The Basics of Cardiac Rb PET/CT

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Cardiac Imaging Research Specialist
Introduction

- Patients with suspected or known CAD benefit from the information provided by a noninvasive cardiac imaging test, regarding the presence, extent, and severity of CAD.

- An important goal of imaging is to provide a high quality appropriate test for the right patient at the right time.

- These goal include effective, safe, efficient, patient-centered, equitable, and timely care.
AMERICAN SOCIETY OF NUCLEAR CARDIOLOGY AND SOCIETY OF NUCLEAR MEDICINE AND MOLECULAR IMAGING JOINT POSITION STATEMENT ON THE CLINICAL INDICATIONS FOR MYOCARDIAL PERFUSION PET

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Clinical Indications

Preferred:

- Patients with known or suspected CAD who meet AUC and are unable to complete a diagnostic level exercise stress imaging study
Clinical Indications

**Recommended:**

- Prior stress imaging study was poor quality, equivocal or inconclusive – attenuation artifact, or discordant with clinical impressions of other diagnostic test results
- Body characteristics (BMI >30, unusual shape, dextrocardia, pleural effusions)
- High-risk patients (kidney dz, DM, known or suspected potentially high-risk CAD)
- Young patients with established CAD
- Myocardial blood flow quantification benefits to exclude multivessel CAD, to improve risk stratification, assessment of microcirculatory function
Important Properties of Myocardial Perfusion PET

1. High Diagnostic Accuracy
2. Consistent High-Quality Images
3. Low Radiation Exposure
4. Short Acquisition Protocols
5. Quantification of myocardial Blood Flow
6. Strong Prognostic Power
Course Outlines

- Compare Cardiac PET Radiopharmaceutical
- Quality Control
  - Rubidium Generator
  - PET/CT Scanner
- Imaging Protocol and Artifacts
The Basics of PET Imaging

Positron emission and positron-electron annihilation

Positron-emitting radionuclide

Positron

Electron

511 keV gamma ray

Annihilation

511 keV gamma ray

PET scanner

Front. Oncol., 13 August 2013
The Basics of PET Imaging

Proton (P) decays into neutron (N), emitting positron (e+) and neutrino (v)

Positron (e+) - electron (e-) annihilation results in two antiparallel 511 keV photons (γ)
## PET MPI Tracers

<table>
<thead>
<tr>
<th>Property</th>
<th>$^{82}\text{Rb}$-chloride</th>
<th>$^{13}\text{N}$-ammonia</th>
<th>$^{15}\text{O}$-water</th>
<th>$^{18}\text{F}$-flurpiridaz</th>
</tr>
</thead>
<tbody>
<tr>
<td>Isotope production method</td>
<td>Generator</td>
<td>Cyclotron</td>
<td>Cyclotron</td>
<td>Cyclotron</td>
</tr>
<tr>
<td>Isotope half-life (min)</td>
<td>1.27</td>
<td>10</td>
<td>2.0</td>
<td>110</td>
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<tr>
<td>Positron range (mm) RMS</td>
<td>2.6</td>
<td>0.57</td>
<td>1.0</td>
<td>0.23</td>
</tr>
<tr>
<td>Image resolution (mm) FWHM</td>
<td>8</td>
<td>5</td>
<td>6</td>
<td>5</td>
</tr>
<tr>
<td>Effective dose (mSv/GBq)</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>20</td>
</tr>
<tr>
<td>Peak stress/rest* extraction (%)</td>
<td>35/70</td>
<td>95/100</td>
<td>100</td>
<td>95/100</td>
</tr>
<tr>
<td>Peak stress/rest* retention (%)</td>
<td>25/70</td>
<td>50/90</td>
<td>0</td>
<td>55/90</td>
</tr>
<tr>
<td>Spillover from adjacent organs</td>
<td>Stomach wall</td>
<td>Liver and lung</td>
<td>Liver</td>
<td>Early liver</td>
</tr>
<tr>
<td>Regulatory status</td>
<td>FDA-approved; 2 suppliers</td>
<td>FDA-approved; ANDA required for onsite production</td>
<td>Not FDA-approved</td>
<td>Phase 3 trials partially completed</td>
</tr>
<tr>
<td>Typical rest dose for 3D/2D (mCi)</td>
<td>30/45</td>
<td>10/15</td>
<td>20/30</td>
<td>2/3</td>
</tr>
<tr>
<td>Typical stress dose for 3D/2D (mCi)</td>
<td>30/45</td>
<td>10/15</td>
<td>20/30</td>
<td>6/7</td>
</tr>
<tr>
<td>Protocol features</td>
<td>Rapid protocol</td>
<td>Permits exercise‡; delay of 4–5 half-lives between rest and stress unless different doses used</td>
<td>Rapid protocol; no tracer retention for routine MPI</td>
<td>Permits exercise‡; different doses for rest and stress required</td>
</tr>
</tbody>
</table>
Myocardial Blood Flow

