MYOCARDIAL PERFUSION STUDY
(Tc-99m-Sestamibi / Tc-99m Tetrofosmin / TI-201 Chloride)

2.7.4
Radiology Associates of Clearwater

Overview

The Myocardial Perfusion Study demonstrates the distribution of blood flow and perfusion to the myocardium at stress and rest (1).

The preferred study will be a same day exam performed with Tc-99m MIBI.

Indications

Detection of coronary artery disease (2).

Emergency room evaluation of chest pain (3).

Documentation of myocardial perfusion abnormalities before and after interventional therapy (4).

Detection of hibernating myocardium in conjunction with thallium-201 or F-18-fluorodeoxyglucose (5-7).

*Exams ordered for indications which are not listed above need to be discussed with the Nuclear Medicine Physician.

Examination Time: One Day Tc-MIBI/MIBI or 201-TI/MIBI Study

Rest study (8):
1. Initially: 15 minutes for injection.
2. 45 minutes later: 15 minutes for image acquisition (MIBI)
   5-10 minutes later: 15 minutes for imaging acquisition (201-TI).

Stress study (Immediately after rest imaging)
1. Initially: 20 minutes for stress and injection.
2. 45 minutes later: 15 minutes for stress acquisition.

Patient Instructions

Instruct patient to schedule treadmill/medication induced stress test through the Nuclear Medicine Department. If patient weight is >300 pounds or BMI is >= 35% then the exam will be schedules as a two day Tc-MIBI study.

Obtain patient's weight, as treadmill limit is 350 lb., and pharmacologic stress calculations must be based on weight.
Instruct outpatients to bring/wear comfortable shoes and clothing appropriate for exercise.

For optimal results the patient should discontinue all cardioactive medications before the study (9). See protocol 2.6 for list of medications:

1. Beta-blockers, e.g. propranolol, for at least 24 hours.
2. Long acting nitrates for at least 4 hours, nitroglycerin for at least 1 hour.
3. Calcium channel blockers.

**Dietary restrictions**
- No caffeine for 24-36 hours prior to pharmacologic stress with adenosine (10).
- Patients scheduled for stress before 11:00am should be NPO after midnight.
- Patients scheduled for stress test after 11:00am may have a light breakfast (cereal, toast) to be completed no later than 4 hours prior to testing.
- Determine if the patient is an insulin dependent diabetic. These patients should be scheduled at the beginning of the day whenever possible. Usually breakfast and insulin are held until completion of the test. Patients should be instructed to contact their referring physician for specific instructions.

**Lab / Imaging correlation:**
For inpatients initially admitted to rule out myocardial infarction, all ordered cardiac enzyme levels must be obtained.

Obtain all previous myocardial perfusion scans and MUGA studies when available.

**Patient Preparation:**

Before proceeding, check with the patient to ascertain that all instructions regarding medications, oral intake, and clothing have been followed.

Explain the test to the patient, including the stress consent form(s). This will require signatures of the patient, witness, and supervising physician.

A team member is to insert a #20 or 22 gauge IV line in a vein as close to the antecubital as possible. The brachial(medial) vein is preferred.

Outpatients are to remove clothing from waist up, and wear proper protective gowns.

**Equipment & Energy Windows**

Gamma camera: Rotating gamma camera for SPECT, preferably a dual head system with the heads at 90 degrees (13). A camera with hardware and software attenuation correction may be used.

Collimator: Low energy, high resolution, parallel hole (14).
Energy window: 20% window centered at 140 keV. (99m-Tc-MIBI)
20% window centered at 70 keV and 167 keV. (TI-201)

Computer with SPECT capability (15).

**Radiopharmaceutical and Dose**

**Dual Isotope – Same Day**
Rest: 2.5 mCi (92.5 MBq), TI-201-Chloride IV.
Stress: 25 mCi (925 MBq) Tc-labeled agents (Tetrofosmin, Sestamibi), IV.

**Tc-labeled agent (Myoview, Cardiolite) – Same Day**
Rest: 8mCi (296 MBq) Tc-labeled agents (Tetrofosmin, Sestamibi), IV.
Stress: 25mCi (925 MBq) Tc-labeled agents (Tetrofosmin, Sestamibi), IV.

**Two Day Study**
Rest: 25mCi (814 MBq) Tc-labeled agents (Tetrofosmin, Sestamibi), IV.
Stress: 25mCi (925 MBq) Tc-labeled agents (Tetrofosmin, Sestamibi), IV.

**Patient Positioning & Imaging Field**

Patient position: Supine on the SPECT imaging table (20).

The left arm is placed above the patient's head. (If the patient is unable to keep the left arm above the head, planar imaging may need to be substituted for SPECT imaging.

Imaging field: Lower chest.

