MYOCARDIAL PERFUSION & VIABILITY STUDY
(Thallium-201)

Overview

- The Myocardial Perfusion & Viability Study demonstrates the distribution of perfusion as well as viability throughout the myocardium (1,2).

Indications

- Detection of coronary artery disease by way of classification of the left ventricular myocardium as normal, irreversibly ischemic, and reversibly ischemic (1,2).

- Detection of hibernating myocardium (1,2).

- Detection of myocardial perfusion abnormalities secondary to causes other than coronary artery disease.

- Evaluation of the septum in patients with left bundle branch block (must use pharmacologic stress rather than exercise) (3).

Examination Time

- Initial stress acquisition: 1 hour.

- Delayed redistribution & reinjection acquisition at rest: 30 minutes.

Patient Preparation

- For optimal results the patient should discontinue all cardioactive medications before the study (4):
  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.
  4. Caffeine for 24-36 hours prior to pharmacologic stress with dipyridamole or adenosine (5).

- The patient will undergo a stress electrocardiogram (EKG) on a treadmill or bicycle in the upright position (6). It is important that the patient accomplish the maximum amount of exercise that he/she can safely perform (7).

- The patient should be fasting and should eat nothing until after the redistribution acquisition (8,9).
Carefully instruct the patient not to move during the SPECT acquisition.

**Equipment & Energy Windows**

- Gamma camera: Rotating gamma camera for SPECT, preferably a dual head system with the heads at 90 degrees (12).
- Collimator: Low energy, high resolution, parallel hole.
- Energy windows (13,14):
  - One pulse height analyzer: 25% window centered at 75 keV.
  - Two pulse height analyzers: 25% window centered at 75 keV and 20% window centered at 167 keV.
  - Three pulse height analyzers: 25% window centered at 75 keV, 20% window centered at 167 keV, and 15% window centered at 135 keV.
- Computer with SPECT capability (15).

**Radiopharmaceutical, Dose, & Technique of Administration**

- Radiopharmaceutical: Thallium-201 as thallous chloride (16-19).
- Dose (should be weight adjusted):
  1. 3 mCi (111 MBq) at stress.
  2. 1.5 mCi (55.5 MBq) 5 minutes prior to rest/redistribution imaging, i.e. reinjection technique (13,17-22).
- Technique of administration: Since the injection is made while the patient is exercising, and, therefore, moving, an intravenous line is placed prior to the beginning of exercise. The intravenous line should be placed in the medial (brachial) vein of the antecubital fossa (23). The radiopharmaceutical is then injected 1-2 minutes before the anticipated end of the patient's exercise endurance.

**Patient Positioning & Imaging Field**

- Patient position: Supine.
  - Prone position may be used (24,25).
- 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 Protocols**

**General:**
1. The stress study is performed first followed by the rest study approximately 3 hours later (13).
   Attenuation correction is helpful if available (26,27).

**Stress study:**
1. Imaging should begin about 10 minutes after the end of the EKG stress. (It is important that the EKG stress lab is located in close proximity to the nuclear medicine department.) Ten minutes represents a compromise between beginning later which decreases the sensitivity of the study for reversible ischemia (28,29) and beginning earlier which causes image artifacts secondary to "cardiac creep" (30).
2. SPECT acquisition parameters:
   a) Collection arc: 180° beginning at 45° RAO and ending at 45° LPO (31,32).
   b) Orbit: Circular
   c) Projections: 32 images (6° intervals over 180°) (33).
   d) Dwell time: 60 seconds.
   e) Image matrix: 64 x 64 matrix.
   f) Magnification: 1.3
3. The patient is instructed to return in 3-4 hours for the rest study.

**Rest study:**
1. 3-4 hours following the initial injection, an additional dose of thallium is injected at rest, i.e. reinjection technique (13,17-22).
2. 5 minutes after the resting injection of thallium, redistribution/rest SPECT images are acquired using the same acquisition parameters that were used for the stress acquisition.

**Data Processing**

- The exact procedure for processing SPECT myocardial perfusion images depends on the computer software being used. This varies with the manufacturer and, in general, the manufacturer’s protocol should be followed.
  All processing will be done using the Xeleris or e-soft software.