(Gould KL, *Am J Cardiol* 1974;33:87-94.)
Myocardial Flow Quantification
**Extraction Fraction of Tracers**

**SPECT Tracer**
- \(^{99m}\text{Tc-teboroxime}\) (>90%)
- \(^{201}\text{Tl}\) (85%)
- \(^{99m}\text{Tc-sestamibi}\) (60%)

**PET Tracer**
- \(^{15}\text{O water}\) (100%)
- \(^{18}\text{F flurpiridaz}\) (94%)
- \(^{13}\text{N ammonia}\) (80%)
- \(^{82}\text{Rb}\) (65%)

**Higher extraction fractions:**
- More accurate stress myocardial blood flow
- Greater defect resolution
- Increased cardiac counts at stress
- Decreased dose to other organs
# PET Radiopharmaceuticals

<table>
<thead>
<tr>
<th>Radiopharm</th>
<th>Year of FDA Approval</th>
<th>Clinical Indication</th>
</tr>
</thead>
<tbody>
<tr>
<td>F-18 Fluoride</td>
<td>1972</td>
<td>Bone imaging</td>
</tr>
<tr>
<td>Rb-82</td>
<td>1992</td>
<td>Myocardial perfusion imaging</td>
</tr>
<tr>
<td>F-18 FDG</td>
<td>1994</td>
<td>Epileptic foci</td>
</tr>
<tr>
<td>F-18 Fluoride</td>
<td>2000</td>
<td>Bone imaging</td>
</tr>
<tr>
<td>N-13 NH3</td>
<td>2000</td>
<td>Myocardial perfusion imaging</td>
</tr>
<tr>
<td>F-18 FDG</td>
<td>2000</td>
<td>Epileptic foci in brain</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Myocardial glucose metabolism</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Tumor glucose metabolism</td>
</tr>
<tr>
<td>F-18 FDG</td>
<td>2005</td>
<td>Alzheimer’s disease and Fronto-temporal dementia</td>
</tr>
</tbody>
</table>
82Rb-chloride

- Potassium analog
- Actively transported across the cell membrane by Na-K pump
- Produced from a Sr-82/Rb-82 generator and IV administered using an infusion pump
- Contains Sr-82 and Sr-85 in a hydrous stannic oxide column
  - Sr-82 $T\frac{1}{2} = 25$ days (parent isotope)
  - Sr-85 $T\frac{1}{2} = 65$ days (unintended byproduct)
- The “daughter” is Rb-82 chloride ($T\frac{1}{2} \approx 75$ sec)
- Same dose for rest and stress imaging
- On-demand availability
Course Outlines

- Compare Cardiac PET Radiopharmaceutical
- Quality Control
  - Rubidium Generator
  - PET/CT Scanner
- Imaging Protocol and Artifacts
CardioGen-82 Generator

- Generator sits inside a shielded container in the cart
- Automatic infusion system
- Positron detector (Dose calibrator)
- Control Panel
CardioGen-82 Infusion System
CardioGen-82 Infusion System

➢ Quality Control

1. Daily column wash

2. Rb-82, Sr-82 and Sr-85 level testing daily prior to patient administration

3. Daily Calibration
CardioGen-82 QC Records

Setpoint Values:
- Elution Vol. = 99 ml
- Patient Vol. = 50 ml
- Patient Dose = 99 mCi
- Dose Rate Thld. = 1.0 mCi/sec
- Flow Rate = 50 ml/min
- Cal. Factor = 1090