**Acquisition Protocol - One Day Study** (14,17)

General:
1. The rest study is performed first followed immediately by the stress study. (14, 17, 21-24). Attenuation correction (25,26) will be used at the discretion of the nuclear medicine physician.

**Rest study:**
1. An intravenous line is started and the radiopharmaceutical is injected at rest at time zero.
2. After 45 minutes the patient is positioned supine for SPECT imaging (Tc-MIBI). After 5-10 minutes the patient is positioned supine for SPECT imaging (201Tl).
3. SPECT acquisition parameters:
   a) 180° collection arc beginning at 45° RAO and ending at 45° LPO (28).
   b) Orbit: Circular
   c) Projections: 32 images (over 180°) for 60sec each.
d) Image matrix: 64 x 64 matrix.
e) Magnification: 1.33

Stress study:
1. EKG leads are placed and gating will be performed at 8 frames per cardiac cycle (14).
2. The patient undergoes exercise (or pharmacologic) stress.
3. The radiopharmaceutical is injected 1-2 minutes before the end of exercise.
4. The patient is instructed to drink a can of ensure or they may go to the cafeteria to eat.
5. After a 45 minutes wait the patient is positioned supine for SPECT acquisition.
6. SPECT acquisition parameters (same as rest study - see above + Gating).

Viability Assessment (TI-201)
If a rest thallium defect is present, a 24 hour redistribution acquisition may be obtained to differentiate hibernating from infarcted myocardium (34). SPECT acquisition parameters (same as rest study - see above).

Data Processing (14)
SPECT images are processed for display on the reading stations.

The reconstruction process in general terms is:
1. Correct the planar acquisition images for decay from the start of image acquisition.
2. Correct the 64 planar images for uniformity (camera non-uniformity) using a high count, e.g. 30 million count, cobalt-57 flood acquisition.
3. Check the images for patient motion and apply a motion correction algorithm if indicated.
4. Indicate the superior and inferior limits of the heart so that computer time is not expended in reconstructing tomograms outside of the heart.
5. Specify the filters to be used in the reconstruction process; the filters for rest and stress reconstruction may be somewhat different because the injected doses are quite different.
6. Specify the pixel thickness of the tomogram (usually 1 or 2 pixels).
7. The computer then constructs tomograms through the heart that are transaxial to the long axis of the body using filtered backprojection. (These initial tomograms will be oblique to the long and short axes of the left ventricle.)
8. In order to obtain images in standardized anatomic orientations, indicate the long axis of the left ventricle; the initial tomograms are then reoriented to give transverse, sagittal, and coronal tomograms of the left ventricle relative to the long axis of the left ventricle. An automated program has been reported (29).
9. A 1x dataset will also be saved for use with Emory Toolbox.

OPTIONAL (Emory Cardiac Toolbox): The transaxial tomograms of the left ventricle
are then quantitatively analyzed and compared to normal ranges for perfusion at stress and change from stress to redistribution, e.g. bullseye display and analysis (7):

1. This analysis usually requires the technologist to indicate the center and outer limits of the left ventricle in each transaxial tomogram.

The following are routinely saved and submitted for interpretation:

1. Tomograms of myocardial perfusion for both stress and rest in the transaxial, sagittal, and coronal planes.
2. Gated images will also be included for evaluation of LV EF.
3. The EKG report with interpretation and exercise data.

Optional Protocols

Same day (Tc-labeled) protocol

1. Inject 8 mCi (296 MBq) of Tc-99m-Sestamibi or Tc-99m Tetrofosmin at rest.
2. After a 45-60 minute delay acquire a resting SPECT study (Use rest acquisition protocol).
3. At 2-3 hours after the initial injection, stress the patient and inject 22 mCi (814 MBq) of Tc-99m-Sestamibi or Tc-99m Tetrofosmin. (Patient is asked to drink a can of ensure after stress).
4. 30-45 minutes later acquire a stress Tc-99m-Sestamibi or Tc-99m Tetrofosmin SPECT study.

Two Day (Tc-labeled) Protocol

1. Inject 22 mCi (814 MBq) of Tc-99m-Sestamibi or Tc-99m Tetrofosmin at rest.
2. After a 60 minute delay acquire a resting SPECT study (Use rest acquisition protocol).
3. The following day, stress the patient and inject 22 mCi (814 MBq) of Tc-99m-Sestamibi or Tc-99m Tetrofosmin. (Patient is asked to drink a can of ensure after stress).
4. 45 minutes later acquire a stress Tc-99m-Sestamibi or Tc-99m Tetrofosmin SPECT study (Use stress acquisition protocol).

