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 (1,2).
- Emergency room evaluation of chest pain (3).
- Risk stratification of coronary artery disease (4).
- Detection of hibernating myocardium in conjunction with thallium-201 or F-18-fluorodeoxyglucose (5-7).

Examination Time

- Several hours overall (7).
- The exact timing and duration for stress and rest parts depends on the chosen protocol and method of stress (7,8).

Patient Preparation

- For optimal results the patient should discontinue all cardioactive medications before the study (9):
  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 (10).
- 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 (11).
- The patient should be fasting.

- Record the patient's height, weight, and, for females, bra cup size; this information assists in identifying attenuation artifacts in the tomographic images (12).

- Carefully instruct the patient not to move during the SPECT acquisition.

θ For females, bind the breasts up away from the left ventricle.

Equipment & Energy Windows

- Gamma camera: Rotating gamma camera for SPECT, preferably a dual head system with the heads at 90 degrees (13).

- Collimator: Low energy, high resolution, parallel hole (14).

- Computer with SPECT capability (15).

- EKG image gating device (16).

- Energy window: 20% window centered at 140 keV.

Radiopharmaceutical, Dose, & Technique of Administration

- Radiopharmaceutical (7):
  - θ Tc-99m-tetrofosmin (17,18).
  - θ Tc-99m-sestamibi (19).

- Dose - 1 day protocol (14,18):
  1. First injection (either rest or stress): 15 mCi (370 MBq).
  2. Second injection either stress or rest): 30 mCi (925 MBq).

- 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 (14).

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, clearly mark on the film and/or requisition that the images were acquired with the left arm by the patient's side.)

- Imaging field: Lower chest.

Acquisition Protocol - One Day (7,14,17)

- Imaging sequence (21-24):
  - θ Rest study first, followed by stress study.
  - θ Stress study first, followed by rest study.

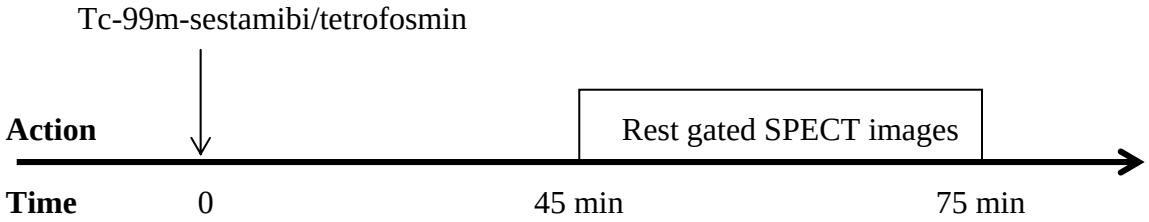
- General:
  1. The patient is imaged supine.
  2. SPECT acquisition parameters:
     a) 180° collection arc from 45° RAO to 45° LPO (25).
     b) Orbit: Usually elliptical (25):
        - θ Circular may be used.
     c) Projections: 64 images (3° intervals over 180°).
        - θ 32 images (6° intervals over 180°) may be substituted.
     d) Dwell time: 25 seconds.
        - θ 40 seconds for 32 images.
     e) Image matrix: 64 x 64 matrix.
  3. Attenuation correction should be used if available (26,27).
  4. Gate both the rest and stress acquisitions (14,28-31):
     a) Divide the cardiac cycle into 8 parts.
  5. Allow 2 hours between studies regardless of whether rest or stress is done first.

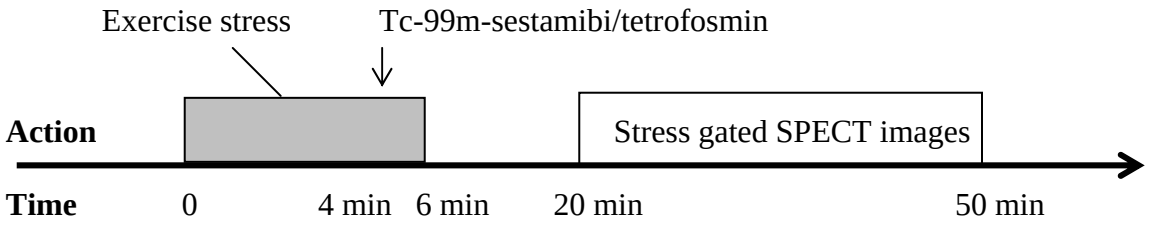
- Rest-stress protocol:
  1. Place an intravenous line.
  2. Inject radiopharmaceutical at rest.
  3. Delay before beginning rest acquisition: 45 minutes.
  4. Instruct the patient to return to the department in 2 hours.
  5. Place EKG leads.
  6. The patient undergoes exercise (or pharmacologic) stress.
  7. The radiopharmaceutical is injected 1-2 minutes before the end of exercise.
  8. Delay before beginning stress acquisition:
     - > Exercise stress: 15 minutes.
     - > Pharmacologic stress: 45 minutes.