Actual Infusion Data:
- Elution Vol. = 60 ml
- Patient Vol. = 50 ml
- Patient Dose = 74.7 mCi

Infused Activity Present At End Of Infusion = 51.4 mCi

Activity Present Between Det. and Waste Valve = 0.274 mCi
in Volume of 0.592 ml

Activity Present Between Waste Valve and Pat. = 0.584 mCi
in Volume of 1.250 ml

Infused Activity Present At End Of Infusion = 49.9 mCi

Activity Present Between Det. and Waste Valve = 0.279 mCi
in Volume of 0.592 ml

Activity Present Between Waste Valve and Pat. = 0.594 mCi
in Volume of 1.250 ml

Setpoint Values:
- Elution Vol. = 99 ml
- Patient Vol. = 50 ml
- Patient Dose = 30 mCi
- Dose Rate Thld. = 1.0 mCi/sec
- Flow Rate = 50 ml/min
- Cal. Factor = 1090

Actual Infusion Data:
- Elution Vol. = 20 ml
- Patient Vol. = 10 ml
- Patient Dose = 30.2 mCi

Infused Activity Present At End Of Infusion = 29.0 mCi

Activity Present Between Det. and Waste Valve = 1.957 mCi
in Volume of 0.592 ml

Activity Present Between Waste Valve and Pat. = 4.600 mCi
in Volume of 1.250 ml

Setpoint Values:
- Elution Vol. = 99 ml
- Patient Vol. = 50 ml
- Patient Dose = 99 mCi
- Dose Rate Thld. = 1.0 mCi/sec
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in Volume of 1.250 ml
CardioGen-82 Label

Alert Limits

- Sr-82 level exceeds 0.002 µCi Sr-82/mCi Rb-82, or
- Sr-85 level exceeds 0.02 µCi Sr-85/mCi Rb-82, or
- A total elution volume of 14 L has passed through the generator column

Expiration Limits

- Sr-82 level exceeds 0.01 µCi Sr-82/mCi Rb-82, or
- Sr-85 level exceeds 0.1 µCi Sr-85/mCi Rb-82, or
- A total elution volume of 17 L has passed through the generator column, or
- 42 days post calibration date
# Worksheets

## Generator Data

<table>
<thead>
<tr>
<th>Generator Lot #</th>
<th>09101-180381</th>
</tr>
</thead>
<tbody>
<tr>
<td>Generator Calibration Date</td>
<td>5/20/2018</td>
</tr>
</tbody>
</table>

**Previous Day Cumulative Generator Elution Volume (mL)**

(Enter information from the previous day's worksheet)

(If first day of use, Enter 0)

**Daily Quality Control (QC) Elution Volume Readings from Infusion Print-Out (ml)**

**Site Name**: __________

**CSMC**: __________

**Reviewed by site signature**: __________

<table>
<thead>
<tr>
<th>Decay Factors</th>
<th>Generator Data</th>
</tr>
</thead>
<tbody>
<tr>
<td>Decay Time</td>
<td>Factor</td>
</tr>
<tr>
<td>2 min 30 Sec</td>
<td>2:30</td>
</tr>
<tr>
<td>3 min 45 sec</td>
<td>3:45</td>
</tr>
<tr>
<td>5 min</td>
<td>5:00</td>
</tr>
</tbody>
</table>

**Decay Factor**

**Calibration Lot #:** 09101-190041

**Calibration Date:** 1/4/2019

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**Calibration Worksheet**

**Calibration should always be done at the same patient dose settings as will be used for patient infusions.**

The first elution of the day must be discarded in accordance with site specific procedures before starting quality control procedures. Calibration is performed using the standard patient dose parameters. Refer to Rb 82 Infusion System Calibration Data Sheet In the Infusion System User Guide for Instructions.