Adenosine / Lexiscan Stress Test (35,36):

1. A physician experienced in managing cardiac emergencies must be immediately available in case of complications.
2. Mechanism of action: Adenosine/LexiScan causes a direct increase in the extravascular concentration of adenosine promoting coronary vasodilatation.
3. Contraindications:
   a) severe asthma or bronchospasm.
   b) unstable angina.
   c) recent myocardial infarction, e.g. less than 48 hours.
d) sick sinus syndrome, and 2nd and 3rd degree AV block unless the patient has a functioning cardiac pacemaker.
e) hypotension, e.g. resting systolic pressure < 80 mm Hg

4. The patient should be NPO for 4-6 hours prior to the study (adenosine may cause nausea and vomiting).
5. The patient should be off all interfering medications such as Xanthine derivatives (aminophylline) and caffeine containing products for 24 hours prior to the test (See protocol 2.6 for complete list).
6. Drug administration:
   Adenosine: Infuse 140ug/kg per minute intravenously for 6 minutes.
   The clinic computer can be used to calculate the volume of adenosine to be drawn based on patients weight. The computer will then provide the parameters needed for the Graseby pump.
7. Blood pressure, Pulse oximetry and electrocardiogram will be monitored throughout the study.
8. Timing of radiopharmaceutical injection:
   Inject Tc-99m-Myoview 3 minutes after the start of the adenosine infusion.
9. Acquire images as described above beginning 45minutes following the end of the drug infusion.
10. Treatment of severe side effects (39):
    Termination of infusion. Aminophylline may also be given (50-75mg IV).

Lexiscan Stress Test:
1. A physician experienced in managing cardiac emergencies must be immediately available in case of complications.
2. Mechanism of action: Lexiscan is a selective A2A adenosine receptor agonist.
3. Contraindications:
   a) severe asthma or bronchospasm.
   b) unstable angina.
   c) recent myocardial infarction, e.g. less than 48 hours.
   d) sick sinus syndrome, and 2nd and 3rd degree AV block unless the patient has a functioning cardiac pacemaker.
   e) hypotension, e.g. resting systolic pressure < 80 mm Hg
4. The patient should be NPO for 4-6 hours prior to the study (Lexiscan may cause nausea and vomiting).
5. The patient should be off all interfering medications such as Xanthine derivatives (aminophylline) and caffeine containing products for 24 hours prior to the test (See protocol 2.6 for complete list).
6. Drug administration:
   Lexiscan: Infuse 0.4mg / 5ml intravenously over 20-30 seconds.
7. Blood pressure, Pulse oximetry and electrocardiogram will be monitored throughout the study.
8. Timing of radiopharmaceutical injection:
   Inject Tc-99m-Myoview immediately after the Lexiscan injection.
9. Acquire images as described above beginning 45minutes following the end of the drug injection.
10. Treatment of severe side effects (39): Aminophylline may be given (150mg IV).

**Dobutamine Stress Test** (40-42):
1. A physician experienced in managing cardiac emergencies must be immediately available in case of complications.
2. Mechanism of action: Dobutamine increases myocardial contraction by direct stimulation of the heart's beta-1 receptors.
3. Contraindications
   a) severe aortic stenosis.
   b) unstable angina.
   c) recent myocardial infarction, e.g. less than 48 hours.
   d) history of tachyarrhythmias.
   e) hypertension, e.g. resting systolic pressure > 200 mm Hg.
   f) poor left ventricular function
4. Withhold beta blockers for 48-72 hours.
5. The patient should be NPO for 4-6 hours prior to the study.
6. Monitor the blood pressure, pulse oximetry and electrocardiogram every minute during administration of the drug and for 6 minutes afterwards.
7. Dobutamine administration and radiopharmaceutical injection:
   a) infuse dobutamine at 5 µg/kg/min for 3 minutes followed by stepped increases to 10, 20, 30, and 40 µg/kg/min for each successive 3 min.
   b) inject radiopharmaceutical 1 minute following initiation of the maximum dose over a 1 minute time period.
   c) continue dobutamine infusion for 2 minutes after end of injection of radiopharmaceutical.
   d) Atropine 0.5-1.0 mg may be used to increase the HR.
8. Acquire stress images as described above beginning 45 minutes following injection of the radiopharmaceutical.
9. Emergency medications: Atropine, Lopressor, Verapamil and Proventil must be available to treat severe side effects.

**Principle Radiation Emission Data - Tc-99m** (51)

Physical half-life = 6.01 hours.

