wave trigger begins recording data
    - 16 or 32 segments per heart beat
  - Arrhythmia filtering
    - 90% R-R Interval acceptance
    - 60% Allowable variance
Rest

Gating – Arrhythmia Filtering

Heart Beats

489 ms

msecs

Heart Beats

122 bpm

bpm

200

135

70

A: 971 Beats

Counts

R: 7
Stress Equilibrium

Purpose

- Left Ventricle response to stress
- EF change
- Regional wall motion
- Severity of CAD
Stress Equilibrium Technique

• Radiopharmaceutical
  – Same as Rest

• Imaging 0.5 – 1.5 million counts, 2-4 minutes
  – LVEF rest & stress (same method: bike)
  – Gating
    • Arrhythmia filtering
      – 90% R-R Interval acceptance
      – up to 120% Allowable variance
Stress Equilibrium

Results

Rest LAO
on bike

Stress LAO
on bike
MUGA Planar vs. SPECT

• **Planar** *Gold Standard*
  – Measurement from 1 projection angle, 2D

• **SPECT** (Single Photon Emission Computed Tomography)
  – Measurement from 32 projection angles, 3D
  – Additional data
    • Right Ventricle Ejection Fraction
    • Multiple views of wall motion
SPECT Advantage
Calculate Ejection Fraction

\[ \text{LVEF} = \frac{\text{End Diastolic Volume} - \text{End Systolic Volume (ESV)}}{\text{End Diastolic Volume (EDV)} - \text{background}} \]

**Normal Range**

- **RVEF**  > 40%
- **LVEF**  > 50%
- **Stress LVEF**  ~ 5 - 10% higher than Rest
“Cardiologists do not order MUGA scans.”
Why?
Directly Controlled

- Requires a radiation injection
- Blood handling
- User dependent results
- Time consuming
- Not cheap
Why?

Outside Contributions

• Physician/Cardiologist Preference
• Turf battle with other modalities?
• Not as accurate as MRI & CT
<table>
<thead>
<tr>
<th>Procedure</th>
<th>CPT Code</th>
<th>Price</th>
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<tbody>
<tr>
<td>Echocardiogram</td>
<td>CPT 93306</td>
<td>$301</td>
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<tr>
<td>MUGA LVEF</td>
<td>CPT 78472</td>
<td>$317</td>
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<tr>
<td>MUGA 1st Pass</td>
<td>CPT 78496</td>
<td>$57</td>
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<td>Cardiac CT</td>
<td>CPT 75572</td>
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<td>Cardiac MRI</td>
<td>CPT 75557</td>
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Medicare Fee Schedule 2015
Global Price (Includes Technical and Professional Components)
Echocardiography

Advantages

• Faster 30-45 minutes & Less expensive
• Widely available
• Non-invasive, no radiation or IV
• Evaluate all four chambers
• Assesses diseases of the heart valves
• Evaluates patterns of blood flow
• Obtain specific measurements
Echocardiography

Disadvantages

• Makes geometric assumptions
  – Not optimal for patients that do not have “normal” hearts
• Accuracy reduced by obesity
• Structures at the back of heart difficult to see
• Less accurate & reproducible than MUGA
3D Echocardiogram

Viewed from the Apex
Cardiovascular Magnetic Resonance (CMR) Advantages

- Fast = 20 minutes
- Non-invasive, no radiation or IV
- Highly accurate
- Highly reproducible
Cardiovascular Magnetic Resonance (CMR) Disadvantages

• Expensive
• Not widely available
• Need:
  – Highly trained technologist
  – Cardiologists/Radiologists trained to read CMR
  – Specific equipment and software
• Not a good starting point for evaluation
CMR spin-echo Sequence

Blood is: White

Black
Cardiac CT

Overview

• Main indication is for Coronary Artery Disease (CAD)
• Radiation exposure
• Expensive
• Never indicated as a first line test
Conclusion

• MUGAs have a special place in the cardiology world
  – Superior in Quantitative LVEF measurement

• There is strong competition for quantitative evaluation of the heart

• We need to be dynamic and adjust to our competition
  – Evidence based medicine
    • Improve our technology, growth of accurate SPECT
  – Competitive pricing
  – Accommodate patients & clinicians
Thank You!

We need to keep building...

Dmitry Beyder
dmitry.beyder@bjc.org