<table>
<thead>
<tr>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
<th>F</th>
<th>G</th>
<th>H</th>
<th>I</th>
<th>J</th>
<th>K</th>
<th>L</th>
<th>M</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calibration</td>
<td>Dose Reading from Dose Calibrator (mCi)</td>
<td>Decay Corrected Dose (mCi)</td>
<td>Printed Activity at End of Infusion (mCi)</td>
<td>Ratio D to E</td>
<td>Calib +/- 5%</td>
<td>Calib +/- 10%</td>
<td>Is this the first calibration of the new generator?</td>
<td>Current Calib Factor</td>
<td>New Calib Factor</td>
<td>Comments</td>
<td>Operator Initials</td>
<td></td>
</tr>
<tr>
<td>Ex: 9/28/05</td>
<td>6.07</td>
<td>3:45</td>
<td>48.56</td>
<td>57.2</td>
<td>0.85</td>
<td>NO</td>
<td>NO</td>
<td>Yes</td>
<td>1000</td>
<td>850</td>
<td>KM</td>
<td></td>
</tr>
<tr>
<td>Ex: 9/28/05</td>
<td>6.88</td>
<td>3:45</td>
<td>54.88</td>
<td>55.7</td>
<td>0.985</td>
<td>YES</td>
<td>YES</td>
<td>Yes</td>
<td>850</td>
<td>850</td>
<td>KM</td>
<td></td>
</tr>
<tr>
<td>1/16/19 0630am</td>
<td>3.56</td>
<td>3:45</td>
<td>28.48</td>
<td>28.9</td>
<td>0.985</td>
<td>YES</td>
<td>YES</td>
<td>No</td>
<td>1090</td>
<td>1050</td>
<td>JSF</td>
<td></td>
</tr>
<tr>
<td>1/17/19 0640am</td>
<td>3.63</td>
<td>3:45</td>
<td>29.04</td>
<td>28.7</td>
<td>1.012</td>
<td>YES</td>
<td>YES</td>
<td>No</td>
<td>1090</td>
<td>1090</td>
<td>JSF</td>
<td></td>
</tr>
</tbody>
</table>

---

**Example of circles:сто**

1. **Dose Reading from Dose Calibrator (mCi)**
2. **Decay Corrected Dose (mCi)**
3. **Printed Activity at End of Infusion (mCi)**
4. **Ratio D to E**
5. **Calib +/- 5%**
6. **Calib +/- 10%**
7. **Is this the first calibration of the new generator?**
8. **Current Calib Factor**
9. **New Calib Factor**
10. **Comments**
11. **Operator Initials**
## End of Day

- **Total Elution Volume from Patient Doses (mL):** 124
- **Total Number of Patients Dosed on this Day:** 3
- **Cumulative Daily Volume (mL):** 269
- **Cumulative Volume for this Generator (L):** 5.061

### Notes

- **Was this the last usage of generator?** No
- **If Yes, Date of Last Use (DD/MMM/YYYY):**

---

**Threshold criteria:**
- The ratio of Sr-82 reaches 0.002 μCi / mCi Rb-82
- The ratio of Sr-85 reaches 0.02 μCi / mCi Rb-82
- Cumulative volume of the generator reaches 14 Liters

**Expiration criteria:**
- The ratio of Sr-82 reaches 0.01 μCi / mCi Rb-82
- The ratio of Sr-85 reaches 0.1 μCi / mCi Rb-82
- Cumulative volume of the generator reaches 17 Liters
- 43 days of use post generator calibration date has occurred
**RUBY-FILL Generator**

<table>
<thead>
<tr>
<th>Advancing cardiac PET imaging to be:</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Precise</strong></td>
<td>Constant-activity infusion option</td>
</tr>
<tr>
<td></td>
<td>Maintains consistent activity rate profiles throughout the life cycle of the generator(^1-3)</td>
</tr>
<tr>
<td><strong>Flexible</strong></td>
<td>Accurate patient-specific dosing</td>
</tr>
<tr>
<td></td>
<td>Long shelf life—60 days</td>
</tr>
<tr>
<td><strong>Efficient</strong></td>
<td>Automated daily quality control</td>
</tr>
<tr>
<td></td>
<td>Built-in safety controls</td>
</tr>
</tbody>
</table>
Determine Rb 82, Sr 82, Sr 85 in the generator eluate:
- Once a day, prior to any drug administration, and
- At additional daily tests after detection of an Alert Limit.
  - 20 L for the generator’s cumulative eluate volume, or
  - An eluate Sr 82 level of 0.004 μCi/ mCi (kBq/MBq) Rb 82, or
  - An eluate Sr 85 level of 0.04 μCi/ mCi (kBq/MBq) Rb 82.
- Perform additional daily tests every 4 patients after detection of an alert limit