<table>
<thead>
<tr>
<th>Radiation</th>
<th>Mean % per disintegration</th>
<th>Mean energy (keV)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gamma-2</td>
<td>89.07</td>
<td>140.5</td>
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**Dosimetry - Tc-99m-Tetrofosmin (at stress)** (27)

<table>
<thead>
<tr>
<th>Organ</th>
<th>rads/25 mCi</th>
<th>mGy/925 MBq</th>
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<tbody>
<tr>
<td>Gallbladder wall</td>
<td>3.08</td>
<td>30.8</td>
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<tr>
<td>Upper large intestine</td>
<td>1.88</td>
<td>18.8</td>
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<tr>
<td>Urinary bladder wall</td>
<td>1.45</td>
<td>14.5</td>
</tr>
<tr>
<td>Lower large intestine</td>
<td>1.43</td>
<td>14.3</td>
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</tbody>
</table>
Small intestine 1.13 11.3
Kidneys 0.98 9.8
Ovaries 0.73 7.3
Thyroid 0.40 4.0
Red marrow 0.38 3.8
Testes 0.33 3.3
Liver 0.30 3.0

Dosimetry - Tc-99m-Sestamibi (at stress) (19)

<table>
<thead>
<tr>
<th>Organ</th>
<th>rads/25 mCi</th>
<th>mGy/925 MBq</th>
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</thead>
<tbody>
<tr>
<td>Upper large intestine</td>
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<td>38.8</td>
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<tr>
<td>Lower large intestine</td>
<td>2.68</td>
<td>26.8</td>
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<tr>
<td>Gallbladder wall</td>
<td>2.41</td>
<td>24.1</td>
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<tr>
<td>Small intestine</td>
<td>2.32</td>
<td>23.2</td>
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<tr>
<td>Kidneys</td>
<td>1.39</td>
<td>13.9</td>
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<tr>
<td>Urinary bladder wall</td>
<td>1.29</td>
<td>12.9</td>
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<tr>
<td>Ovaries</td>
<td>1.02</td>
<td>10.2</td>
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<tr>
<td>Thyroid</td>
<td>0.68</td>
<td>6.8</td>
</tr>
<tr>
<td>Red marrow</td>
<td>0.60</td>
<td>6.0</td>
</tr>
<tr>
<td>Whole body</td>
<td>0.38</td>
<td>3.8</td>
</tr>
<tr>
<td>Liver</td>
<td>0.36</td>
<td>3.6</td>
</tr>
<tr>
<td>Testes</td>
<td>0.24</td>
<td>2.4</td>
</tr>
</tbody>
</table>

Principle Radiation Emission Data - Ti-201

Physical half-life = 3.05 days.

<table>
<thead>
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<th>Radiation</th>
<th>Mean % per disintegration</th>
<th>Mean energy (keV)</th>
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<tbody>
<tr>
<td>Gamma-4</td>
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<td>Gamma-6</td>
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<td>ce-K, gamma-8</td>
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<td>K alpha-1 x-ray</td>
<td>46.2</td>
<td>70.8</td>
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<tr>
<td>K alpha-2 x-ray</td>
<td>27.2</td>
<td>68.9</td>
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<tr>
<td>K beta-1 x-ray</td>
<td>10.5</td>
<td>80.3</td>
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</table>

Dosimetry - Ti-201 as Thallous Chloride

<table>
<thead>
<tr>
<th>MBq</th>
<th>Organ</th>
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<th>mGy/111</th>
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<tr>
<td></td>
<td>Kidneys</td>
<td>4.8</td>
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<td></td>
<td>Thyroid</td>
<td>2.6</td>
<td>26.0</td>
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<td></td>
<td>Liver</td>
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<td>22.0</td>
</tr>
<tr>
<td></td>
<td>Heart wall</td>
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<td>20.0</td>
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<tr>
<td></td>
<td>Testes</td>
<td>2.0</td>
<td>20.0</td>
</tr>
<tr>
<td></td>
<td>Ovaries</td>
<td>1.9</td>
<td>19.0</td>
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Gastrointestinal tract

<table>
<thead>
<tr>
<th>Part of the Gastrointestinal Tract</th>
<th>Value 1</th>
<th>Value 2</th>
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<tbody>
<tr>
<td>stomach wall</td>
<td>1.7</td>
<td>17.0</td>
</tr>
<tr>
<td>small intestine</td>
<td>1.5</td>
<td>15.0</td>
</tr>
<tr>
<td>upper colon</td>
<td>1.0</td>
<td>10.0</td>
</tr>
<tr>
<td>lower colon</td>
<td>0.8</td>
<td>8.0</td>
</tr>
<tr>
<td>Total body</td>
<td>0.8</td>
<td>8.0</td>
</tr>
</tbody>
</table>

References


Normal Findings


> He ZX, Verani MS, Mahmarian JJ: Separate normal patient data banks for thallium-201 and technetium-99m sestamibi are unnecessary when


**Note:** This procedure complies with the Society of Nuclear Medicine procedure guideline for myocardial perfusion approved June 15, 2002