MYOCARDIAL PERFUSION STUDY
(Tc-99m-Tetrofosmin, Tc-99m-Sestamibi)

Overview

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

Indications

- Detection of coronary artery disease
- Emergency room evaluation of chest pain
- Documentation of myocardial perfusion abnormalities before and after interventional therapy
- Detection of hibernating myocardium in conjunction with thallium-201 or F-18-fluorodeoxyglucose

Examination Time

- Rest study:
    1. Initially: 15 minutes for injection.
    2. 1 hour later: 30 minutes for image acquisition.
- Stress study (3 hours after the end of the rest acquisition):
    1. Initially: 20 minutes for stress and injection
    2. 15 minutes later: 30 minutes for stress acquisition

Patient Preparation

- For optimal results the patient should discontinue all cardioactive medications before the study:
    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
- The patient will undergo a stress electrocardiogram (EKG) on a treadmill or bicycle. It is important that the patient accomplish the maximum amount of exercise that he/she can safely perform.

- The patient should be fasting.
- Record the patient's height, weight, and, for females, bra size; this information assists in identifying attenuation artifacts in the tomographic images.
- For females, bind the breasts up away from the left ventricle.
- 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.
- Collimator: Low energy, high resolution, parallel hole.
- Energy window: 20% window centered at 140 keV.
- Computer with SPECT capability.

Radiopharmaceutical, Dose, & Technique of Administration

- Radiopharmaceutical:
    - Tc-99m-tetrofosmin
    - Tc-99m-sestamibi
- Dose:
    1. Rest: 1 day protocol: 7 mCi
    2. Stress: 22 mCi
- Technique of administration:
    1. Rest: Routine intravenous injection.
    2. Stress: 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. 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 on the SPECT imaging table

- 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

- General:
    1. The rest study is performed first followed by the stress study approximately 3 hours later
        - o Attenuation correction is helpful if available

- Rest study:
    1. The radiopharmaceutical is injected at rest at time zero.
    2. The patient is instructed to:
        a) Return to the department in:
            > Tc-99m-tetrofosmin: 15-30 minutes
            > Tc-99m-sestamibi: 60 minutes (drink 8 ounces of whole milk at about 30 minutes from injection)
    3. After the waiting period the patient is positioned supine for SPECT acquisition.
    4. SPECT acquisition parameters:
        a) 180E collection arc beginning at 45E RAO and ending at 45E LPO
        b) Orbit: Usually elliptical:
            - o Circular may be used
        c) Projections: 64 images (3E intervals over 180E)
            - o 32 images (6E intervals over 180E) may be substituted.
        d) Dwell time: 25 seconds
            - o 40 seconds for 32 images
        e) Image matrix: 64 x 64 matrix
    5. The patient is instructed to return in 3 hours for the stress study

- Stress study:
    1. An intravenous line and EKG leads are placed
    2. The patient undergoes exercise (or pharmacologic) stress
    3. The radiopharmaceutical is injected 1-2 minutes before the end of exercise
    4. At 15 minutes the patient is positioned supine for SPECT acquisition
    5. SPECT acquisition parameters (same as rest study - see above)

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.

- 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, eg. 30 million count, cobalt-57 flood acquisition.
    3. Check the images for patient motion and apply a motion correction algorithm if indicated and if available.
    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.

- 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, eg. bullseye display and analysis:
    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 recorded on film and submitted for interpretation:
    1. Tomograms of myocardial perfusion for both stress and rest in the transaxial, sagittal, and coronal planes
    2. Bullseye or bullseye equivalent displays of:
        a) Myocardial perfusion at stress and rest in a continuous gray scale
        b) Myocardial perfusion at stress and rest by standard deviations from normal reference standards
        c) Normal, irreversibly ischemic, and reversibly ischemic areas
        d) With some software it is possible to also quantitate the percent of left ventricular myocardium that is normal, reversibly ischemic, and irreversibly ischemic
    3. Images of the line used to indicate the long axis of the left ventricle

4. All of the parameters used in the reconstruction process
5. The patient's predicted heart rate, 85% of predicted heart rate, and achieved heart rate
6. Patient's height, weight, and, for females, bra size

Optional Maneuvers

- Separate acquisition, dual isotope (thallium-201/Tc-99m-sestamibi or Tc-99m-tetrofosmin) protocol:
    1. Inject 3 mCi (111 MBq) of thallium-201 at rest.
    2. Acquire a resting thallium-201 SPECT study.
    3. Immediately stress the patient and inject 25 mCi (925 MBq) of Tc-99m-sestamibi.
    4. 15 minutes later acquire a stress Tc-99m-sestamibi SPECT study
    5. If a rest thallium defect is present, a 24-hour redistribution acquisition may be obtained to differentiate hibernating from infarcted myocardium

- Perfusion & viability study: Inject Tc-99m-tetrofosmin or Tc-99m-sestamibi at stress and F-18-fluorodeoxyglucose at rest. Acquire both sets of data simultaneously with dual energy windows using single photon mode (SPECT) and a 511 keV collimator [See Myocardial Viability-FDG Section].

- In-patients who cannot exercise, "stress" may be induced pharmacologically with adenosine or dipyridamole:
    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 extravascular concentration of adenosine. Adenosine acts directly; dipyridamole acts indirectly.
    3. Contraindications:
        a) Severe asthma or bronchospasm
        b) Unstable angina
        c) Recent myocardial infarction, eg. 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, eg. 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.
        - Dipyridamole: Infuse 0.142 mg/kg per minute for 4 minutes (a large

vein is preferred because of the acidic pH of dipyridamole).

7. Timing of radiopharmaceutical injection:
   > Adenosine: Inject Tc-99m-sestamibi 3 minutes after the start of the adenosine infusion.
   > Dipyridamole: Inject Tc-99m-sestamibi 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:
    > 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:
  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, eg. less than 48 hours.
     d) History of tachyarrhythmias
     e) Hypertension, eg. 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 ìg/kg/min for 3 minutes followed by stepped increases to 10, 20, 30, and 40 ìg/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.
Treatment of severe side effects: Intravenous beta-blockers.

- Gated SPECT study: May be acquired at the time of the stress SPECT acquisition for evaluation of resting regional wall motion, ejection fraction, and myocardial thickening. Eight frames per cardiac cycle are obtained.

- Nitrate administration at rest: Improves detection of hibernating myocardium.

- First pass angiocardiogram: May be performed at the time of injection of the radiopharmaceutical. This is best done when a full 25 mCi (925 MBq) dose is injected, ie. at the time of the stress study. (See section on First Pass Radionuclide Angiocardiography for protocol details.)

- Lung uptake: Lung uptake may be quantitated

Principle Radiation Emission Data - Tc-99m

- Physical half-life = 6.01 hours.

Radiation	Mean % per disintegration	Mean energy (keV)
Gamma-2	89.07	140.5

Dosimetry - Tc-99m-Tetrofosmin (at stress)

Organ	rads/25 mCi

Lower large intestine	2.68	26.8
Gallbladder wall	2.41	24.1
Small intestine	2.32	23.2
Kidneys	1.39	13.9
Urinary bladder wall	1.29	12.9
Ovaries	1.02	10.2
Thyroid	0.68	6.8
Red marrow	0.60	6.0
Whole body	0.38	3.8
Liver	0.36	3.6
Testes	0.24	2.4