Stop use of a generator at any of the following Expiration Limits.
- 30 L for the generator’s cumulative eluate volume, or
- Expiration date of the generator (60 days post-manufacturing)
- An eluate Sr 82 level of 0.01 μCi /mCi (kBq/MBq) Rb 82, or
- An eluate Sr 85 level of 0.1 μCi /mCi (kBq/MBq) Rb 82
## Comparison of Limits: CardioGen-82® vs RUBY-FILL®

<table>
<thead>
<tr>
<th>Limit</th>
<th>Volume (liters)</th>
<th>$^{82}\text{Sr}$ Breakthrough (mCi/mCi $^{82}\text{Rb}$)</th>
<th>$^{85}\text{Sr}$ Breakthrough (mCi/mCi $^{82}\text{Rb}$)</th>
<th>Time (days)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>RUBY-FILL</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Alert</td>
<td>20</td>
<td>0.004</td>
<td>0.04</td>
<td></td>
</tr>
<tr>
<td>Expiratory</td>
<td>30</td>
<td>0.01</td>
<td>0.1</td>
<td>60</td>
</tr>
<tr>
<td><strong>CardioGen-82</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Alert</td>
<td>14</td>
<td>0.002</td>
<td>0.02</td>
<td></td>
</tr>
<tr>
<td>Expiratory</td>
<td>17</td>
<td>0.01</td>
<td>0.1</td>
<td>42</td>
</tr>
</tbody>
</table>
Course Outlines

- Compare Cardiac PET Radiopharmaceutical
- Quality Control
  - Rubidium Generator
  - PET/CT Scanner
- Imaging Protocol and Artifacts
PET/CT QC

Ge-68 Source

CT Phantom
<table>
<thead>
<tr>
<th>Procedure</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acceptance testing (NU 2-2012)&lt;sup&gt;5&lt;/sup&gt;</td>
<td>Once upon delivery and upon major hardware upgrades</td>
</tr>
<tr>
<td>Daily QC, as recommended by vendor (attenuation blank scan, phantom scan, etc.)</td>
<td>Daily</td>
</tr>
<tr>
<td>Sensitivity and overall system performance</td>
<td>Weekly preferred (or at least monthly)</td>
</tr>
<tr>
<td>Accuracy (corrections for count losses and randoms)</td>
<td>At least annually</td>
</tr>
<tr>
<td>Scatter fraction</td>
<td>At least annually</td>
</tr>
<tr>
<td>Accuracy of attenuation correction</td>
<td>At least annually</td>
</tr>
<tr>
<td>Image quality</td>
<td>At least annually</td>
</tr>
<tr>
<td>Measurements specified by the manufacturer</td>
<td>As per the manufacturer</td>
</tr>
</tbody>
</table>
PET QC: Sinogram

1. Detector Info
2. Plane Display
3. Fansum Display
4. Plane Numbers
PET QC: Normalization

Normal Sinogram

Recon image of NEMA/IEC phantom

Non-operational Detector Blocks

Recon image of NEMA/IEC phantom

Detector Controller Failure

Normal

Recon image of NEMA/IEC phantom

Sorting Memory Failure

Before Normalization

After Normalization

Detector Failure
## Phantom Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Isotope</td>
<td>Ge-68</td>
</tr>
<tr>
<td>Assay Activity</td>
<td>2.305382 [mCi]</td>
</tr>
<tr>
<td>Assay Date and Time</td>
<td>Thursday, September 17, 2015, 7:37:00</td>
</tr>
<tr>
<td>Volume</td>
<td>8407 [cc]</td>
</tr>
<tr>
<td>Calibration Factor</td>
<td>1.030000</td>
</tr>
</tbody>
</table>

## Input for Computation

<table>
<thead>
<tr>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Daily Sinogram location</td>
<td><code>PETACS\sinograms\CTIEMSINO_2_1_4.0.251570314.s</code></td>
</tr>
<tr>
<td>Proposed ECF Value</td>
<td>3.173e+007 [Bq*s/ECAT counts]</td>
</tr>
<tr>
<td>Last Partial Setup</td>
<td>Monday, August 01, 2016, 7:54:32</td>
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## Results

- **System Quality Results**: Passed
- **QC Phantom Activity**: Passed

QC successfully completed. All values are within valid ranges. QC Phantom has remaining activity greater than 0.5 mCi.