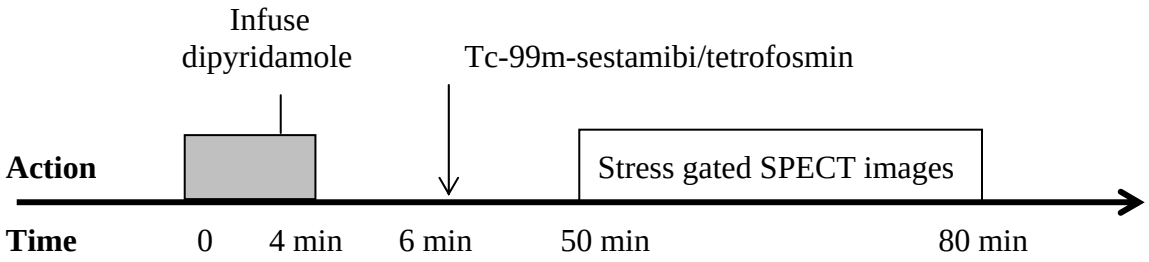
- Stress-rest protocol:
  1. Place an intravenous line and EKG leads.
  2. The patient undergoes exercise (or pharmacologic) stress.

3. The radiopharmaceutical is injected 1-2 minutes before the end of exercise.
4. Delay before beginning stress acquisition:
   > Exercise stress: 15 minutes.
   > Pharmacologic stress: 45 minutes.
5. Instruct the patient to return to the department in 2 hours.
6. In patients with a low likelihood of coronary disease, e.g. women without a previous infarct, reconstruct the stress tomograms at this time. If they are normal, the study can be terminated with considerable savings of time and effort (32).
7. Inject radiopharmaceutical at rest.
8. Delay before beginning rest acquisition: 45 minutes.

Protocol Summary Diagrams







Data Processing (14)

- 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, e.g. 15 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 iterative reconstruction (33). (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 (34).

- 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 rest, e.g. 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.

- Analyze the gated tomograms for left ventricular ejection fraction and wall motion. Display results in a beating contour and birdcage format.

- The following are routinely recorded 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 color or 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 (35).

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 cup size.

Optional Maneuvers

- Separate acquisition, dual isotope (thallium-201/Tc-99m-sestamibi or Tc-99m-tetrofosmin) protocol (4,7,36-39):
  1. Inject 3-6 mCi (111 MBq) of thallium-201 at rest.
  2. Delay before rest acquisition: 10 minutes.
  3. Acquire a resting thallium-201 study.
  4. Immediately stress the patient and inject 30 mCi (925 MBq) of radiopharmaceutical.
  5. Delay before stress acquisition:
     > Exercise stress: 15 minutes.
     > Pharmacologic stress: 45 minutes.
  6. Acquire a stress Tc-99m-sestamibi study with cardiac gating.
  7. If a fixed thallium defect is present, a 24 hour redistribution acquisition may be obtained to differentiate hibernating from infarcted myocardium (38).

- 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 (5).

- In patients who cannot exercise, "stress" may be induced pharmacologically with adenosine (40,41) or dipyridamole (1,42):
  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
  3. Contraindications:
     a) severe asthma or bronchospasm.
     b) severe chronic obstructive pulmonary disease (43).
     c) unstable angina.
     d) recent myocardial infarction, e.g. less than 48 hours.
     e) sick sinus syndrome, and 2nd and 3rd degree AV block unless the patient has a functioning cardiac pacemaker.
     f) 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:
   - θ Adenosine: Infuse 0.14 mg/kg per minute intravenously for 6 minutes.
   - θ Dipyridamole: Infuse 0.14 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 45 minutes 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 (44):
    - > 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 (1,45-47):
  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 45 minutes following injection of the radiopharmaceutical.
9. Side effects: The side effects are similar to exercise stress.
10. Treatment of severe side effects: Intravenous beta blockers.

- Nitrate administration at rest: Improves detection of hibernating myocardium (48,49).

- Administration of milk and water to reduce interfering abdominal activity: Give patient 150 mL of whole milk and 450 mL of water 10 minutes before starting the acquisition of SPECT images (50).

- Lung uptake: Lung uptake may be quantitated (51).

- Calculation of other physiologic parameter:
  1. Regional wall thickening (52).
  2. Left ventricular volumes (53).

- Measurement of transient ischemic ventricular dilatation: Transient dilatation of the left ventricle from exercise can be calculated and is an indicator of extensive coronary artery disease (54).

Principle Radiation Emission Data - Tc-99m (55)

- 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) (56)

Organ	rads/25 mCi	mGy/925 MBq
Gallbladder wall	3.08	30.8
Upper large intestine	1.88	18.8
Urinary bladder wall	1.45	14.5
Lower large intestine	1.43	14.3
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) (57)

Organ	rads/25 mCi	mGy/925 MBq
Upper large intestine	3.88	38.8
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

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Normal Findings

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