- The reconstruction process in general terms is:
1. Correct the 32 planar images for uniformity (camera non-uniformity) using a high count, e.g. 30 million count, cobalt-57 flood acquisition (10,34).
2. Check the images for patient motion and apply a motion correction algorithm if indicated and if available (35,36).
3. Indicate the superior and inferior limits of the heart so that computer time is not expended in reconstructing tomograms outside of the heart.
4. Specify the filters to be used in the reconstruction process and the pixel thickness of the tomogram (usually 1 or 2 pixels) (37,38).
5. 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.)
6. 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.

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 (39,40):
1. This analysis usually requires the technologist to indicate the center and outer limits of the left ventricle in each transaxial tomogram. Use separate normal ranges for males and females if available (14,34).

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.
3. Time from injection of the radiopharmaceutical to the start of the acquisition.
4. The patient's EKG data with interpretation.
5. Patient's height, weight.

Optional Maneuvers

The average lung to maximum heart activity ratio may be calculated using SPECT tomographic images or the ANT planar image at stress (The planar image must have been acquired as a digital image.) (42).
In patients who cannot exercise, "stress" may be induced pharmacologically with adenosine / Lexiscan (43-45) or dipyridamole (46,47):

1. A physician experienced in managing cardiac emergencies must be immediately available in case of complications.
2. Mechanism of action: Both adenosine and dipyridamole cause an increase in the extracellular concentration of adenosine. Adenosine acts directly; dipyridamole acts indirectly.
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 (both drugs may cause nausea and vomiting).
5. Monitor the blood pressure and electrocardiogram for 15 minutes beginning just before administration of the drug.
6. Drug administration:
   Adenosine: Infuse 0.14 mg/kg per minute intravenously for 6 minutes.
   Lexiscan: 0.4mg IV push followed by 10cc saline.
   Dipyridamole: Infuse 0.142 mg/kg per minute for 4 minutes (a large vein is preferred because of the acidic pH of dipyridamole).
   Adenosine or dipyridamole may be combined with submaximal stress to increase the sensitivity of the test (48,49).
7. Timing of radiopharmaceutical injection:
   Adenosine: Inject Thallium-201 2-3 minutes after the start of the adenosine infusion.
   Dipyridamole: Inject Thallium-201 8 minutes after the start of the dipyridamole infusion.
8. Acquire images as described above beginning 1 hour following the end of the drug infusion.
9. Side effects: Similar for the two drugs although the reported frequencies vary. The side effects are similar to exercise stress plus bronchospasm.
10. Treatment of severe side effects (50):
    Adenosine: Termination of infusion. Aminophylline may also be given.
    Dipyridamole: Intravenous administration of a bolus of 50-75 mg of aminophylline followed by 250-500 mg in normal saline over 20 minutes.
In patients who cannot exercise and who cannot be stressed pharmacologically with adenosine or dipyridamole because of asthma, "stress" may be induced pharmacologically with dobutamine (51,52):

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 24-48 hours.

5. The patient should be NPO for 4-6 hours prior to the study.

6. Monitor the blood pressure 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 (inject radiopharmaceutical from 13th to 14th minute).
   c) continue dobutamine infusion for 2 minutes after end of injection of radiopharmaceutical.

8. Acquire images as described above beginning 10 minutes following injection of the radiopharmaceutical.

9. Side effects: The side effects are similar to exercise stress.


Additional resting images may be obtained in patients demonstrating a fixed defect in the initial stress and reinjection-resting images:
   Additional delayed images may be obtained at 18-24 hours (20).
   A separate resting study with another injection of thallium-201 plus 4 hour delayed images may be performed at a later time (53,54).

Nitrate augmented redistribution: Administration of 20 mg of isosorbide dinitrate orally immediately following stress imaging may improve the sensitivity of the study for jeopardized myocardium (55).

Left ventricular regional wall motion and thickening at systole: Can be quantitatively evaluated with gated thallium-201 images (56,57).
**Principle Radiation Emission Data - TI-201 (69)**

- Physical half-life = 3.05 days.

<table>
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<th>Radiation</th>
<th>Mean % per disintegration</th>
<th>Mean energy (keV)</th>
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<tr>
<td>Gamma-4</td>
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<tr>
<td>K beta-1 x-ray</td>
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**Dosimetry - TI-201 as Thallous Chloride (70,71)**

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<th>Organ</th>
<th>rads/3 mCi</th>
<th>mGy/111 MBq</th>
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<tbody>
<tr>
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**References**


Normal Findings

Reviewed 7/1/17 JM