## Detailed System Quality Report

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<tr>
<th>Item</th>
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<th>Lower Bound</th>
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<td>Scanner Efficiency</td>
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<td>22.82 [cps/Bq/cc]</td>
<td>33.9 [cps/Bq/cc]</td>
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<tr>
<td>Scatter Ratio</td>
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<td>3.173e+007 [Bq*s/ECAT counts]</td>
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## Combined PET/CT QC Procedures

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<tr>
<td>Field uniformity</td>
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*or as recommended by the manufacturer

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<td>Tube warm-up</td>
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<tr>
<td>Air calibration (&quot;fast QA&quot;)</td>
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<tr>
<td>Water phantom checks: slice thickness, accuracy, positioning</td>
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<table>
<thead>
<tr>
<th>Test</th>
<th>Requirement</th>
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<tr>
<td>Attenuation correction accuracy</td>
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CT QC

Noise & Uniformity

Linearity
## CT QC Record

### Taper Biograph Quality Assurance Record - Technologist Daily, Weekly and Monthly Checks

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<tr>
<th>DATE</th>
<th>UNIT STATUS</th>
<th>ARTIFACTS</th>
<th>DAILY CT # CHECK</th>
<th>WEEKLY SMPTE CHECK</th>
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CT QC Artifacts

- Ring Artifact
- Streak Artifact
- Texture Artifact
Course Outlines

- Compare Cardiac PET Radiopharmaceutical
- Quality Control
  - Rubidium Generator
  - PET/CT Scanner
- Imaging Protocol and Artifacts
Technical Advantages of Rb PET

- High spatial & temporal resolution
- High count density
- Reliable attenuation & scatter correction
- Short half-life radionuclides
- Short image acquisition protocols
- Tracers with superior kinetics
- Validated models for quantifying myocardial blood flow (MBF)
**PET 2D vs 3D Imaging**

**Recommendation:**
Validated 3D imaging should be used whenever possible for both dose reduction & high-quality images

---

**INFORMATION STATEMENT**

Status of cardiovascular PET radiation exposure and strategies for reduction: An Information Statement from the Cardiovascular PET Task Force

James A. Case, PhD,a Robert A. deKemp, PhD,b Piotr J. Slomka, PhD,c Mark F. Smith, PhD,a Gary V. Heller, MD, PhD,a and Manuel D. Cerqueira, MDf

J Nucl Cardio. May 2017
Count Sensitivity (%)
## Radiation Effective Doses (mSv)

<table>
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<tr>
<th>Study protocol</th>
<th>Isotope</th>
<th>Modality</th>
<th>Activity (mCi)</th>
<th>E (mSv)</th>
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<td>Rest + stress perfusion</td>
<td>$^{82}$Rb-chloride</td>
<td>3D PET</td>
<td>25 + 25</td>
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<td>2D PET</td>
<td>50 + 50</td>
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<td>Rest + stress perfusion</td>
<td>$^{13}$N-ammonia</td>
<td>3D PET</td>
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<td>Rest viability, sarcoid, or inflammation (+ perfusion)</td>
<td>$^{18}$F-FDG (+ $^{13}$NH$_3$ or $^{82}$Rb)</td>
<td>3D PET</td>
<td>5 (+10 or 25)</td>
<td>3.5 (+ 1)</td>
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<td>2D PET</td>
<td>10 (+20 or 50)</td>
<td>7 (+ 2)</td>
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<td>Stress-only perfusion (ultra-low-dose)</td>
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<td>CZT-SPECT</td>
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<td>Rest + stress perfusion one-day (half-dose)</td>
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<td>CZT-SPECT</td>
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<td>10 + 30</td>
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Rb-PET MPI Protocol

A

B

C

Vasodilator stress

Vasodilator stress

Vasodilator stress

40 mCi

2.5 min 2D dynamic scan

5 min 3D scan gated

2.5 min 2D dynamic scan

Tx scan

5 min 3D scan gated

Tx Scan (optional)
Pharmacologic Stress Comparison

**LEXISCAN**
- Inject Lexiscan (0.4-mg/5-mL IV injection for ~10 seconds)
- Saline Flush (5 mL)
- Inject Radiotracer (10-20 seconds after flush)

**ADENOSCAN**
- Infuse Adenoscan (140-mcg/kg/min IV infusion)
- Inject Thallium-201

**DIPYRIDAMOLE**
- Infuse Dipyridamole (0.142-mg/kg/min IV infusion)
- Inject Thallium-201 (within 5 minutes of infusion)
Rest Rb Study

- Coronary Calcium Screening (as needed)
- Scout
- Rest CT
- Rb82 Admin (25 – 60 mCi)
- Rest Rb82 Acquisition

- 5min
- 2sec
- 3sec
- 30sec
- 6min

- a. Coronary Calcium Screening (as needed)
- b. Scout (Topogram)
- c. Rest CT
- d. Rb82 administration
- e. Rest Rb 6 min list mode (begin acquisition at the beginning of Rb administration)
Lexiscan Pharm Rb Stress

- Acquire Stress CT
- Administer Lexiscan
- Wait 60 seconds, injection Rb82 (25-60 mCi)
- Immediately begin 6 minute list mode stress acquisition
Lexiscan-Induced Coronary Blood Flow

- Activation of the $A_{2A}$ adenosine receptor by Lexiscan produces coronary vasodilation and increases coronary blood flow (CBF).
- Lexiscan causes a rapid increase in CBF that is sustained for a short duration.

Dosing and Administration

✓ Recommended dose of 0.4 mg/5 mL for all patients, regardless of body weight
✓ Rapid (approximately 10 seconds) IV injection administration
  ▪ No pump required
✓ Administration of stress and tracer complete in less than 1 minute

*Flush after radionuclide administration per your lab protocol.
The New Lexi/Rb-82 Injection Protocol

Inject Regadenoson

Saline flush

0.4 mcg/5 mL IV injection over 10-20 seconds

5 mL

Recovery ECG Begin

60 seconds after Lexiscan

Inject Rb-82

Time, seconds
When to Inject Radiotracer for MBF after Regadenoson

**Background:** Rb-82 infusion is commonly begun 10 seconds following regadenoson (Reg) injection, similar to SPECT protocols. However,

**Conclusion:** This study indicates that peak vasodilation after regadenoson injection occurs considerably later than 10 seconds after beginning of Rb-82 infusion. Specifically, delaying the start of the Rb-82 infusion for 60 to 120 seconds following regadenoson injection provides higher peak MBFR measurements. Further studies are needed to determine if a longer delay also improves image accuracy.
Adenosine Pharm Rb Stress

7 min Adeno admin
3 sec Rb admin
Administer 25-60 mCi Rb @ 1.5 min or @ 2.5 min
Acquire stress images for 6 min

- Acquire Stress CT
- Begin adenosine administration for 7 or 8 minutes (depending on rate selection by NP)
- Injection Rb82 (25-60 mCi) at 1.5 min of Adenosine administration or at 2.5 min
- Begin a 6 minute list mode stress acquisition at 1.5 min of Adenosine administration or at 2.5 min
- Adenosine administration completes at 7 or 8 minutes
- Stress Rb acquisition completes at 8.5 or 9.5 minutes
Dipyridamole Pharm Rb Stress

- Administer Dipyridamole over 4 minutes
- Wait 3 - 5 minutes, injection Rb82 (25 – 60 mCi)
- Immediately begin 6 minute list mode stress acquisition.
- At end of imaging, begin recovery and administer aminophylline as needed
Dobutamine Pharm Rb Stress

- Begin Dobutamine administration
- As patient nears 85% of peak heart rate, acquire Stress CT
- At peak heart rate administer Rb82 (25-60 mCi) begin 6 minutes stress acquisition
- Maintain Dobutamine administration rate for 2 minutes post peak heart rate
- At 2 minutes reduce rate to previous administration rate until end of stress acquisition
Diagnostic Accuracy of Rb-PET MPI

- Spatially-relative image interpretation (visual & quantitative)
- Rest & peak stress LVEF, EDV, ESV
- Rest & peak stress global & regional WM & WT
- Myocardial blood flow (MBF) & coronary flow reserve (CFR)
Cardiac PET MPI
Multi-dimensionaL List-Mode Acquisition

A Static

B Dynamic

C ECG-Gated

D Respiratory Gating
Dynamic Cardiac PET
Myocardial Perfusion SPECT/PET

Perfusion

Quantification

Function

Peak Stress

Rest

Flow
Conclusions: Clinical Response Nonischemic  
ECG Response Nonischemic  
Perfusion Abnormal (Reversible)  
Function Abnormal rest, worse after stress

These test results indicate a very high (>98%) likelihood for the presence of hemodynamically significant coronary artery disease.

- LAD: a large severe reversible defect in the anterior, septal, inferior and apical walls.

The severity of the anterior, septal, inferior and apical perfusion defects suggests that the LAD stenosis is critical (>90%).

Patient was transferred to emergency room.

Impression:
1. Severe native coronary artery disease as described above.
2. Status post successful percutaneous coronary intervention to the left anterior descending and first diagonal branch.

Recommendations:
Initiate dual antiplatelet therapy as well as statin therapy.
The patient is to be observed under the hospital service overnight for postprocedure care.
Rb-PET MPI w/Flow (case #2)

Conclusion: Clinical Response Nonischemic  Perfusion Normal
ECG Response  Nondiagnostic (RBBB)  Function Normal

These test results indicate an intermediate (30-69%) likelihood for the presence of jeopardized myocardium.

- The right ventricle is enlarged and hypertrophied
- Stress flow 1.04 ml/gm/min. Rest flow 1.42 ml/gm/min. The markedly decreased myocardial flow reserve of 0.75 (normal > 2.0) suggests increased risk of cardiac hard events. Cannot rule out triple vessel disease with balanced flow reduction
Cardiac Mortality by CFR & Scan Abnl

Murthy: Circ, 2011
Tx/Em Registration QC

Dedicated PET System
Tx/Em Registration QC

PET/CT System
Mis-registration Artifacts
3D Fusion Registration

Before

After
Infusion System Errors

Rest#1

Stress

Rest#2
Vertical Motion

Before →

After →
Horizontal Motion

Before →

After →
Cardiac/Respiratory Motion Motion

SPECT

PET

Raw Projection 2D Cine

Raw 3D MIP Cine
Cardiac/Respiratory Motion

Slomka et al, J Nucl Cardiolo 2016;23:486-90
Cardiac/Respiratory Motion

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Total Duration: 360 sec

Motion Stress
Cardiac/Respiratory Motion

NAC → AC → AC w/mc 5-6 min
Physiologic Artifact

CHF & Low EF

NAC

16mm AC

AC

240 sec 16mm AC
Physiologic Artifact

CHF & Low EF

NAC

AC

16mm AC

240 sec

16mm AC
Physiologic Artifact

Lung Uptake, Ischemic Cardiomyopathy & Low EF

Rb-NAC  Rb-AC  Rb-AC_240  FDG-AC
Physiologic Artifact

Lung Uptake, Ischemic Cardiomyopathy & Low EF

Rb-NAC
Rb-AC
Rb-AC_240
FDG-AC
IV Problems

Small IV

PICC Line

Rest  Stress  Rest  Stress
Excessive Gut Uptake
ECG Gating Artifact

Stress

Rest
Rb-PET MPI Analysis

- **Quality:**
  - Blood pool activity
  - Lung uptake

- **Perfusion defects**
  - Location, qualitative (visual) evaluation of severity
  - Semi-quantitative segmental score

- **Gated data**
  - RV and LV size, relative uptake
  - Volume, EF and regional wall motion

- **Dynamic data**
  - Rest & peak stress myocardial blood flow and flow reserve

- **Extra-cardiac findings and calcium score (CT)**
Summary

- Cardiac PET imaging offers unique & robust technique in detecting and risk assessment of CAD in patient who is not able to exercise adequately.

- PET imaging artifacts are different than the SPECT

- Causes include; breathing, patient motion
  - 21% of PET scans (JNM 2004; 45:1029-39)
  - Up to 40% if CTAC (JNM 2007; 48: 1112-1121)

- Solutions:
  - Patient prep & history
  - Software based – realign transmission & emission scans
  - Reconstruct partial data (list mode)
  - Repeat study